STRUCTURAL CHANGE AND ECONOMIC GROWTH.

A LONGITUDINAL AND CROSS-COUNTRY STUDY

by

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Vita

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Abstract

The main purpose of the present study is to contribute for a deeper understanding of the growth process of the Portuguese economy over the last three decades, by explicitly taking into account the relationship between changes occurring at the industry level of the economy and overall macroeconomic changes. Although a few studies have already addressed the matter for the Portuguese case, a number of important issues relating structural transformation, technology and economic growth remained unexplored, and it is our purpose to fill this gap by considering the neo-Schumpeterian stream of research as the main theoretical frame of analysis.

After comprehensively surveying the relevant literature on the field, a preliminary assessment of the relationship between technology, structural change and the macroeconomic performance of the Portuguese economy is undertaken using shift-share analysis. This technique is applied considering total factor productivity growth, and employing different levels of breakdown of economic activity, which include the division of industries according to their skills and innovativeness potential. The impact of Verdoorn effects is also acknowledged.

The inclusion of capital in the measurement of productivity growth reveals that the performance of the Portuguese economy was globally mediocre in the period under scrutiny, which was characterised by very slow rates of TFP growth. The results show furthermore that most of the (low) productivity gains came from the shift of labour and capital resources across sectors, rather than from intra-productivity gains. Structural change gains arose, however, in a context of relatively slow change in the broad Portuguese economic structure, which maintained a strong bias towards traditional and low-skilled activities.

The latter part of the thesis is dedicated to the investigation of the benefits in terms of productivity growth arising from an increase in the relative importance of technologically dynamic industries. This is done using panel data regression methods and analysing the Portuguese case with reference to a number of other countries that presented similar structural characteristics in the late 1970s, but which have experienced widely different growth trajectories since then. The results provide empirical support to the hypothesis according to which substantial benefits have accrued to countries that

successfully changed their structure towards more technologically advanced industries. Moreover, the results lend some support to the view that ICT-related industries are strategic branches of economic activity, but only when *producing industries* are considered. This accentuates the fact that most spillovers from advanced industries, and particularly ICT producing industries are *local* and national in character.

Resumo

O presente trabalho tem como objectivo principal contribuir para um maior conhecimento do processo de crescimento económico Português ocorrido nas últimas três décadas, considerando explicitamente a relação entre mudanças ocorridas ao nível sectorial e transformações de natureza macroeconómica. Embora este assunto tenha sido objecto de análise em trabalhos anteriores, várias questões relevantes relacionadas com a interacção entre progresso tecnológico, mudança estrutural e crescimento económico permaneceram em aberto. Estas questões são abordadas neste trabalho, que tem na teoria neo-Schumpeteriana a sua fundamentação teórica principal.

Após uma primeira parte onde é realizada uma revisão da literatura relevante na área de conhecimento em questão, a análise da relação entre tecnologia, mudança estrutural e desempenho macroeconómico é abordada, utilizando a metodologia shift-share. Esta metodologia é aplicada considerando diferentes desagregações da actividade económica e utilizando a produtividade total de factores como medida de produtividade. São também tidos em conta os efeitos de Verdoorn no cômputo da relevância do efeito de mudança estrutural.

A consideração explícita do factor capital na mensuração do crescimento da produtividade revela que o desempenho da economia Portuguesa entre 1977 e 2003 foi globalmente medíocre. Os resultados revelam ainda que os reduzidos ganhos de produtividade decorreram sobretudo da transferência de trabalho e de capital entre sectores, mais do que de ganhos de produtividade intra-sectoriais. Os benefícios inerentes à mudança estrutural ocorreram, no entanto, no interior dos grandes grupos de actividade da economia Portuguesa, que sofreram poucas alterações ao longo do período em estudo. De facto, no final deste período, a economia Portuguesa conserva os seus principais traços estruturais, registando um grande relevo de actividades com uso intensivo de mão-de-obra pouco qualificada e com reduzida intensidade tecnológica.

A última parte da tese é dedicada à análise da relação entre a importância relativa de actividades tecnologicamente avançadas na estrutura produtiva e o crescimento da produtividade do trabalho. Para este efeito é estimada uma regressão com dados em painel onde, para além de Portugal, são considerados países que no início do período em estudo possuíam características estruturais idênticas ao caso Português, mas que

observaram trajectórias de crescimento muito diversas no período em análise. Os resultados sustentam empiricamente a hipótese segundo a qual os países com maior capacidade de proceder a transformações efectivas da sua estrutura produtiva em torno de actividades tecnologicamente mais avançadas beneficiam de um crescimento superior da produtividade do trabalho. Em simultâneo, a evidência obtida confirma o carácter estratégico das actividades directamente relacionadas com as tecnologias de informação e de comunicação, ainda que tal aconteça unicamente para actividades produtoras destas tecnologias. Este facto sublinha o carácter local dos efeitos de spillover decorrentes de actividades económicas tecnologicamente mais avançadas.

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Introduction

Structural change analysis is differentiated from standard economic research in that it assumes that the infinite multiplicity of reality can be studied by focussing on a relatively small number of groups or activities that comprise the economic system, and thus form the economic structure.[1] In this sense, a structural representation provides a selective description of the economic system, which is obtained by substituting the observed heterogeneity with sets of classes of relatively homogeneous groups of agents or sectors of activity. In this framework, the definition of structure and of the unit of analysis is made to depend on the problem under investigation. This allows for a considerable degree of flexibility that is absent from standard micro and macroeconomic analyses, thus making it an appealing tool for the study of economic dynamics. Indeed the complexity of economic change is probably better understood within a framework which permits changing from one classification scheme to another, so as to obtain the structural representation that is most suited to analyzing the impact of a particular force of change, or to describing the economic system at a particular moment in time. Moreover, the division of the economic system into different subsystems means that differentiated patterns of change in those subsystems can be taken into account (the different elements of a productive structure are transformed at different speeds), which is entirely at odds with stationary state dynamics.[2]

The inherent ability of structural change analysis to cope with the dynamics of economic systems has not, however, been explored by the economic discipline on a regular basis over time. Whereas in the classical period a great deal of attention was given to long-term dynamics and to their association with structural change, those issues became progressively less relevant with the emergence of the marginalist revolution by the end of the 19th century, and its emphasis on the problems of optimal resource allocation. As a matter of fact, the inter-war period was characterized by an almost total neglect of structural change analysis, with only a few notable exceptions – Schumpeter, Leontief and a few other authors – addressing the topic. In the 1950s and 1960s there was a revival of interest on the matter that was intimately related with the appearance

[1] See also Hagemann *et al.* (2003) for a discussion of the purpose and scope of the economics of structural change.
[2] See the discussion in Landesmann and Scazzieri (1990) on this feature of structural change and on the notion of 'relative structural invariance'.

and consolidation of development economics as an autonomous field of research. This increase in interest, however, did not spread to the mainstream, with formal theories of economic growth typically being developed with little reference to the changing structure of the economy. Furthermore, in the 1970s, a deep transformation took place in development economics, with a shift towards a micro approach that made intensive use of the neoclassical framework, consequently inducing a strong decline in structural change analysis within this particular branch of economic research.

The more recent period, more precisely from the late 1980s onwards, has witnessed a new revival of interest on the field, which is apparent from the establishment of a new journal - *Structural Change and Economic Dynamics* – particularly dedicated to this topic. This recent uprise of interest seems to be closely related with an attempt to develop an alternative to mainstream economics for the analysis of the relationship between technical change and economic growth, which has been mostly undertaken within the evolutionary approach to economics.[3] In contrast with mainstream economics, proponents of this latter approach stress the idea of disharmony and competition in the growth process, and place themselves at quite distant from aggregate production function models, by explicitly addressing the connection between processes of change at micro and industrial levels and overall macroeconomic dynamics. In this context, structural change analysis comes to the fore as a powerful analytical tool that is capable of establishing the links between changes at the level of microstructures and higher-level changes, while providing, at the same time, a more realistic account of the process of technology adoption and its effects on the economy, by emphasizing the sequential and path-dependent nature of economic change.[4]

It is precisely in connection with the evolutionary branch of economic thought, and most particularly with its neo-Schumpeterian stream of research whose landmark contributors are Cristopher Freeman, Giovanni Dosi, Richard Nelson and Sidney

[3] Part I provides a more detailed investigation of the relevance of structural change analysis within the economic literature over time, and of the recent developments in the field.
[4] It is worth mentioning at this point that while certain aspects of structural change, such as the emergence of a new technique of production or the enlargement of the varieties of consumer and producer goods, might be encompassed by mainstream analyses of economic growth, the same does not apply to the economic coordination problems that inevitably accompany those changes. In fact, 'endogenous growth models, *like all equilibrium growth models*, are aimed at identifying growth factors and measuring their respective contribution to growth, so as to be able to derive policy implications', but 'there is no attempt to understand the working of the growth mechanism, which is assumed in the model' (Amendola and Gaffard, 1998: 115, emphasis added).

Winter, that the present work is theoretically founded.[5] Stemming from these (heterogeneous) contributions is the idea that processes of microevolutions of technique, organization and institution are significantly affected by higher-level changes and vice-versa, which means that causal connections between macroeconomic variables cannot be fully understood without considering the interdependence among the different levels of analysis. Focusing on the meso-macro relationship, we investigate the extent to which the rate of growth of the economy is dependent on technologically dynamic industries, taking the Portuguese economy as the benchmark case. In so doing, we follow a growing literature that has recently been exploring technological aspects of structural change and their connection with economic growth for several countries (see, for example, Fagerberg, 2000; Peneder, 2003; Saviotti and Pyka, 2004).

To the best of our knowledge, the empirical analysis of the relationship between structural change and economic growth addressing specifically the Portuguese case has been attempted only by a few studies.[6] For the most part, these studies have been concentrated on the assessment of the relative contribution of the three macro-sectors (primary, manufacturing and services) and on the analysis of the contribution of manufacturing industries to aggregate productivity growth, without an explicit account of the relationship between structural change and technological progress.[7] Furthermore, given the accounting nature of the methodologies used, the analysis has been performed in essentially descriptive terms, with no attempt to analyse causality chains or to assess the influence of additional variables, and of their interaction with structural change, in the growth process. In this context, a deeper understanding of the relationship between technology, structural change and economic growth for the Portuguese economy seems to be in order. This constitutes the main purpose of the present study, which is aimed at providing answers to the following questions:

- To what extent has structural change influenced Portuguese aggregate productivity performance over the last three decades?

[5] For a systematic presentation of the neo-Schumpeterian theory and its analysis of technical change and long-term growth patterns see Dosi et al (1988). See also our discussion in Part I.

[6] A brief description of these studies, including an assessment of the methodologies used and a comparison of the main findings is provided in Part II.

[7] An exception can be found in the work of Godinho and Mamede (2004), in which the technological feature of structural change is taken into account through the clustering of manufacturing industries according to the technological OECD taxonomy.

- Which industry branches have contributed most extensively to overall economic growth? Is there any relationship with their technological content?
- How does the Portuguese experience compares with other countries that in the late 1970s shared a relatively similar structure? Can the differences in overall economic performance among these countries be explained by different paces of structural change, especially in what relates to the relative importance of technologically-oriented sectors?

In order to provide answers to the aforementioned questions, the work is structured as follows.

Part I provides a comprehensive survey of the economic literature on structural change, covering the early foundations until the more recent years. Despite the fact that structural change analysis has an important tradition in economic theory, to the best of our knowledge such a survey has not yet been provided in the literature. In order to fill this gap and clarify the theoretical foundations that sustain our empirical work, we organize the economic literature on structural change analysis, presenting, at the same time, an overview and interpretation of the recent research trends on the field. Over the period under study an enormous amount of potentially relevant literature has been published, and as such, there is no reasonable way in which justice can be done to its entirety. In these circumstances, emphasis was thus placed on selecting 'seminal' contributions, and from there, an attempt was made to establish links with more recent works.

Parts II and III constitute the core of the empirical work. Part II is devoted to a preliminary assessment of the relationship between technology, structural change and the macroeconomic performance of the Portuguese economy using shift-share analysis. In contrast with previous work focusing on the Portuguese economy, which relied exclusively on the analysis of the effect of labour transfers within industries, we apply shift-share analysis to the evolution of total factor productivity (TFP), which provides a more complete measure of the structural change component. We also get a more explicit account of the relationship between structural change and technological progress by considering different technological taxonomies, which are critically examined. Finally, we improve the accuracy of the method by increasing the disaggregation level of the economy, and extend the analysis beyond the traditional borders, by explicitly exploring the role of technology within the services sector.

Since TFP series are not readily available for the Portuguese economy, a preliminary step concerns their estimation, which, in turn, requires information on labour and capital accumulation. In order to derive estimates of capital stock series we use the Perpetual Inventory Method (PIM). TFP growth estimates are then derived as the residual growth component, apart from labour and capital accumulation. Finally, in the last section of Part II we examine the role of structural change in explaining aggregate productivity growth, by comparing aggregate TFP growth and output-weighted sectoral TFP growth, following the procedure outlined by Timmer and Szirmai (2000).

Part III complements and enriches the analysis on the relationship between technology, structural change and economic growth developed in Part II. Because of the essentially accounting nature of the shift-share procedure, shift-share results are complemented with econometric estimation methods in order to analyse causality chains and take into account spillover effects among industries. Part III also widens the perspective, by considering along with Portugal a number of other countries that shared similar structural characteristics in the late 1970s. Econometric testing is undertaken by estimating a fixed effects panel data regression, which is aimed at investigating the role of technology leading sectors in explaining the widely different growth trajectories of the selected countries between 1980 and 2003, controlling for the influences of physical and human capital variables.

The latter part of the thesis provides a synthesis of the main results achieved, critically reviewing the work that has been done, and offering some guidelines for further improvements in future research.

Part I. A dynamic account of the changing relevance of structural change analysis

Section 1. Concept and Foundations of Structural Change Analysis

1.1. Introductory considerations

Despite the fact that structural change analysis has an important tradition in economic theory, to the best of our knowledge, there has been no attempt to provide an overall survey on the matter. Several factors may account for this. Firstly, even though the phenomenon of structural change is as old as the very problems of economic development, the term 'economics of structural change' was until recently practically unknown. The enormous heterogeneity of studies in this area, inherently related with the complexity of the matter, does not lend itself easily to a unified approach and only recently there have been some attempts (Baranzini and Scazzieri, 1990; Landesmann and Scazzieri, 1996) to organize the theoretical approach in a systematic manner. Secondly, the terms 'structure' and 'structural change' are widely used in economic research under very different meanings, and in many cases those meanings have no connection with 'structural change analysis'. This presents several difficulties when trying to identify and organize the existing theoretical and empirical work in the field.

In order to fill this gap and provide an adequate treatment of the literature on the field, a clarification of the meaning of 'structural change analysis' and of its specificity relatively to other streams of research within the realm of economic dynamics is put forward in Section 1.2.. In this section a description of the different economic uses of 'structure' and 'structural change' is provided building on Machlup's (1991) earlier work, and an attempt to define 'structural change analysis' is undertaken.

After having clarified the nature and focus of structural change analysis, we go a step further in providing a comprehensive survey of the literature in the field, by presenting an overview of its conceptual foundations in Section 1.3.. Earlier studies on the matter (e.g., Hagemann *et al.*, 2003; Baranzini and Scazzieri, 1990) have identified the earliest roots of structural change analysis in the works of Classical Economists. Our survey thus starts with an investigation of classical economic theory and its use of the structural change approach in the study of the dynamics of economic systems. As is widely known, the formative period of economic theory was characterized by a great concern on the study of the causes of economic progress of nations, with a 'systemic' approach being used by its leading representatives: Smith, Ricardo and Marx. After Marx, however, the analysis of long-term dynamics and their association with structural change became progressively less relevant, with the emergence of the marginalist revolution at the end of the 19th century, and its emphasis on the problems of optimal resource allocation. Interest on these matters would only be retaken by Joseph Schumpeter in his study of the dynamic processes of the capitalist economy (Schumpeter, 1934, 1939, 1943), which, nevertheless, stands out for its singularity at a time of almost entire neglect of the subject by his contemporaries. The analysis of conceptual foundations of structural change analysis thus ends with a brief overview of Schumpeter's ideas on the endogenous explanation of economic change (Section 1.4.), which became a major source of inspiration for many of the modern contributions on structural change analysis.

1.2. 'Structural change' and 'Structural change analysis'

An important aspect to be taken into account when analyzing the literature on the economics of structural change is that the terms 'structure' and 'structural change' are used in economic research under very different meanings, and some of those meanings have no direct bearing on 'structural change analysis'. Moreover, in many cases, there is considerable vagueness in the ways in which the terms are used, which hampers a precise interpretation of what is meant. Indeed, structure (and thus structural change) 'is often a weaselword used to avoid commitment to a definite and clear thought' (Machlup, 1991: 75).

In his semantic study of 'structure' and 'structural change', Machlup (1991) provides an extensive list of the various economic uses of the terms, distinguishing them according to their relative degree of clearness. Taking into account only the clearer definitions, there are at least nine different meanings to which structure and structural change can be related. Along with the notion of economic structure as 'different arrangements of productive activity in the economy especially to different *distributions* of productive factors among various sectors of the economy, various occupations, geographic regions, types of product, etc.' (Machlup, 1991: 76, original emphasis), which seems to be the most common use of the term in development economics and in economic history, there are several other meanings, expressing the appeal of this term in an extensive array of theoretical and applied research. For example, *structure* is also employed to denote the conditions that are assumed as invariant for purposes of analysis and modelling, regardless of the nature of the model; and the *structural* attribute is frequently used to distinguish permanent (structural) changes from temporary changes, and changes in ‘real’ factors from monetary and policy-led changes. At the same time, structure is often taken as synonymous of a ‘composition that does not change easily’ (Machlup, 1991: 78), referring mostly to the composition of basic macro-economic magnitudes, such as national product, investment, employment, exports or imports. This latter feature of structure as composition is also apparent in Ishikawa’s definition of structural change, in which it is taken as ‘a change in the relative weight of significant components of the aggregative indicators of the economy, such as national product and expenditure, exports and imports, and the population and labour force’(Ishikawa, 1987: 523).

From this array of possible meanings of the terms, which could be easily extended to encompass further interpretations, it seems clear that a precise definition of what ‘structural change analysis’ is, and of what makes it a distinctive field of economic research is necessary, in order to avoid possible misunderstandings, and be able to proceed with the literature survey.

In their introduction to ‘The Economics of Structural Change’, Hagemann et al. (2003) emphasize the ‘selective’ and ‘compositional’ features of this approach relative to mainstream economics. Structural change analysis, it is argued, starts with the premise of high, but limited, heterogeneity. It assumes that it is possible to study the infinite multiplicity of reality by focusing attention on a relatively small number of groups or activities that comprise the economic system. These relatively homogeneous groups (which form the economic structure and reduce the heterogeneity of reality to a manageable dimension) are obtained through the consideration of a classification scheme that varies according to the problem under investigation. In this way, the economics of structural change differentiates from standard micro and macroeconomic analyses, since it allows for a degree of flexibility in the choice of the unit of analysis that is absent in conventional research. Furthermore, structural change analysis provides a more detailed description of reality than would be the case with a totally aggregate macroeconomic representation, while offering, at the same time, a more focused approach than conventional microeconomic analysis.

The decomposition of the economic system into a limited number of subsystems through the consideration of a particular classification scheme is seen as a fundamental step towards a comprehensive understanding of economic dynamics. From the decomposition undertaken it becomes easier to identify the main causal linkages among the groups and variables under study, making it possible to get a more thorough understanding of the historical processes of medium and long-term change. Furthermore, it allows for the consideration of different patterns of change within the economic system, which provides a far more realistic account of processes of change than do equi-proportional and stationary state dynamic analyses. In this way, the structural change perspective opens the way for the study of qualitative change and of the analytical problems that it involves (namely inter-temporal coordination and restructuring problems), which are not appropriately taken into account by models based on equilibrium assumptions, in which co-ordination of economic activity is taken for granted.

The definition of 'structural change analysis' in these terms may be seen as encompassing some of the meanings of the terms 'structure' and 'structural change' defined above, but clearly not all of them. To be precise, for the purposes of this survey we consider only research that starts from the decomposition of the economic system into a limited number of subsystems, in order to analyze the dynamic properties of the economy as a whole. We are thus interested in theoretical, empirical and historical studies that associate the dynamics of economic systems with changes in their composition. Research focusing on other possible uses of the terms, such as studies concerned with the development of testing procedures to cope with the phenomenon of time series structural change, is completely disregarded.

1.3. Foundations of structural change analysis

1.3.1. Classical economists (1700s-1870)

The idea that the dynamics of economic systems is inherently associated with changes in their composition had already been explored by classical economists. Although they did not actually use the term 'structure' in any significant way, many authors (e.g., Steuart, 1767; Turgot, 1766; Smith, 1776) contended that the progress of wealth was intimately related to changes in the pattern of interaction among a few critical variables, which can be seen as distinct representations of the economic structure. For example, in Smith's *An Inquiry into the Nature and Causes of the Wealth of Nations* (1776), there is an explicit reference to the relationship between the sectoral composition of the economy and the stage of development reached. In fact, each stage is characterized by a particular composition of product, and a change in this composition is seen as a major requirement to reach higher stages of development.

Furthermore, in classical essays, there is an explicit attempt to identify the major forces that allow the economy to switch from one structure to another. In Smith's (1763; 1776) work, the main dynamic impulse to change comes from the division of labour. The productivity gains associated with labour specialization, related to the greater dexterity of the workforce, to the rationalization of resources and to higher incentives to innovate, induced changes in the identity and composition of economic activities, thus giving rise to a new structure of the economy. Another contribution in this period, from Rae (1834), points to invention, rather than the division of labour, as the major force driving structural change. From his perspective, the invention of new tools and machines brings on the division of labour (and not the other way around), which is then reflected in the changing structure of the economy. Rae also points out that the advantages arising from the division of labour, contrarily to Smith's point of view, come mostly from a more efficient use of the stock of instruments in the society, rather than from the increased efficiency of the workforce. Ricardo (1817), in his turn, emphasized the role of non-producible resources in the progress of wealth. Output growth requires growth of factor inputs but land is 'not unlimited in quantity and uniform in quality' (Ricardo, 1817: 70). This means that as growth proceeds, more land must be taken into cultivation, but land cannot be created. The growth of overall production requires then a continuous substitution of produced for non-produced inputs, which implies the changing composition of the productive system, together with significant changes in income distribution.

For the most part, classical economics was carried out in a rather descriptive fashion, without an explicit analytical account of the economic structure. Some exceptions to this general pattern can nevertheless be found in the works of Quesnay (1758) and Marx (1885). The first author, in his *Tableau Économique* (1758), provided a simple description of the analytical structure of the economy, exploring the general interdependence between economic sectors. Crucial to Quesnay's analysis was the notion that 'natural proportions' between sectors could be identified and that it would be possible to examine whether or not a given pattern of social expenditure was a sustainable one. The same idea was also present in Marx's schemes of accumulation and reproduction of capital (Marx, 1885), perhaps the most rigorous formulation to date of a growth model. Distinguishing between 'constant' and 'variable' capital, the former representing circulating capital such as fixed assets and raw materials, and the latter meaning advances to labour (i.e., wage payments), Marx (1885) argued that the tendency for increases over time in the ratio of constant to variable capital (the 'organic composition of capital') implied a re-proportioning of the various commodities produced. He also stressed that this transformation had to follow a particular pattern, so as to achieve a viable expansion of the economic system.

In both Quesnay and Marx's theoretical schemes, the analytical representation of the economic structure is based on a circular view of the productive process. Goods are produced not only from natural factors of production, but also from each other, and a particular good *x* entering the production of a good *y* can also use the latter in its production.[1] The interdependence of the economic system is captured by considering the flows of commodities among different sectors and income groups within a particular period (one year, for example). The two schemes are therefore characterized by a static representation of the production relationships, without any indication about the specification of the time structure of interrelationships between sectors. It should be noted, however, that whereas Quesnay's scheme is inherently static, without any indication about the way in which the economic system is supposed to evolve over time, Marx does also consider structural dynamics, through its schemes of extended reproduction. This is accomplished through the consideration of a 'dynamic behavioural principle', associated with the utilization of the surplus of a particular accounting period in the subsequent period, which allows for the introduction of dynamics within a 'pure circular-flow model'.[2]

1.3.2. The Schumpeterian legacy

After Marx, the interest in the study of the causes of the 'progress of wealth' strongly declined. The emergence of the marginalist revolution by the end of the 19th century, with its emphasis on the problems of optimal resource allocation, shifted the focus away from long-term dynamics and their association with structural change. A long hiatus thus existed until the appearance of Schumpeter's work, which took up again the

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[1] In contrast with this view, the Austrian theory of the formation of capital (Böhm-Bawerk, 1891) analyzes the productive process from a linear perspective. Defining capital (whether fixed or circulating) as an aggregate of intermediate products, Böhm-Bawerk formulates the concept of 'period of production', which corresponds to the time lag between the investment of 'original factors' (land and labour) and the acquisition of consumable commodities. From this perspective, all goods are grouped according to their distance in time from the consumer, which provides an overall linear picture of the productive process.

[2] See, in this respect, Landesmann and Scazzieri (1990).

analysis of long-term economic movements of the economy at a time of almost complete neglect of the matter.

Like Marx and other classical authors, Schumpeter was aware that structure had to change if there were to be long-term shifts in economic well-being. In his view, innovation[3] - arising from technological competition among firms -, was the major driving force behind such changes: once an (important) innovation was introduced, the prospect of extra profits would lead to a complex process of dissemination by imitation and further improvement by other firms in the market, along with the appearance of other innovations in related fields of activity.[4] There was thus a tendency for innovations to cluster, not only in certain activities, but also in particular time periods. For a while, the 'cluster' of activities in which innovation appeared would grow at a higher rate than the overall growth rate of the economy, but sooner or later, the potential for further growth would become exhausted, and growth would slow down. According to Schumpeter (1939), this cyclical development of clusters could be transmitted to the overall economy, contributing in this way to the observed discontinuity of the growth process and to the formation of business cycles of varying lengths.[5]

In Schumpeter's analysis a major thrust is thus entitled to structural change, which is taken not as an additional feature of the growth path, but rather as representing the *very essence* of economic development.[6] The introduction of basic innovations leads to a process of 'creative destruction' –a more colourful way to express structural change–, with 'old' sectors declining while new sectors emerge and assume progressively higher importance. Nevertheless, apart from a general description of the 'swarming' and 'bandwagon' effects associated with the cyclical pattern of the economy, Schumpeter

[3] Schumpeter defines innovation in a broad sense as 'new combinations of existing factors of production' (Schumpeter, 1928: 377), exemplifying with the emergence of new products and new methods of production, the creation or exploitation of new markets and new ways to organize business.

[4] In Schumpeter's early work the introduction of innovation is made by the individual (visionary) entrepreneur, who plays a vital role in the process, fighting the prevalence of inertia and the resistance to new ideas. However, later in his life Schumpeter changed his views on the matter, considering that innovation would be mainly carried out within the context of large oligopolistic firms. This notwithstanding, Schumpeter's perspective on the role of basic innovations and on their diffusion throughout the economy in the process of economic change remained essentially unaltered.

[5] Schumpeter's ideas on the relationship between innovation and business cycles were not well received by the economic community at the time of their publication, and were severely criticized by Kuznets (1940), who questioned their logical coherence and adherence to reality. In the 1970s, however, those ideas were once again brought to the fore, and became the centre of an intense debate among the supporters of Schumpeter's thesis on 'long waves' and its detractors, a debate that still persists today. See Fagerberg (2003) for a discussion on the matter.

[6] Schumpeter uses the term 'economic development' to denote changes caused in the economic process by endogenous factors, which are distinguished from mere quantitative changes, labelled as 'growth'.

leaves largely unexplored the structural adjustment process of the economy following innovation. In particular, as pointed out by Gualerzi (2001), the impact of the demand side in shaping the overall transformation of the economy is left totally aside, with attention being exclusively focused on the supply side of the economic process.[7]

These limitations do not obscure, however, the notable contribution of Schumpeter in providing an endogenous explanation of economic change in the economy, which laid the foundations for much of the recent literature on structural change analysis.[8] The acknowledgement and widespread recognition of Schumpeter's seminal contribution came, nevertheless, many years after the publication of his work,[9] which although reflecting the singularity of Schumpeter's concerns in his lifetime period, may also reflect the non-formalized character of his approach, in a period in which neoclassical economics and mathematical theorizing were becoming increasingly dominant.[10] As a matter of fact, the relative lack of interest in structural change analysis for a long period of time may indeed be related to the strong unbalance towards empirical and historically-related studies in detriment of more formally-oriented research, as will be further explored in the following section.

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[7] Schumpeter even argues that 'it is the producer who as a rule initiates economic change and consumers are educated by him if necessary' (Schumpeter, 1934, cited in Gualerzi, 2001), which makes clear the general irrelevance attributed to consumers and demand in his analysis of economic growth.

[8] This point is further developed in Section 3.

[9] Fagerberg (2003) locates the revival of interest in Schumpeter's work in the period following the economic slowdown of the 1970s.

[10] The mathematization of economics is probably the most important feature in the history of twentieth-century economics (see, in this respect, Mirowski, 2000 and Weintraub, 2002). The use of models has become the dominant practice – in the view of many, the way of doing 'good economics' which can explain the poor reputation of 'appreciative theorizing' (Nelson and Winter, 1982), that is, of theories not expressed in mathematical terms.

Section 2. Theoretical versus applied analysis of structural change

2.1. Introductory considerations

In the post-war period, the economic analysis of structural change has gradually emerged as the result of the appearance and consolidation of development economics as an autonomous field of research. At the time, development economics was largely concerned with the ways in which the different sectors of the economy adapted over time to overall changes in the economy, making an extensive use of the concepts and methodologies of structural change analysis. The early stages of development economics as an autonomous field of research were indeed characterized by a 'systemic' view of economic reality, with most studies attempting to explore theoretical arguments by which the observed processes of structural transformation could best be explained (e.g., Rosenstein-Rodan, 1943, 1961; Nurkse, 1953; Lewis, 1954). Those theoretical explanations were mainly developed along appreciative strands, with little recourse to formal reasoning, and a policy-oriented approach was generally undertaken, where a number of policy recommendations aimed at improving countries' economic performance were formulated.

Along with this literature, several attempts were made to identify generalizations about long-term economic development and structural change based on inter-country economic comparisons and time-series data for selected countries. Major contributions to this stream of research are found in the works of authors such as Simon Kuznets and Hollis Chenery.

Contrasting with the rather prolific stream of research on structural change within an appreciative-historical-empirical focus, there was a general neglect of the topic on the part of pure economic theory. Formal theories of economic growth were typically developed with little reference to structural change, despite the widespread evidence regarding its major role in countries' development experiences. Difficulties arising with the formalization of structural change may partially account for the fact, although they should not deter efforts in the direction of obtaining a theoretical framework more in line with empirical evidence. This was, indeed, attempted by a few authors, who developed important contributions on the analytical representation of the economic structure and on its elaboration within structural theories of economic growth (e.g., Leontief, 1928, 1941; Hicks, 1965, 1973; Pasinetti, 1973, 1981, 1993).

In the present section we undertake a comprehensive survey of the seminal theoretical and applied works on structural change analysis, and from there we attempt to establish links with more recent works. As will be made clearer in the foregoing discussion, both approaches (theory and empirics of structural change) have been developed quite independently over time, with only a few convergence points being observed. Notwithstanding the increasing sophistication of statistical and econometric methods and the growing availability of data, a wide gap between economic theory and empirical research of structural change still persists in the more recent period. We thus conjecture that a critical step in the development of the economics of structural change must necessarily involve some cross-fertilization between modelling efforts and empirical research.

2.2. Structural theories of economic growth

Economic theories of growth have been typically developed with little reference to the changing structure of the economy. Yet it is well-known that growth fundamentally changes the structure of the economy and the composition of its main aggregates.

Formal structural theories of economic growth take as their point of departure an analytical representation of the economic structure, which provides a selective description of the economic system. This analytical step permits the move from 'infinite variety' to a relatively small number of classes in which agents or activities are clustered, thus allowing uneven economic dynamics to be explored more easily (Hagemann et al., 2003). The adoption of a particular structural specification is, of course, dependent upon the focus of the investigation. At this level, a traditional distinction stresses the differences between 'horizontal' and 'vertical' representations of the economic structure. Horizontal representations describe the economic system as a circular structure, with economic activities being clustered into mutually dependent classes. As mentioned earlier, this type of representation of the economic system was a hallmark of classical economists' works, in which production was seen as an essentially circular process. In the modern period, a circular representation of this type, in which no information is given about the time structure of the horizontal interdependencies among sectors (that is, in which a point-input point-output representation of processes is assumed), can be found in the von Neumann (1937) and Sraffa (1960) models. Even though they developed their works based on different backgrounds and different intentions, both authors perceived production as a circular process where commodities are produced by means of commodities and production takes place through processes of unit time duration.[11] Leontief (1928, 1941) also explores the idea of general interdependence and circularity of production in his detailed quantitative description of the economic system. In his model, the production process is illustrated by means of multiple causal relationships, where certain commodities are generated by other commodities that are themselves used and consumed in further production. In the dynamic formulations of the Leontief system (e.g. Leontief, 1953, 1970), the horizontal-flow description is supplemented by the specification of construction and delivery lags that incorporate the time structure of inter-sectoral flows. These formulations permit the simulation of structural changes (such as changes in the composition of final demand and changes in technology), assessing their implications in terms of the overall workings of the economic system. Lowe (1955, 1976) also makes a combined use of the horizontal approach and the specification of the time structure of inter-sectoral flows in his studies on ‘traverse analysis’.

Differently from these contributions, vertical representations exclude the consideration of horizontal interdependences, stressing unidirectional relationships and asymmetric dependence in the clustering process. An early contribution to the analysis of the economic system in ‘vertically-integrated’ terms can be found in Sraffa’s *Production of Commodities by Means of Commodities* (Sraffa, 1960, Appendix A). Sraffa demonstrates that in the general case of production of commodities by means of commodities it is possible to move from a ‘circular’ to a ‘vertical’ representation of the economy. This is accomplished by splitting up the circular flow into a number of distinct ‘net product’ subsystems, in which each subsystem represents a one-way relationship from dated inputs of original factors (labour and means of production) to the corresponding final commodity. Sraffa’s brief account on the vertical representation of the economic system would be further developed by Pasinetti (1973). In this work, Pasinetti elegantly displays the analytical operation involved in the transformation of the usual input-output scheme (e.g., Leontief, 1941) into a set of vertically integrated sectors, providing at the same time a meticulous examination of the logical properties of the process of vertical integration. Under this framework, the economic system is partitioned into a number of vertically integrated sectors equivalent to the number of

[11] In particular, Sraffa’s (1960) major concern was the revival of the classical approach to the theory of production, value and distribution, whereas von Neumann (1937) basically attempted to find an equilibrium solution for a multi-sectoral economic system.

final commodities produced, with each vertically integrated sector expressing in a consolidated way the quantities of labour and intermediate inputs that are directly or indirectly required to obtain a particular final commodity.[12] The logical operation of forming vertically integrated sectors then allows for an analysis of the general theoretical problems associated with the (uneven) dynamics of growth and its association with technical change without any reference to intermediate uses of the commodities.[13]

An alternative approach to remove horizontal interdependencies in the Sraffa-Leontief system has been proposed by Richard Goodwin (Goodwin, 1976, 1983, Goodwin and Punzo, 1987). This is accomplished by transforming the original space into an imaginary space, in which the eigenvectors of the square input matrix are used as 'general coordinates'.[14] This transformation defines *n* distinct composite commodities, with each commodity being produced entirely out of inputs of its own product. Therefore, the method allows for a separate investigation of a single sector in the economy, as if each sector were a Ricardian 'Corn Economy'.

A totally vertically-integrated representation of production is also proposed by Hicks (1973). Hicks overcomes the difficulty of the Austrian representation of production activities in introducing durable means of production, by defining each productive process as a stream of labour inputs delivering a stream of final product outputs,[15] where all the intermediate products used in the production of final goods are ultimately reduced to the amount of labour that was used in their production. In this 'neo-Austrian' framework, each process of production is seen as comprising two sequentially related phases: a 'construction' phase, in which labour is used to produce machinery and no final product is obtained, and the 'utilization' phase, in which the machinery obtained in the former phase is combined with labour in the production of final goods. The economic system is thus composed of two large interconnected 'sections', the first including the activities that belong to the construction phase, and the second including the activities of the utilization phase. This vision of production allows for the study of

[12] The sum of these inputs and labour requirements must, of course, express the total inputs used in the system as a whole.
[13] In particular, it prevents the system of equations from breaking down, due to a change in the technical coefficients, as was the case with inter-industry systems of equations.
[14] In this method, however, a complete removal of sectoral interdependencies is undertaken, whereas in Pasinetti's work an attempt is made to retain the maximum structure possible. For a comparison of the two methods see Pasinetti (1990) and Cozzi (1990).
[15] A flow-input flow-output profile, instead of the Austrian flow-input point-output framework.

problems of transition between production techniques and, more generally, of problems of non-proportional growth, within the context of historical time.

In an intermediate approach between the two extremes of purely horizontal and vertical representations of the economic structure we have Georgescu-Roegen's (1971) fund-flow model. In this model, the time dimension is explicitly taken into account through the consideration of different time profiles of the inputs, which are classified as being of the 'fund' or the 'flow' type. Under this classification, 'funds' represent the agents of the transformation process, entering and exiting the production process with their efficiency intact, whereas 'flows' are the objects and the products of the process.[16] By adding information on the temporal pattern of use and the combination of the resources in the production process, the model allows for the specification of temporal complementarities that provide additional 'vertical' information along with conventional information regarding technical coefficients provided by the input-output framework. This opens the way for new perspectives in analyzing the dynamics of economic systems.

Horizontal and vertical representations of the economic structure have been used in a number of seminal contributions analyzing the uneven dynamics of economic growth from a structural change perspective. As mentioned before, the use of one particular descriptive-analytical tool, rather than the other, or even the combined use of both methods, is dependent upon the specific focus of the investigation, with the different approaches offering complementary views of the growth process.[17]

Among the studies that explicitly take into account the restructuring of the economy which accompanies growth there is one strand of research - the so-called 'traverse analysis' - that focuses on transition paths, analyzing the changes occurring in an economy that was originally in steady-state and that has been disturbed by changes in the exogenous determinants of growth, such as changes in technology and factor supplies. A common feature of the contributions within this type of research is the

[16] Examples of funds or agents are land, capital and human capital, which transform input flows (raw materials, intermediate inputs and inputs needed for maintenance of capital) into output flows (products and waste) (see Georgescu-Roegen, 1971, pp. 230-233). For a presentation of the 'fund-flow' model see also Tani (1988) and Piacentini (1995).

[17] Though some authors claim the relative superiority of vertical approaches in studying non-proportional growth (e.g. Belloc, 1980; Amendola, 1984), there are also arguments in favour of the opposite view (e.g. Lowe, 1976; Hagemann, 1990), with several authors stressing the complementary nature of both approaches (Hicks, 1973; Zamagni, 1984; Hagemann, 1990). For a comparative account of the relative merits of horizontal and vertical approaches see Hagemann (1990).

emphasis placed on structural rigidities (horizontal, as well as vertical rigidities) as major factors determining the dynamics of an economic system subject to a source of change. It is the consideration of such rigidities that places the analysis in the context of historical time, rather than logical time, where economic dynamics are seen as the result of (irreversible) changes taking place in a sequential manner.

Ricardo's analysis of technological unemployment in his brief chapter 'On Machinery' in *Principles* is generally regarded as laying the grounds for this type of research. Following Ricardo, both Lowe and Hicks, the pioneering authors of 'traverse analysis', put great emphasis on the possibility that technical change could lead to unemployment, analyzing the conditions under which displaced labour originated during the transition could be reabsorbed at the end of the process. This problem is, however, approached by the authors from different perspectives, which rely on distinct descriptive-analytical representations of economic structure. As mentioned above, Lowe (1955, 1976) adopts a horizontal approach, elaborating on a modified version of the Marxian schema of reproduction. The main modification introduced by Lowe – the division of the Marxian capital goods-producing sector into one sector that produces the equipment for the consumer goods sector, and the 'machine-tools' sector that produces the equipment for both subgroups of the capital goods sector - allows him to establish a hierarchical organization of the economy, in which the 'machine-tools' sector assumes the key role. Indeed, under the assumption of full utilization of the economy's capital stock, any process of expansion implies a prior increase in fixed capital in this sector (and subsequently in the other capital-goods producing sector), so as to obtain an increase in the production of consumption goods. The adjustment path of the economy is thus characterized by a *sequential* process of production and re-proportioning of the economy, in which the capital stock is rebuilt.[18]

Hicks made use of the horizontal scheme in his first analysis of the traverse in *Capital and Growth* (1965), in which he develops a two-sector model of an economy which employs labour and tractors to produce corn and tractors, with technical coefficients of production that are fixed for each sector.[19] However, he soon became disappointed with the inter-industry approach, switching to a vertically integrated approach in his *Capital and Time* (1973). At the origin of this change was the need to focus on innovations that

[18] A thorough discussion of Lowe's work can be found in Hagemann (1990) and Gehrke and Hagemann (1996).
[19] It is in this work that the first formal definition of traverse is put forward (see Hicks, 1965, p. 184).

took the form of new methods for making the same final product, which could not be accomplished in a multi-sectoral model with a horizontal structure, since ‘there is no way of establishing a physical relation between the capital goods that are required in the one technique and those that are required in the other’ (Hicks, 1977: 193).[20] In his ‘neo-Austrian’ framework,[21] an once-over change in technology leads to a transition period, until the full utilization of the new technology is reached.[22] In particular, there will be a period of time (the ‘early phase of the traverse’) during which processes using old and new techniques will coexist. Hicks uses this framework to re-examine Ricardo’s analysis of technological unemployment, considering alternative dynamic paths – ‘full-employment’ and ‘fixwage’ traverses. It is shown that technological unemployment may arise in the transition period, but that the long-term effects are likely to go in the other direction, with displaced labour being fully absorbed at the end of the process.

Both Lowe and Hicks’ works on ‘traverse analysis’ have inspired subsequent developments in the literature. For example, Lowe’s concerns with the strategic role of the machines-tool sector were integrated in studies focusing on economic planning in developing economies in the 1950s and 1960s (e.g., Mahalanobis, 1955; Dobb, 1960; Sen, 1960; Navqi, 1963). More recently, a few attempts have been made to analyze some features of transitional paths not explored in the seminal works of Lowe and Hicks, combining both vertical and horizontal representations of the economic structure (e.g., Quadrio-Curzio and Pellizzari, 1999; Baldone, 1996; Quadrio-Curzio, 1986; Belloc, 1980). Baldone (1996), for example, integrates the neo-Austrian method in his inter-industrial representation of the economic system, by defining the production process of the machine sector as a sequence of construction and utilization phases. In this framework, the transition process between two techniques is represented by the emergence of a sequence of mixed techniques, that is, the simultaneous use of several technologies at each moment in time, which lasts until all the ‘old’ processes cease to function. An important result of the model is that residuals may arise in the transition process, due to disproportions between the availability and the effective use of commodities, which makes the determination of transition paths more complex.

[20] Hicks, however, did not exclude entirely the horizontal approach, which is explored, in parallel with the vertical integration approach, in a later work (Hicks, 1985).
[21] The configuration of the productive process under this framework was described earlier.
[22] As in Lowe’s model, but under a different framework, a major result is thus that the inherited stock of fixed capital represents a major bottleneck that the economy has to overcome in order to reach the new steady growth equilibrium path.

Multiple trajectories also feature transition when the impact of technical change is analyzed in terms of the introduction of new products. A rather complex picture of structural dynamics is also present in Quadrio-Curzio's contributions. Inspired by the work of Ricardo and taking Sraffa's *Production of Commodities by Means of Commodities* (1960) as the point of departure for the analysis, Quadrio-Curzio – on his own and in collaboration with Pellizari –, emphasizes the limiting role of scarce, non-produced means of production in the growth process. In particular, it is demonstrated by means of a multi-sectoral model that increasing scarcity leads to the activation of successive technologies in order to produce the raw material, leading to the adoption of mixed technologies at each moment in time. In this context, by introducing a vertical decomposition within the framework of an inter-industrial approach, the mixed technology that is in use in a particular moment of time can be seen as the combination of a number of subsystems equivalent to the number of technologies activated. At the same time, because the structures of the technologies that are successively emerging may differ from 'older' technologies, a residual will be created, with potentially negative effects on the overall growth rate of the economy. A major result within this frame of analysis is then that the maximum sustainable growth rate of the economy is not uniform, but rather depends on the number and type of subsystems that are operated and on their relative compatibility at any point of time.

These recent trends in traverse analysis seem to suggest that important insights on transitional dynamics may be uncovered if horizontal and vertical descriptions of the economic system are taken into account under complementary terms. But despite its inherent potential for the study of economic dynamics, traverse theory seems to remain a relatively unexplored method of enquiry, as only a few authors have introduced relevant contributions in the field.

A different approach to the relationship between structural change and economic growth, developed independently of the analytical construction of the steady-state, can be found in the work of Pasinetti (1981, 1993). In contrast with the studies outlined above, in which structural change is an out-of-equilibrium feature, in Pasinetti's work it represents a permanent feature accompanying growth. Moreover, whereas in those studies the fundamental forces of change are seen as originating mainly in the supply side of the economy (through changes in technology and factor supplies), Pasinetti attributes a fundamental role to changes in demand, which are incorporated in the analysis by means of a generalization of Engel's law.[23]

Pasinetti attempts to provide a general conception of the dynamics of growth and structural change that explicitly takes into account the uneven impact of technological and demand changes among sectors, an issue typically neglected in contemporary theories of economic growth.[24] In a return to the classical tradition, Pasinetti sets out his analysis in terms of the 'natural system', in which all relations are investigated in a pre-institutional context. The basic theoretical scheme, developed in terms of vertically integrated sectors, was presented in great detail in his 1981 book, *Structural Change and Economic Growth*. The 1993 publication, *Structural Economic Dynamics*, represents a continuity in this line of research, but within the more restricted framework of a 'pure labour production model', a minimal model 'that contains the very essential features of the 'production' paradigm, to which classical and Keynesian economics belongs' (Pasinetti, 1993: xiv). The primary concern of the model is the definition of the conditions that must be fulfilled for an economy to achieve and maintain a 'satisfactory state of economic growth', described as a state in which there is approximately full employment of the labour force and full utilization of productive resources (Pasinetti and Scazzieri, 1987: 527). In this framework, individual and social learning is seen as the major engine of economic change. It influences the dynamics of the economic system through two major channels: a 'strictly technological' one (Pasinetti, 1993: 36) which refers to productivity increases and to the emergence of new techniques and new products in the economy, and a demand-related one, associated with the rise in per capita income and its influence on consumer demand, as described by Engel's law. Technology and demand are thus seen as the main determinants of long-term economic dynamics, although their influences are separated. Technology determines the evolution

[23] Leon (1967) also integrates Engel's law in his theoretical analysis of growth and structural change. According to his main argument, the non-uniformity of the increase in demand, as predicted by Engel's law, implies that the rate of profits is permanently differentiated across industries, with the industries that benefit most from consumption increases achieving both higher rates of growth and profit. The simultaneous existence of different profit rates in the economy is, at the same time, explained by the monopolistic structure of the market, which is seen as a 'permanent feature of capitalism' (Leon, 1967: 54). But unlike Pasinetti's comprehensive analysis of growth and structural change, Leon does not express his views in mathematical terms.

[24] According to the author, those theories, though very elegant from a mathematical point of view, were entirely dissociated from the historical records of growth and structural change in industrial economies, as documented in the works of authors such as Kuznets and Chenery (Pasinetti, 1993, ch.1). A notorious example is found in von Neumann's multi-sectoral growth model (von Neumann, 1937), in which it is assumed that the relative weights of the different productive sectors are constant over time, thus leading to an equi-proportional dynamics of the entire economic system.

of prices, in line with the classical labour theory of value, whereas effective demand determines the dynamics of production, as within the Keynesian approach.[25] From the structural dynamics of technology and of demand arises, as a consequence, the structural dynamics of employment. In this respect, Pasinetti (1981, 1993) demonstrates that the full employment condition raises a *permanent* problem of complex macroeconomic coordination.[26] The emergence of technical progress, although extremely beneficial in terms of the new goods and services that it introduces, and the rise in productivity that it brings about, also bears complex problems of adjustment in the economy. In fact, an immediate consequence of technical progress is a decrease in technical coefficients, and thus a tendency to generate unemployment as time goes on. Although there are a number of ways to counter this tendency (see Pasinetti, 1993: 54), full employment can only be reached if there is an adequate level of labour mobility between productive activities and/or a reduction in the available labour (through a decrease in the activity rate and/or an increase in leisure time).[27] In any case, the necessary adjustment that is needed in each single period of time requires the coordination of individual and collective choices that is far from being automatic. This raises a number of institutional and policy questions so as to adequately respond to the challenging task of pursuing full employment.[28]

A common strand of criticism of Pasinetti's theoretical schemes concerns the exogenous treatment of the main engines of structural dynamics, that is, changes in technology and consumer preferences [see, for example, Gualerzi (2001) and Harris (1982)].[29] Although Pasinetti relates both factors with the *learning principle*, learning itself is essentially unexplained and therefore the question of what moves the driving forces of the

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[25] The theoretical framework expresses this separation, by considering two systems of equations, in physical quantities and in prices, which remain separated over time. At the same time, changes in demand and in labour productivity, which determine changes in quantity movements and in prices, respectively, are different in each sector.

[26] Unlike steady-state growth models, in Pasinetti's framework there is never a possibility of maintaining equilibrium conditions through time. Technical change and the evolution of consumption patterns operate continuously, thus leading to new conditions of economic equilibrium, one period after another.

[27] In this respect, increases of per capita demand would not be sufficient, given the inherent tendency of saturation of consumption described by Engel's law.

[28] At this point, it is worth recalling that although this work may be seen as presenting a theory of technological unemployment, following previous insights developed by Keynes, it goes well beyond Keynes' short-term analysis. In fact, it shows the existence of a permanent problem of unemployment that arises from the very nature of long-run growth, which is a distance removed from the usual Keynesian argument.

[29] Gualerzi, in particular, has argued that Pasinetti's reliance on Engel's law and on the inherently simplified notion of needs and needs hierarchy is not capable of capturing the technological and social dimensions that influence consumption, meaning that the articulation with economic development cannot be appropriately explored.

economy remains unanswered. At this level, an extension of Pasinetti's 1981 model that relates productivity growth with the emergence of technological revolutions has been proposed by Reati (1998a, 1998b). In line with the long-wave theory, originated in Schumpeter and recently elaborated in neo-Schumpeterian strands (e.g., Freeman et al, 1982; Kleinknecht, 1986; Freeman and Perez, 1988), in Reati's model (Reati, 1998a) radical process innovations entail a substantial rise in productivity for the innovator that is progressively diffused throughout the sector in a non-linear fashion. The pattern of diffusion influences the productivity curve of the sector, which, in turn, determines the dynamics of the price system. In the more elaborated version of the model (Reati, 1998b), the influence of long-wave patterns on demand and on the dynamics of the quantity system is also explored. In particular, it is shown that demand, as well as physical output in the final sectors, also exhibit an S-shaped profile. The impact of innovation on employment is relatively uncertain, depending on the nature of the particular innovation at hand (that is, if it is a product or a process innovation), and in the case of process innovations, depending on the values assumed by price and income elasticities of demand. Andersen (2001) also attempts to endogenize demand and technology factors in Pasinetti's 1993 model, by transforming this framework into an evolutionary model with explicit microfoundations. The microfoundations rest upon the definition of a number of 'rules of thumb' concerning the endogenous evolution of demand coefficients, labour coefficients and the number of available sectors, which is initially explored in a 'Robinson Crusoe economy', and in the last part of the paper is extended to the more general case of an economy formed by several exchanging consumer-producer firms. As acknowledged by the author, the present version of the model demonstrates that Pasinetti's theoretical scheme can be approached from a 'bottom-up' perspective, but there is still a long way to go before its 'structural economic dynamics' can be derived from a micro-founded evolutionary frame of analysis.

Another attempt to to endogenize demand in a dynamic theory of growth and structural change, this time through the consideration of an endogenous process of market creation, has been developed by Gualerzi (2001). In *Consumption and Growth*, Gualerzi integrates several elements of Schumpeter, Pasinetti and Levine's contributions (among others) into a demand-led growth theory developed within a Keynesian framework, in which market expansion, associated with the evolution of consumption patterns, leads to and is fuelled by investment. More precisely, market expansion depends on the strategies of market development pursued by firms in order to identify and benefit from potential demand, which determine changes in consumption that in turn create conditions for further investment. Those strategies vary according to the ‘stage’ of market development - the innovation, intensive growth and extensive growth phases – which in broad terms follow product cycle stages. Like in Schumpeter’s work, innovation is followed by growth and structural change, but in this case the structural dynamics of market creation is associated with the evolution of consumption patterns. In this context, a great emphasis is put on the adequacy of new products to the individuals’ needs (which are socially determined and as such do not arise ‘naturally’), and an important role is addressed to uncommitted income and to its distribution. As the author clearly recognizes, the theoretical effort carried out is still very general and schematic, and it is not expressed in a formally rigorous manner.[30] But even in these terms, it sheds considerable light on relatively unexplored aspects of the growth process, providing fruitful questions for further theoretical work.

Differently from these contributions, Baumol’s (1967)[31] seminal work on the relationship between structural change and economic growth does not explicitly take into account the demand side. A major emphasis is given to the uneven impact of technology among sectors (as in Pasinetti’s work), which ultimately explains the ‘unbalanced’ nature of economic growth. According to Baumol, the economy can indeed be seen as comprising two major groups of activities: those that are technologically progressive, in which innovations, capital deepening and economies of scale boost a continuous rise in productivity; and those that can only enjoy sporadic increases in productivity. This basic distinction stems from the intrinsic nature of the activities, and particularly from the role played by labour in the corresponding production processes. Whereas in some activities, such as manufacturing, labour is only a means to attain the product, in others, like most of the service activities, it constitutes an end in itself. This particular feature makes technological substitution of the workforce difficult to achieve, and thus productivity increases are slower than in the rest of the economy. The distinction between sectors is put forward in a model, in which labour productivity rises cumulatively in one sector, whereas in the other it is held

[30] Gualerzi himself sees his contribution more as a ‘framework capable of guiding more focused empirical studies’ (Gualerzi, 2001: xiii) than a means to provide determinate predictions.
[31] A more recent application of the original model can be found in Baumol (2001).

constant over time. Since wages increase in the same way in all sectors, this leads to the cumulative rise of relative costs in the non-progressive sector of the economy, which cannot compensate for the rise in wage levels. Consequently, the activities in this latter sector will tend to be driven off the market, unless their demand is relatively price inelastic.[32] In this case, their relative share in output can be maintained, and as a result, an increasing number of the total labour force must be transferred to this sector, with the consequent slowdown in the rate of growth of the economy (the well-known 'cost-disease' effect). Considering that there is a low substitutability in demand structures, this result can explain the increase in the 'service share' in total employment in the economy, an argument that has had considerable echo in the services literature.[33]

Recently, an attempt was made to include the demand side in Baumol's model and examine the consequences of 'cost-disease' on aggregate employment. Extending Baumol's model through the introduction of Pasinetti's sectoral demand functions, Notarangelo (1999) shows that the former can be interpreted as a particular case of Pasinetti's model, with labour mobility between productive activities being a necessary condition for macroeconomic stability, and sectoral growth rates depending on both productivity and demand factors. It is shown furthermore that the change in the relative shares of employment predicted by Baumol may lead in some cases to the rise of involuntary Keynesian unemployment.

As will be further explored in the following section, the above-mentioned seminal formal contributions remained at quite a distance from a contemporaneous far more prolific strand of research within a structural change perspective developed along appreciative and historical lines. Furthermore, with the notable exceptions of Leontief's input-output model and Baumol's unbalanced growth model, which have prompted a vast number of empirical applications,[34] most theoretical developments remained confined into the strict field of economic theory, or gave rise only to a few incursions into the empirical level of analysis. A noteworthy example is Pasinetti's model of economic growth and structural change. Despite being the most prominent theory of

[32] At this point, Baumol (1967) argues that some activities that face relatively inelastic demands may continue in the market, either by receiving public support (like theatres, for example), or by becoming market niches, directed towards luxury trade (such as high-quality food or clothing services).

[33] For a recent survey, see Shettkat and Yocarini (2006).

[34] Leontief's input-output approach, in particular, was mainly conceived as a tool applicable to empirical analysis (cf. Leontief, 1987), which explains the widespread dissemination of the method in empirical work. For an overview of the numerous areas of application of input-output models see Rose and Miernyk (1989).

structural change, it has only given rise (to our knowledge) to a very recent empirical application developed by Hölzl and Reinstaller (2007).[35] The concept of vertically-integrated production has also been used in a relatively small number of empirical studies describing the connections between sectors and the processes of productive integration (see, for example, Peterson, 1979; Wolff, 1985; Sánchez Chóliz and Duarte, 2006). There seems thus to remain a wide gap between economic theory and empirical research, despite the growing availability of data and the increasing sophistication of statistical and econometric methods.

2.3. Empirical and historical perspectives on structural change

Contrasting with its general neglect in formal theories of economic growth, structural change has traditionally played a fundamental role within empirical and theoretical studies of developing and transition economies. In fact, the early stages of development economics as an autonomous field of research were characterized by a 'systemic' view of economic reality, with most studies (e.g., Rosenstein-Rodan, 1943, 1961; Nurkse, 1953; Lewis, 1954) attempting to explore theoretical arguments by which the observed processes of structural transformation could best be explained. Those theoretical explanations were mainly developed along appreciative strands, with little recourse to formal reasoning, and a policy-oriented approach was generally undertaken, where a number of policy recommendations aimed at improving countries' economic performance were formulated. A few examples of this approach can be mentioned. Rostow's 'stage approach' to development (Rostow, 1960) reported the existence of structural discontinuities in the process of development, which were related to the concept of necessary pre-requisites for the transition to higher stages of development. One of the pre-requisites of the centre stage – the take-off – was the emergence of a leading sector that would induce the transformation of the productive structure in order to achieve higher rates of growth. Although this theory was later heavily criticized, in particular by Gershenkron (1962), who argued against the notion of a unique path of development, it had some impact on the contemporary views of development. At about this time, the dual-economy models (Lewis, 1954) and 'big-push' theories were also

[35] Hölzl and Reinstaller (2007) use Pasinetti's (1981, 1993) model of structural dynamics in the specification of a structural vector autoregressive model which allows them to study the relative importance of productivity and demand shocks in generating sectoral growth and their relation to industrial change in Austrian manufacturing during the 1971-1995 period. The results show some correspondence with Pasinetti's main predictions; in particular, it is found that sectoral patterns in employment and output growth depend negatively upon productivity growth and positively upon sectoral growth rates of demand, even though there is some heterogeneity of responses among sectors.

very popular. They all stressed the importance of taking into account sectoral differences in order to explain the overall progress of the economy. In Lewis's model those differences were addressed through the distinction between the traditional and the modern sectors of the economy. In the face of a stagnant traditional sector with a high elastic supply of labour, the shift of labour towards modern sectors would be beneficial at the aggregate level, as workers with low productivity would be put to more productive uses, and growth would continue until the modern sector had exhausted all reserves of labour in the rural sector. The works of Rosenstein-Rodan (1943, 1961) and Nurkse (1953), in their turn, emphasized sectoral differences as a requirement for balanced growth. In the former, the complementarities among different industries, such as those between production and consumption structures, were the main argument in favour of large-scale planned industrialization (the 'big-push'). Only through a planned industrialization effort would it be possible to distribute investment in the 'right' proportions, matching the structure of output to the structure of domestic demand. Nurkse, for his part, argued in favour of the promotion of a diversified increase in output that took into account domestic elasticities of demand in order to create mutually supporting demand (Nurkse, 1953). The need for directing investment resources towards expanding the capacity of the basic sectors of the economy through planning was also stressed by Dobb (1960), Sen (1960) and Navqi (1963), who shared Lowe's concern for the strategic role of the machines-tool sector.

Changes in the composition of production, employment and trade were also crucial within the 'structuralist' school of thought originated at ECLA (Economic Commission for Latin America) (e.g., Prebisch, 1950; Furtado, 1967). The unifying and determinant idea behind this school of thought derived precisely from the notion that developed and developing countries had fundamental differences in the structure of their economies, and that those differences led to a continuous and reinforcing movement towards the progressive dependency of the periphery relative to the centre. According to the views expressed, unless state intervention aimed at promoting the structural transformation of the economy was implemented, developing economies would face unemployment, external disequilibrium and deterioration of the terms of trade which would materialize into a vicious circle of underdevelopment.

In a different approach, a vast amount of studies attempted to identify generalizations about long-term economic development and structural change based on comparative study of historical experience. In many cases the analysis started from the aprioristic decomposition of the economic system into a relatively small number of sectors, and structural dynamics were mainly identified with the process of sectoral re-proportioning of the economy. Hoffman (1931, 1958), for example, investigated the pattern of industrial growth in a group of economies distinguishing between consumer and capital goods industries. According to his view, all industrialization processes could be described by the evolution of the relative weights of the two groups of industries, with the capital goods industry raising its relative importance in the course of the development process. Fisher (1939), in his turn, adopted a tri-partite decomposition of the economy, distinguishing between primary, secondary and tertiary production. Despite using Clark's original nomenclature,[36] Fisher proposed a different interpretation that was based on the structure of consumer demand.[37] Under this formulation, Clark's scheme acquired a more precise connection with the relationship between growth and changes in output and demand composition, which according to the author allowed for attention to be focused on the 'growing points' of the economy. A tri-partite decomposition of the economic system, which in broad terms reflects the 'agriculture, industry and services' classification, was also used by Kuznets (1961, 1971) in his noteworthy empirical contribution on the economic growth of nations.[38] Building upon historical series of national income and product for a vast number of countries, Kuznets found a historical association between high rates of growth of per capita product and productivity and a high rate of shifts in production structure. The strong association between growth and structural change was then explained as the result of the combined action of three main factors – changes in the structure of consumer demand, changes in comparative advantage and changes in technology – from which technological change

[36] Clark (1938) identified in broad terms primary production with agriculture and related industries (like fishery, forestry, and hunting), secondary production with manufacturing, and tertiary production with all economic activities not included under the first two categories.

[37] Under the proposed framework, primary production would be related to the economic activities that satisfy basic primary needs, secondary production would include 'all manufacturing activities designed to produce things for which there is a more or less standardized or conventional demand, but which could not be described as essentials' (Fisher, 1939: 31), and finally, tertiary production would include 'every new or relatively new type of consumers' demand, the production and distribution of which is made possible by improvements in technical efficiency, which release resources hitherto required for primary or secondary production' (Fisher, 1939: 32).

[38] Although reflecting to some extent the basic criterion of Fisher (1939), expressing the position occupied by the products on the scale of the immediacy and priority of demand, this decomposition of the economic system was not used by Kuznets, as it was by Fisher, as a means to infer the growth potential of the economy. In fact, Kuznets points out several flaws in the sectoral structure considered, which arise mainly from its incapacity to reveal the impact of technological progress on growth, the basic source of 'modern economic growth' (Kuznets, 1971).

assumed clear prominence. According to the argument put forward, the uneven distribution of technological innovation among the existing branches of production led to the concentration of its influence on a particular group of 'growth' industries, which induced the overall transformation of the productive structure. This transformation was then followed by changes in other aspects of the social sphere, including demographic, legal and institutional changes, and changes in 'social ideology', which in turn could be translated into further changes in technology and in the structure of production.[39]

Other studies adopted a similar approach, but derived the decomposition of the economic system from the analysis undertaken, rather than relying on an aprioristic classification of economic activities. A few examples can be found in the works of Svennilson (1954), Rosenberg (1963) and Chenery and his co-authors (e.g., Chenery, 1960; Chenery and Taylor, 1968; Chenery and Syrquin, 1975).

Svennilson examined in great detail the process of economic transformation in a number of European countries in the first half of the 20th century, building on long series of national aggregates and markets and industries' data. From this analysis, he pointed out a number of interdependencies between long-term economic growth and structural transformation. Changes in consumer demand accompanying rising income, for example, were seen as giving rise to changes in the industrial and occupational distribution of the labour force, and to changes in the pattern of population settlement, which in turn could influence growth, by revealing new needs that induced further innovation. The role of investment in promoting technological transformation and economic growth was also emphasized by Svennilson, who considered the inertia in the renewal of capital equipment as one of the main factors explaining the observed low rate of economic growth in Europe in the interwar period.[40]

The link between investment and economic growth was also stressed by Rosenberg (1963), although different reasons were called upon. When analyzing the history of today's developed countries, Rosenberg highlighted the crucial role that the capital goods sector has had in stimulating technological innovation. Not only was it in this sector that most of the major innovations arose, but most importantly, it was the

[39] The sequences of change in the economic and social structure as described by Kuznets (1971) can follow a number of different paths. The path described in these lines is only one of the possibilities.

[40] In this context, we may see a convergence between Svennilson's empirical findings and Lowe and Hicks's models of 'traverse analysis', which emphasized precisely the limitations imposed by the inherited stock of fixed capital in the process of economic growth.

emergence of a progressively more highly specialized capital goods sector that opened the way to the formation of a technological background that has provided the necessary skills and attitudes conducive to technical progress. According to Rosenberg, the size of the capital goods sector takes on critical importance: in line with Smith (1776), it is argued that the efficiency of capital-goods industries, more than consumer-goods industries, depends to a considerable degree on the extent of the division of labour, which in turn depends on the size of the market. Because capital-goods industries usually enjoy economies of specialization, benefiting from increasing efficiency levels when they concentrate on a relatively narrow range of products, a large demand for their products is necessarily required.[41]

The search for uniform patterns in the relationship between long-term economic development and changes in the economic structure using both cross-section and time series data was also actively pursued by Hollis Chenery, on his own and in collaboration with other authors (e.g., Chenery, 1960; Chenery and Taylor, 1968; Chenery and Syrquin, 1975). A common feature of these studies is the use of a rigorous statistical framework in the search of regularities from which an endogenous determination of structural classification schemes and an identification of general patterns of economic development can be derived. Chenery and Taylor (1968), for example, compare post-war changes in the composition of the national product of several countries using an array of econometrical tests and from this exercise they derive the clustering of the economies into three distinct groups – large, small primary-oriented and small manufacturing-oriented – which show different growth patterns, and reveal distinct interactions of scale and resource endowments. Chenery and Syrquin (1975) extend the search for uniformities, broadening the number of structural variables considered and applying regression analysis to a very large sample of countries.[42] From the regression results they derive 'stylized facts' of development, and establish a typology of developing countries that takes into account resource endowments and differences in development strategies along with other structural variables.

[41] Applying this argument to underdeveloped economies, Rosenberg (1963) argues that their incapacity in developing capital-saving techniques in a symmetrical way to that which occurred in developed economies (where the relative scarcity of labour gave rise to the development of labour-saving technology) is explained by the absence of an organized domestic capital goods sector. Indeed, the capacity to develop capital-saving technologies would necessarily imply the development of a capital goods sector in the first place.

[42] Only socialist countries and countries with very low levels of population were excluded.

It is worthwhile pointing out that this line of research associated with the study of developing and transition economies has been developed quite independently from formal theories of growth and structural change, analyzed in the previous section. In fact, there are only a few points of convergence between both streams of the literature, most notably related to the Marxian-based contributions to development and economic planning (e.g., Feldman, 1928; Mahalanobis, 1955; Dobb, 1960; Sen, 1960) which, as already noted, adopted theoretical schemes similar to Lowe's model, and to the application of Leontief's input-output model to the analysis of developing economies.[43] Many early applications of the input-output method were carried out precisely within the broad area of economic development, with the method being used in the analysis of a full range of problems facing developing economies, such as the allocation of investment, barriers to trade, inflation or income distribution.[44] For the rest, it seems fair to say that both approaches enjoyed quite separate existences.[45]

The literature on structural change associated with the study of developing and transition economies suffered, however, considerable decline in the 1970s, when development economics experienced a profound transformation in its core methodologies and major topics of debate (Backhouse, 1990). The interest in the formulation of (ambitious) macro theories of development strongly declined with the shift of development economics towards a micro approach that made intensive use of the neoclassical toolbox. In contrast with earlier models that stressed 'structural rigidities', this new (neoclassical) approach assumed the existence of a reasonable degree of flexibility in the economy (e.g., Little, 1982). The answers to be given to the problems of underdeveloped economies, according to this new approach, ought to be based on the definition of the right incentives to get markets working (Easterley, 2002), rather than on substituting the market through (structuralist) planned intervention. The resurgence of neoclassical development economics and its reliance on the price mechanism led inevitably to decreasing interest in structural change analysis, although the latter on its own does not necessarily translate into state intervention. As Chenery

[43] Interestingly, a recent contribution from Araújo and Teixeira (2002) formally demonstrates that the Feldman-Mahalanobis growth model can be seen as a particular case of Pasinetti's (1981, 1993) model of structural change, a relation that had already been established in descriptive terms by Halevi (1996).

[44] For a comprehensive overview of the application of input-output analysis in development planning and policy see Rose and Miernick (1989).

[45] It is worth noting, at this point, that while Chenery did not made use of any particular theory in the study of the relationship between structural change and long-term development, he did consider the Walrasian general equilibrium theory in what concerned the overall functioning of markets and prices [see, in this respect, Chenery (1988) and Ascher (1996)].

(1988) puts it, 'recognizing the interrelations among the principal elements of the structural transformation does not in itself constitute an argument for more government intervention or overall planning' (Chenery, 1988: 201). But even though to a considerably lesser extent than before, some studies still follow the traditional approach, attempting to formalize earlier theoretical contributions (e.g., Murphy *et al.*, 1989; Ros, 2000), and to extend and refine the search for regularities regarding structural transformation and economic growth from intercountry and intertemporal comparisons (e.g., Wang *et al.*, 1992; Raiser *et al.*, 2004). Murphy *et. al.* (1989), for example, formalize Rosenstein-Rodan theoretical arguments, developing various models that take explicitly into account the relevance of externalities between sectors, and in which multiple equilibria exist, exploring the mechanisms through which a big-push can be generated in less developed economies. More recently, Ros (2000) combines Lewis, Rosenstein-Rodan and Nurkse's contributions into a formally rigorous development model, which generates multiple equilibriums, so that depending on initial conditions, vicious or virtuous circles of development can arise, explaining both observed patterns of divergence and convergence among countries. Raiser et al. (2004), for their part, develop an analytical framework that is able to overcome some of the drawbacks associated with the methodology used by Chenery and his co-authors in a cross-country comparison of economic structures. In particular, a model is developed in which the notion of 'stylized facts' of development is made compatible with the existence of structural differences in countries with similar levels of income.

Some of the earlier structuralist analysis has also reemerged within the SCEPA (Schwartz Center for Economic Policy Analysis) research group of the New School for Social Research, although in a way more in line with conventional economic analysis. An important part of the research undertaken in this centre which has a broad policy-oriented approach focuses on growth and development experiences of developing and transition economies from a structural change perspective (e.g., Pieper, 2000; Ocampo and Tovar, 2000; Milberg, 2004; Rada and Taylor, 2006). These studies examine the ways by which transition and developing economies have responded to liberalization and market-oriented policies, emphasizing the role of structural and institutional changes in the process. In studies in which a comparison between countries is undertaken, the general conclusion is that sustained growth experiences in successful regions are intimately connected with strong structural transformation, comprising changes in output, employment and international trade sectoral shares, whereas slow-growing regions experience much more modest changes (e.g., Pieper, 2000; Rada and Taylor, 2006). At the same time, there is a widely expressed view according to which broad-based industrial upgrading and higher labour standards in developing economies can only be attained if industrial policies, combined with focused competition policies aimed at promoting R&D and developing technological capabilities are put into practice (e.g., Pieper, 2000; Milberg, 2004).

As already mentioned, although this stream of research integrates some of the assumptions and hypotheses of the 'structuralist school', it has been developed in a way more in line with conventional economic analysis and its methods of research. In particular, some efforts have been made to integrate modellization and formal reasoning in the traditional analysis (see, for example, Rada and Taylor, 2006; Barbosa-Filho, 1999). But even in a more formalized way, the analysis remains considerably distant from the earlier mentioned theories on structural economic dynamics based on analytical representations of economic structure, from which Pasinetti's model of economic growth and structural change constitutes the most prominent example. Indeed, it seems fair to say that there has been little if any interaction between this 'structuralist' strand and the work on formal theories of structural change surveyed in Section 2.2..

Section 3. Recent trends in structural change analysis and thesis's theoretical standpoint

3.1. Introductory considerations

In the more recent period, more precisely from the late 1980s onwards, there has been a marked upsurge of interest on structural change analysis. This growth of interest is clearly apparent from the considerable increase in the number of articles published in the field, as shown in recent bibliometric work.[46] The greater appeal of structural change analysis is also evident from the establishment in the early 1990s of a new journal particularly dedicated to the topic – *Structural Change and Economic Dynamics*–, and from the attempts that have recently been made to consolidate the *Economics of Structural Change* as an autonomous field of enquiry into economic analysis.[47]

In the following section we present an overview of these recent developments, making an assessment of the more recent contributions in theoretical and applied analysis of structural change. We also attempt to provide an interpretation for the recent upsurge of interest in the field, taking into account the changes that have been occurring both at the general level of economic theory and within the realm of structural change analysis. We argue that the changing perspective of economic theory relative to the study of technical change in the 1980s and 1990s documented in several studies (see, for example, Freeman, 1994), has opened the way for the resurgence of structural change analysis as a powerful analytical tool for the study of innovation and technical change. Deficiencies associated with blind aggregate production function models have made clear the necessity of an approach capable of establishing links between changes at the level of microstructures and higher-level changes, as that developed by the structural change perspective.

After comprehensively surveying the literature on the economics of structural change and providing an interpretation of its recent developments, in Section 3.3. we locate our research interests in the present study within the economic realm of structural change analysis. Being, as it is, an essentially empirical work, an attempt is made to establish a connection with theoretical arguments, in order to clarify our perspective and provide a

[46] See Silva and Teixeira (2008).

[47] A major example of these efforts is the recent inclusion of three volumes on 'The Economics of Structural Change' in the Edward Elgar collection of critical writings in Economics.

more precise interpretation of empirical findings. We therefore deviate from a substantial stream of applied work on structural change that assumes no connection with theory, being, in this sense, inherently a-theoretical. It is argued that the development of structural change analysis requires indeed that such a connection is made, which in the present case is accomplished with recourse to structural change arguments developed within the evolutionary branch of economic thought. Although the present state of development of evolutionary economics does not permit a precise empirical orientation for the study of 'meso-macro' relationships, it definitely provides a sounder analytical framework for this type of research than does conventional mainstream economic analysis.

3.2. An assessment and interpretation of recent trends in structural change analysis

Recent bibliometric work on structural change analysis (Silva and Teixeira, 2008) reveals a marked upsurge of empirical and theoretical studies in the field in the last two decades. Furthermore, it is shown that the growing interest on the matter has been accompanied by a change in the main topics of research. Along with 'convergence and growth' that remains the most relevant topic of analysis in the 1969-2005 period, but which has recently lost ground (see Silva and Teixeira, 2008), there is a notable increase in 'international trade' and in 'technical change and innovation', topics of analysis whose importance has been continuously rising, and is particularly relevant in more recent years.

In light of these results, the rising importance of structural change analysis seems to be primarily related with increasing interest in the explanation of the phenomena of technical change. As is repeatedly pointed out in the literature (see, for example, Freeman, 1994), the 1980s and 1990s witnessed 'a far greater readiness to look inside the 'black box' (Rosenberg, 1982) and study the actual processes of invention, innovation and diffusion within and between firms, industries and countries' (Freeman, 1994: 464). The emergence of the *New Economy* and the controversy generated around the impact of information and communication technologies (ICTs) on aggregate productivity growth (the so-called 'productivity paradox') further stimulated the debate on technical change and its impact on growth.[48] Together with important developments

48 See, for example, Baily and Gordon (1988), David (1990) and more recently Freeman (2001) and Amendola *et al.* (2005).

occurring in mainstream economics (e.g., Lucas, 1988, 1993; Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992), a growing body of the literature has been developed in the last 20 years under an alternative approach, known as 'neo-Schumpeterian' or 'evolutionary' economics. Proponents of this latter approach strongly criticize mainstream economics, arguing that a theory which is firmly grounded on purely rational behaviour and equilibrium assumptions cannot deal appropriately with the complex and uncertain nature of technology (see, for example, Nelson and Winter, 1982; Dosi, 1988; Dosi *et al.*, 1988). In contrast, they stress the idea of disharmony and competition in the growth process, and place themselves at quite distant from aggregate production function models, by explicitly addressing the connection between processes of change at micro and industrial levels and overall macroeconomic dynamics.[49] From this perspective, processes of microevolutions of technique, organization and institution are significantly affected by higher-level changes and vice-versa, which means that causal connections between macroeconomic variables cannot be fully understood without considering the interdependence among the different levels of analysis (Nelson and Winter, 1982). It is precisely in connection with this attempt to develop an alternative to mainstream economics for the analysis of the relationship between technical change and economic growth that, according to our view, a substantial part of the recent rise of interest in structural change analysis can be explained. Indeed, structural change analysis comes to the fore as a powerful analytical tool that is capable of establishing links between changes at the level of microstructures and higher-level changes, while providing, at the same time, a more realistic account of the process of technology adoption and its effects on the economy, by emphasizing the sequential and path-dependent nature of economic change. In particular, it provides a useful foundation for the study of the problems of adjustment and intertemporal coordination brought on by technical progress, an issue that is totally neglected by the mainstream equilibrium approach, which takes intertemporal coordination for granted.[50] As Amendola and Gaffard (1998: 107) clearly state 'it is only through the consideration of relations which bring about different aggregations that we introduce real time,

[49] One of the main challenges posed by Nelson and Winter in their landmark book *An Evolutionary Theory of Economic Change* (Nelson and Winter, 1982) concerns precisely the need to establish the links between diversity and uncertainty at the micro level and relatively ordered growth and technological patterns at the macroeconomic level.

[50] See in this respect Amendola and Gaffard (1998), and more recently Amendola *et al.* (2005).

irreversibilities, and qualitative change', and are thus able to address the complexity and uncertainty of technical progress.

It is no surprise, in this context, to find amongst Silva and Teixeira's (2008) results on the most influential works in structural change analysis, along with the seminal works by Pasinetti, Goodwin, Leontief and Baumol, several contributions associated with neo-Schumpeterian and evolutionary strands of thought. Indeed, a significant part of the most-cited works is developed by authors who elaborate on Schumpeter's theoretical scheme, relating innovation, economic growth and structural change into a systemic theory of innovation and diffusion (such as Christopher Freeman, Giovanni Dosi, Richard Nelson and Sidney Winter, among others).[51] Within such a perspective, the strong connection between major technological breakthroughs, structural change and economic growth is analyzed in terms of technological systems, trajectories of technology and technological paradigms. Freeman, Clark and Soete (1982), in one of the seminal contributions in the field, suggest the notion of 'new technological system' to account for the 'constellations of innovation which are technically and economically interrelated' (Freeman, 1991: 223). A historical overview of the succession of 'technological systems' since the First Industrial Revolution is provided by Freeman and Soete (1997), who characterize the current era, strongly based on the application of information and communication technologies, as the 'information age'. Dosi (1982), in his turn, uses the Kuhnian concept of 'scientific paradigm' to derive the analogous concept of 'technological paradigm', which in his model ultimately determines the cluster of possible technological directions to pursue ('technological trajectories').[52] This framework allows him to distinguish between continuous changes and discontinuities in technological innovation by considering, respectively, changes along a technological paradigm and changes in the paradigm itself. At the same time, it sheds some light on the procedures by which new technological paradigms emerge and are selected among a set of possible options, thus being able to identify regularities in the pattern of technical change that may partially account for the relatively ordered patterns

[51] Along with this very large 'cluster' comprising neo-Schumpeterian insights, Silva and Teixeira's results show a smaller cluster of authors that focus on economy-environment relationships and on the long-term viability of economic processes. This cluster includes contributions from Nicholas Georgescu-Roegen, Faye Duchin, Robert Ayres and Robert Costanza.

[52] Nelson and Winter (1982) use the concept of 'natural trajectories' to refer to the same technological paths within a technological paradigm.

of growth.[53] Perez (1983, 1985) further explores the relationship between technological trajectories and structural change introducing the concept of ‘techno-economic paradigm’. According to Perez, it is possible to identify the Kondratiev waves with the rise and fall of successive technological revolutions, which introduce new ways of managing and organizing the economy that are so pervasive that they affect almost all industries and economic activities. In this case, the change from one paradigm to another not only lies in the opportunity to economically explore a cluster of radical innovations, as in Dosi’s work, but it is crucially dependent on the emergence of a ‘key factor’ whose abundant supply, rapidly falling costs and multiple applications facilitate the spread of innovation throughout the economy.[54]

All these contributions stress the profound impact of the *diffusion* of major technological breakthroughs on the structure of the economy and in economic growth. As the diffusion of the pervasive new technologies unfolds, the dynamic set of industries that is more closely related with its exploitation assumes progressively higher importance, stimulating growth, whereas sectors associated with older technologies see their relative influence diminish. Not only is there considerable change in the growth rates and in the productive structure of the economy, but also important institutional and social changes arise. As argued in the neo-Schumpeterian theory, diffusion is never immediate or automatic, but is strongly dependent on a number of characteristics of the ‘receiving’ economy, and in particular in its ability to adapt its institutions to the new forms of organization and management of the economic activity required by the new technological paradigm [see especially Perez (1985) and Freeman and Perez (1988)]. At the same time, because the assimilation and development of technology by the country (firms) is strongly influenced by the specific historical, cultural and institutional environment where the firms are located, geographical factors gain theoretical relevance, as explored by Nelson and Wright (1992) in their concept of ‘national technology’ and by Freeman (1987, 1992), Nelson (1992, 1993) and Lundvall (1992), among others, in the literature on national systems of innovation.

Research developed in neo-Schumpeterian and evolutionary strands focusing on the diffusion process in an international perspective is also heavily cited in Silva and

[53] In this respect, Dosi (1982) explicitly considers the interplay between scientific advances, economic factors and institutional variables, providing a more comprehensive account of the factors behind technological change than the pure ‘demand-pull’ (Schmookler, 1966) or ‘technology-push’ theories.

[54] At the turn of the 20th century, for example, the role of key-factor was played by low-cost steel, whereas in our days, according to Perez, it falls upon cheap microelectronics.

Teixeira's (2008) work (e.g., Fagerberg, 1987, 1988a, 1994; Verspagen, 1993; Abramovitz, 1986, 1994; Dosi, Pavitt and Soete, 1990). In this 'technology-gap' literature, the non-automatic character of diffusion is once again strongly emphasized. Successful catch-up, it is argued, can only be achieved by countries that possess adequate 'social capabilities', that is, those with sufficient educational attainments and adequately qualified and organized institutions that enable them to exploit the available technological opportunities.[55] The pace at which the potential for catch-up is realized depends furthermore on a number of factors, related with the ways in which the diffusion of knowledge is made, the domestic capability to innovate, the pace of structural change, the rates of investment and expansion of demand, and the degree of 'technological congruence' (Abramovitz, 1986, 1994) of the backward country in relation to the technological leader. Recent work in this area (Fagerberg and Verspagen, 2002) suggests that catching up on the basis of diffusion has become more difficult in the more recent period, whereas innovation has increased its relative importance. This finding is interpreted as reflecting the new (and higher) requirements imposed by the new technological paradigm (the ICT revolution), in terms of skills and infrastructure, in the process of technological imitation.

As already indicated, the neo-Schumpeterian approach to the analysis of the relationship between technical change and economic growth is built upon a much broader (and realistic) account of technical change than conventional mainstream analysis. Technical change is conceived as a cumulative and path-dependent 'learning' process that is strongly embedded in organizational and institutional structures.[56] In this process, there is an ever-presence of elements of uncertainty and diversity, and the technology that is ultimately 'selected' by market forces is not necessarily the most efficient one (which once more contrasts sharply with mainstream assumptions of optimizing rationality). This issue is explored in great depth in the works of Paul David and W.B. Arthur (e.g., David, 1975, 1985; Arthur, 1988, 1989, 1994), which lie amongst the most cited works in Silva and Teixeira's results. In general terms, David and Arthur show that the occurrence of random events or 'historical accidents', particularly in the early phases of the introduction of a technology, may have a decisive influence on the long-run

[55] See Fagerberg (1994) for an overview on the matter.

[56] It is worth recalling at this point that the idea of technical change as a learning process, strongly opposed to the neoclassical construction of production functions, is also present in Pasinetti's seminal contributions on structural change and economic growth (Pasinetti, 1981, 1993).

outcomes of the economy. In some cases, the presence of scale economies and increasing returns, whether derived from network externalities, learning effects or investment indivisibilities, may even 'lock-in' the economy to an inferior technology, as the example of the QWERTY typewriter keyboard so clearly illustrates (David, 1985).

The above-mentioned neo-Schumpeterian contributions focusing on the long-term dynamics behaviour of the economic system and on its association with technical and institutional change have been mostly developed under appreciative and empirical strands, with little recourse to formalization.[57] Nevertheless, in the recent past a growing body of research has attempted to formalize the main insights from this literature, following Nelson and Winter's (1982) urge to combine 'appreciative theorizing' with formal modelling. In the long-waves literature, for example, Goodwin (1987) presents a model in which the impact of technology on the economy is transformed by the internal dynamics of the economic system, which reshapes the non-cyclical rate of emergence of a major innovation cluster into both business cycles and long waves. Silverberg and Lehnert (1993), in their turn, develop a Schumpeterian dynamic model based on the Goodwin growth cycle, in which a capital stock 'vintage' structure is assumed. Their main finding is that 'clustering' of innovations is not necessary for generating long-waves; it is only necessary that the process of arrival of new technologies be stochastic. More recently, Silverberg (2002) presents a 'mosaic-avalanche' model based on percolation theory that illustrates the emergence of macro-innovations from a stream of incremental innovations, which are then transmitted to changes in sectoral structures and macro-economic performance.[58] The conceptual framework of 'technology gaps' has also been formalized by Verspagen (1991), Amable (1993), and more recently, Los and Verspagen (2006). Verspagen (1991) develops a non-linear model of convergence that accounts for both situations of 'catching-up' and 'falling-behind'. It is shown that countries with relatively low 'social capability' levels and with high technological backwardness are in great risk of widening the gap relative to the more developed countries, whereas countries with high relative levels of 'social capability' and a small

[57] Notable exceptions are Arthur's (1988, 1989, 1994) and Nelson and Winter's (1982) contributions. These seminal works are, however, mostly focused on the industry-level dynamics of technological evolution, rather than on the analysis of the long-term dynamics of the economic system and its association with structural change.

[58] Andergassen and Nardini (2005) have recently developed a model in which innovation waves emerge endogenously from the interaction of single sectors. Their model is, however, explicitly grounded on maximizing behaviour and representative agent assumptions, which are very much at odds with the evolutionary perspective.

initial technological gap are more likely to catch up. Amable (1993) presents a linear catch-up model in which some of the determinants of 'social capability' - investment, innovation and education - are endogenized, and that also allows for both converging and diverging tendencies. More recently, Los and Verspagen (2006) develop a dynamic model in which the impact of innovation, learning and technology spillovers on output growth, convergence and structural change is analyzed. In line with the technology-gap literature, it is found that convergence between countries is far from being automatic, depending on social capability and on the degree of technological congruence of countries. The simulation results demonstrate, however, that in order to obtain a greater understanding of the dynamics of productivity gaps, the influences of learning-by-doing and of the interaction between economic structure and technology also have to be taken into account.

Other attempts to formalize neo-Schumpeterian and evolutionary insights explicitly address the links between changes at the level of microstructures and higher-level changes, drawing attention to the disequilibrium processes by which new technologies are generated and disseminated in the economy. These theories reveal close connections with structural change analysis, since the dynamics of the economic system are seen as strongly dependent on the structural configuration of the economy and on its pattern of change. One of the earliest contributions in the field can be found in Silverberg, Dosi and Orsenigo's (1988) evolutionary model of the diffusion of innovations. This model attempts to integrate some crucial features of technology and technical change – namely its inherent diversity and uncertainty, cumulativeness and path-dependency – in the process of diffusion, considering an evolutionary environment characterized by micro-diversity and selective pressures at the firm level. Simulation results show that relatively ordered diffusion paths (the conventional S-shaped form of the diffusion curve) can be derived from turbulent dynamics at the micro-economic level. The emergence of relatively ordered patterns in macroeconomic variables from the interaction among heterogeneous agents in a context of technological diversity is also found in Chiaromonte and Dosi's (1993) evolutionary model of endogenous economic growth. A relatively stable macroeconomic growth pattern is compatible and indeed requires high heterogeneity at the micro level. The interaction between the micro and macro levels in the economy has been also deeply examined by Eliasson in several studies using the Swedish micro-to-macro MOSES model (e.g., Eliasson, 1984, 1991; Eliasson *et al.*, 2004). In Eliasson *et al.* (2004) this model is used to perform simulations on the impact and sustainability of the New Economy, under the hypothesis that the full potential of the new technologies can only be achieved when it is diffused in the 'older industries' through the Schumpeterian process of creative destruction. The simulation experiments show that the time length required by new technological paradigms to realize their potential productivity gains is extremely long, which may provide an explanation for the observed productivity paradox. It is also demonstrated that the successful adoption of radical technologies is dependent on the local 'receiver competence' of the society, which is in line with previously mentioned studies focusing on institutional and 'social capability' factors.

These modelling exercises (and, in general terms, most of the neo-Schumpeterian and evolutionary literature) places great emphasis on technology-driven growth (although combined with factors such as institutional change and industry dynamics), lacking a systematic treatment of the demand side. In the recent past there have been, however, some attempts to combine both supply-side and demand-side factors within the micro-to-macro approach to the process of economic development. Saviotti and Pyka (2004a, 2004b), for example, present a model in which changes in the composition of the economic system accompanying the emergence of pervasive innovations are seen in connection with changes occurring on the demand side of the economy.[59] Indeed, in this model, it is the saturation of given sectors due to Engel's law that induces changes in the composition of the economic system that in turn provides the stimulus for economic growth. Montobbio (2002) also takes into account the role of demand in his evolutionary model of structural change. In this work the intermediate 'meso' level of analysis is brought into the fore, through the extension of Metcalfe's (1998) model on evolutionary dynamics within a single-industry to a multi-sectoral framework.[60] Along with supply and demand factors, it is shown that specific characteristics of firms and sectors, and the specific combination of the characteristics of the interdependent sectors account for patterns of productivity growth at macroeconomic level. In particular, changing sectoral composition due to selection and sorting mechanisms within and

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[59] The composition of the economic system is defined in the model in very broad terms, comprising all levels of aggregation, with sectors being defined as 'collections of firms that produce a differentiated product' (Saviotti and Pyka, 2004b: 272).

[60] In so doing, the model goes a step further relative to the abundant evolutionary literature on the partial frameworks of firm and industry, approaching the relationship between industrial and macro levels of inquiry while taking explicitly into account the role of microfoundations.

between industries plays a significant role, which means that positive rates of aggregate productivity growth can occur, even in the absence of technical progress at the firm level. The relationship between the meso and macro levels of inquiry is also approached in a recent paper by Metcalfe, Foster and Ramlogan (2006). The authors develop an evolutionary model in which growth is perceived as an essentially adaptive process in response to innovation and changes in demand. Productivity growth differences at the industry level and macroeconomic productivity growth emerge from market coordination processes and are explained on the basis of the combined influence of Fabricant's Law and differential income elasticities of demand at the industry level. In a way similar to the seminal work from Pasinetti (1981, 1993), the explicit consideration of demand issues in these models has been accomplished with recourse to a generalization of Engel's law. As stated before, the reliance on Engel's law permits only that a broad hierarchization of needs be taken into account, and for this reason, it is not capable of addressing the complex interactions between technological change and changes in patterns of consumer behaviour. In this context, the development of a dynamic theory of demand and its interactions with the formal treatment of technological change seems to be an imperative issue for future research in the field.

At the same time, despite the progress that has been achieved with neo-Schumpeterian insights in modelling several aspects of the economic reality which were previously ignored (such as the heterogeneity of agents, bounded rationality, path-dependency and economic learning), there is still a long way to go before a satisfactory (and useful) formal representation of the economic system is reached. In order to reconcile rigour requirements with empirical evidence, simulation exercises cannot loose contact with the findings and problems identified by historical and empirical research, which has a major tradition both in neo-Schumpeterian and structural change strands of thought. It is precisely within the realm of empirical research, whose recent developments are described in the following lines, that the present study is included.

In the more recent period, there has been an intense proliferation of empirically-led studies focusing on the role played by technical change as a major source of structural transformation. The emphasis put by neo-Schumpeterian theory on the relationship between economic growth and the group of dynamic industries associated with the new technological paradigm, together with the debate on the impact of ICT on aggregate productivity growth, gave rise to a vast amount of empirical research examining the impact of leading technological sectors on the processes of economic growth and structural change. The contribution from technologically leading industries to aggregate productivity growth has been assessed using both purely descriptive techniques, such as shift-share analysis (e.g., Quah, 1997; Fagerberg, 2000; Timmer and Szirmai, 2000; Peneder, 2003), and econometric estimation methods (e.g., Amable, 2000; Fagerberg, 2000; Carree, 2003; Peneder, 2003). Typically, purely accounting procedures find that the structural change effect has only a minor role in explaining productivity growth, whereas the use of econometric approaches reveals in most cases a significant positive relationship between structural variables and economic growth, suggesting the existence of substantial positive spillovers arising from leading technological industries to the rest of the economy (see, for example, Amable, 2000; Fagerberg, 2000; Peneder, 2003).[61] At the same time, the role of technology as a source of productivity growth and structural transformation has been examined in a vast number of contributions using input-output analysis (e.g., Oosterhaven and Hoen, 1998; Peneder *et al.*, 2003; Franke and Kalmbach, 2005; Sánchez Chóliz and Duarte, 2006). The evidence found in these studies points to the important role played by technology in the overall processes of growth and structural change. The results reveal, furthermore, a differentiated impact of technological change among sectors, where the 'modern sectors' that have the higher growth rates (generally ICT-related sectors and business-related services) are simultaneously the sectors that experience the most positive impact of technological change (e.g., Oosterhaven and Hoen, 1998; Peneder *et al.*, 2003; Franke and Kalmbach 2005).

The empirical literature on the role of technologically-leading industries on economic growth has led furthermore to a changing image of the services sector, with several studies pointing out the impact of the new technological paradigm on the creation of new and improved services, and on the development of knowledge-intensive service branches (e.g., Petit and Soete, 2000; Petit, 2002; Peneder *et al.*, 2003). The high productivity growth rates found in these sectors, together with evidence showing the declining role of manufacturing in economic growth in the more recent period (e.g., Fagerberg and Verspagen, 1999, 2002) has led to the abandonment of the traditional

[61] A significant spillover effect of ICT-related industries is also found in Ten Raa and Wolff (2000), who find that 'computers and office machinery' were the main 'engine of growth' in the US economy during the 1970s and 1980s. These findings are based on a new method for the decomposition of total TFP growth that takes into account the spillovers of technical change among sectors within a general equilibrium input–output framework.

view regarding manufacturing as the major producer and user of technology and as the sector providing the major stimulus for growth (e.g., Kaldor, 1966, 1970; Cornwall, 1976, 1977).[62] The new evidence on the performance of service sectors has inclusively led to a change of focus in the services literature, as the debate on the consequences of de-industrialisation and on the impact of rising services in productivity slowdown is to some extent replaced by a far more optimistic view. In this context, although much of the literature explaining tertiarization still focuses on demand determinants of sectoral growth and on 'cost-disease' arguments (Baumol, 1967, 2002; Baumol *et al.*, 1989), an increasing amount of research has recently emphasized the role of technological factors in the process (e.g., Andersen *et al.*, 2000; Miles and Tomlinson, 2000 Peneder *et al.*, 2003).

Along with theoretical insights, much of the empirical literature can be criticized for not addressing such fundamental issues as the change in patterns of demand associated with the spread of new technologies, suffering, to some extent, from 'technological determinism'. In a rather singular approach, Gualerzi (2001) has recently provided an empirical account of the structural dynamics of the U.S. economy in the post-war period in which the ICT revolution is seen in connection with changes in demand and modes of life. His findings suggest that transformations occurring within the consumption sphere were the key factors in explaining the structural dynamics of the 1980s. Although leading to important advances in technology and innovation, within a process of industrial dynamics that favoured the selective expansion of technologically advanced industries (such as computers, electronics and advanced chemicals), the process of market creation was not able to sustain generalized expansion and rapid growth. According to the argument expressed, in the 1990s the pace of aggregate growth accelerated because the new technologies were successful in transforming modes of life, thus overcoming some of the limitations that constrained market expansion in the 1980s. But even in this more optimistic scenario, there remains a 'pattern of selective and highly concentrated expansion' that makes the extent to which the new technologies can effectively sustain a new long wave of development unclear. Gualerzi's analysis

[62] There are, however, other studies that find that the rapid growth of highly-qualified/specialized services and other services is not reflected in a parallel improvement in their productive efficiency (Sánchez Chóliz and Duarte, 2006; Ten Raa and Wolff, 2000), or see their good performance mostly as a consequence of the structural changes occurring in the manufacturing sector (Franke and Kalmbach, 2005).

remains, however, a rather singular case in the empirical study of processes of structural change, which can definitely be enriched with the inclusion of demand considerations.

3.3. Thesis's theoretical underpinnings and main research issues

After having surveyed in detail the literature on structural change and its recent developments, we attempt in this section to elucidate the specific stream of research that is followed in the present work, and the main theoretical arguments that sustain the empirical exercise undertaken.

As already mentioned, the last decades witnessed a marked upsurge of empirical research on structural change, which has inclusively been growing at a faster rate than fundamental theoretical analysis. This growing interest was related, as referred in the previous section, with a greater concern by a number of economists with the study of technological change and innovation, to which the emergence of the *New Economy* and the controversy generated around the 'productivity paradox' have deeply contributed. A prolific strand of applied work focusing on the impact of leading technological sectors, and in particular of IT-related industries, has thus emerged, using a vast assortment of empirical methods. The present study can be included in this stream of research, exploring the connection between structural change and technological progress in a relatively under explored case (the Portuguese economy), and making use of a number of alternative empirical techniques.

In our view, the intense proliferation of empirical research in the field has not been accompanied by a clarification of the corresponding theoretical foundations. Indeed, a substantial amount of studies in this area does not provide any indication whatsoever about the fundamentals of the research undertaken, which in these terms becomes inherently a-theoretical. In other cases, the references given are so broad, encompassing in simultaneous concurrent views on the study of technology and innovation (such as evolutionary and neoclassical views), that they can hardly offer a satisfactory guidance to the empirical analysis. In this context, we contend that an elucidation of the theoretical fundaments of applied work is not only desirable, but it is indeed required to guide the empirical research and to more adequately interpret its findings.

It is important to stress here that with respect to applied work of structural change, mainstream economic theory does not seem to provide a sound theoretical foundation. The prevailing theory of economic growth has been capable of producing totally aggregate growth models, generally based on neo-classical production functions, and multi-sectoral models in which structure remains unchanged through time [‘proportional growth models’, in Pasinetti’s (1993) words], but not models which represent the changing structure of the economy that inevitably accompanies growth. The analytical treatment of economic growth has been carried out more in a way to avoid analytical complications, than in a way to get as close as possible of the concrete facts of reality. In this context, descriptive realism and historical evidence have been sacrificed to the requirements of formal mathematization, and qualitative changes, such as changes in the composition of the economic system have been omitted in the modelling framework.

At the same time, mainstream economic theory has been developed considering equilibrium analysis and optimization assumptions, which by definition rule out any investigation of problems of disruption and restructuring of productive structure. The dynamics of models of this type, dictated by the choice of the relevant conditions – such as preference parameters –, allows for a comparative analysis of different steady growth paths but does not permit the analysis of out-of-equilibrium situations (Amendola and Gaffard, 1998). Therefore, although some structural change features can be taken into account, such as a change in technique or an increase in the variety of consumer goods, the notion of growth as a *process* is irremediably lost: ‘equilibrium models are aimed at identifying growth factors and measuring their respective contribution to growth, so as to be able to derive policy implications’, but ‘there is no attempt to understand the *working of the growth mechanism*, which is assumed in the model’ (Amendola and Gaffard, 1998: 115, emphasis added).

In this context, theoretical fundaments of applied work of structural change have to be found elsewhere in the literature. In the survey undertaken in the precedent sections we have identified Pasinetti’s work on structural dynamics as one of the most rigorous formulations to date of a structural model of economic growth. The point of departure of the model consists precisely in assuming that technical progress and demand changes (the main engines of growth) have an uneven impact across sectors. Uneven technical progress allows for an increase in productivity that is translated into growing uncommitted income; higher levels of disposable income generate, in turn, a change in demand patterns (through Engel’s law), with the consequent changes in the composition of the economy and in the path of sustained growth. The model thus establishes a link between technological advances, growth and structural change, in a way that can be useful for the empirical research on the matter. This notwithstanding, for the present study Pasinetti's theoretical scheme does not offer more than a general guidance. Indeed, the model is centred on the accomplishment of a single purpose – the definition of the conditions under which it is possible to obtain approximate full employment of resources in an environment of continuous technical change –, which although exploring some of the links approached in our work, namely the connection between the emergence of new industries and economic growth, does that in a side manner. As Gualerzi makes clear, although 'new industries and new products can be represented in the model', they 'do not become forces of change and the model does not acquire dynamism from them' (Gualerzi, 2001: 27), which rules out any strict application of Pasinetti's theoretical framework in the present work.

In order to obtain a closer theoretical background for the applied work undertaken we therefore turn to an alternative (but complementary) approach for the study of the process of economic growth and structural change: the neo-Schumpeterian framework. Neo-Schumpeterian theory elaborates on the original contribution of Schumpeter relating innovation with renewed economic growth and 'creative destruction'. As indicated earlier, Schumpeter saw economic development as being endogenously determined by innovation and entrepreneurial investment. Economic fluctuations, and most particularly, Kondratieff waves of half a century, were explained on the basis of the discontinuous introduction of swarms of basic innovations and its subsequent diffusion in a bandwagon pattern throughout the economy. As previously noted, these ideas were received with great scepticism at the time of their publication. Kuznets (1940), in particular, made strong critical comments concerning the mechanism through which innovation was supposed to generate such large economy-wide fluctuations, and the strict periodicity attributed to innovation. In the recession period of the 1970s and 1980s, however, the role of basic innovations in generating 'long waves' of growth gained new interest, with a number of new-Schumpeterian economists addressing the issue and giving rise to what is currently known as the 'long-wave' literature (e.g., Mensch, 1979; Clark *et al.*, 1981; Kleinknecht, 1986, 1990; Freeman and Perez, 1988).

In order to answer to the criticisms raised by Kuznets (1940), and subsequently extended by other authors who questioned both the very existence of long waves and the innovation-based theoretical explanations of the phenomenon (e.g., Rosenberg and Frischtak, 1984; Solomou, 1987), several contributions attempted to provide a more elaborate account of the process of 'clustering' of innovations. In some cases, this was done by presenting historical evidence of the clustering of basic innovations (e.g., Mensch, 1979; Kleinknecht, 1986), whereas in others, emphasis was put on the technological and economic interrelatedness of important innovations (e.g., Clark *et al.*, 1981; Freeman *et al.*, 1982; Perez, 1983, 1985). This latter stream of research emphasizes the idea that it is the *diffusion* of innovation (and not innovation *de per se*, as implicitly considered in Mensch and Kleinknecht's works), which might explain overall fluctuations in the economy. The focus is thus shifted from the dating of single innovations to the analysis of their diffusion processes as interconnected systems of technical change. In one of the seminal contributions in the field, that from Christopher Freeman (e.g., Freeman, 1982; Freeman *et al.*, 1982; Freeman, 1991), this is done with recourse to the concept of 'new technological systems', which accounts for the emergence of clusters of interrelated innovations in products, processes, techniques and organization that have widespread influence throughout the economy. According to the views expressed, 'technological systems' might generate a long-wave pattern of aggregative growth if there is sufficient synchronization of the various diffusion paths in the economy (Freeman *et al.*, 1982). This point is further developed by Perez (Perez, 1983, 1985), who goes beyond the notions of 'technological systems' and 'technological trajectories' (Nelson and Winter, 1977; Dosi, 1982),[63] establishing a link between the emergence of technological revolutions and the introduction of 'new technological styles' (or 'new techno-economic paradigms'), which represent new ways of management and organization of the economy. Following Perez's arguments, major technological breakthroughs require specific socio-institutional arrangements that are likely to conflict with precedent ones, leading to the occurrence of a period of adjustment in which growth slows down. The length and severity of the crisis is dependent on the degree of 'mismatch' between the socio-institutional framework and the new technological conditions, and on the country's ability to adapt to the new requirements imposed by the new technological regime. The establishment of each new 'techno-economic paradigm' depends furthermore on the emergence of a 'key factor', whose abundant supply, rapidly falling costs and multiple applications facilitate the spread of innovation throughout the economy.

[63] As mentioned earlier, this concept is used to describe the path followed by a particular technology along the economic and technological conditions defined by the 'technological paradigm'.

While providing an explanation for the emergence of economy-wide effects in a long-wave pattern of aggregative growth, these contributions face, however, some difficulties in answering to the second main source of criticism of long-wave theory: the recurrence over time of cyclical fluctuations of roughly half-century length. Indeed, although the arguments put forward provide a compelling description of overall fluctuations of economic activity, which are based on the rise and fall of successive technological revolutions, it seems difficult to understand why this has to happen with a strict periodicity. This remains the most controversial aspect of the literature, despite the attempts that have been made to provide a plausible explanation of the phenomenon.[64]

In this context, in the present study we take into account the theoretical insights developed by the neo-Schumpeterian literature, namely its emphasis on the profound impact of the diffusion of major technological breakthroughs on the structure of the economy and in economic growth, without adhering to the idea of a strict periodicity of 'long-waves', which is not critical for the purposes of our work.

As mentioned in the Introduction, we are particularly interested in exploring the joint impact of structural change and technological progress in the evolution of Portuguese total factor productivity in the 1977-2003 period, focusing on the role played by technologically leading sectors. According to neo-Schumpeterian literature, the technological revolution underlying this period is based on Information and Communication Technologies (ICT), which would drive a new upswing of economic growth starting in the 1980s or 1990s (see Freeman *et al.*, 1982 and Freeman and Soete, 1997). This new 'information age', based on the exploration of cheap microelectronics (Perez, 1985), followed the older paradigm based on mass production technologies and low-cost oil, which had its golden period in the 1950s and 1960s.

Following the arguments expressed in the literature [see especially Perez (1985) and Freeman and Perez (1988)], the emergence of a major technological breakthrough has a profound impact in the restructuring of the techno-economic and in the socio-institutional spheres of the economy. With respect to the sectoral composition of the economy, the introduction of a new technological paradigm originates significant changes, with the dynamic set of industries that is more closely related with its

[64] Forrester (1981), in particular, has argued that the factors lying behind the repetition of long waves - psychological factors associated with human life cycles and the replacement of capital assets - , changed very little in the last two centuries, leading to the observed regularity of cyclical fluctuations every half a century.

exploitation assuming progressively higher importance and stimulating growth, whereas sectors associated with older technologies see their relative influence diminish. In this context, it seems pertinent to investigate whether this hypothesis gets confirmation in the Portuguese case, investigating to what extent has structural change been driven by the emergence of new technologically-leading sectors and what effects it has produced in the overall performance of the economy. As indicated earlier, to our knowledge, this issue has not yet been explored in the literature, notwithstanding the evidence of a relatively significant impact of the structural change effect in explaining Portuguese economic growth in the period under study.[65]

In order to perform such an investigation, we commence by using shift-share analysis (Part II), which seems to be a well-suited technique to analyze the restructuring of the economy in terms of the (eventually) higher significance of leading technological sectors, and make a preliminary assessment of the impact of structural change on economic growth. However, because shift-share analysis is a purely descriptive technique and does not permit to capture the indirect productivity gains arising from spillover effects,[66] the analysis will be complemented in Part III by the use of econometric estimation methods. Econometric methods permit not only to take into account the indirect effects in overall productivity growth of leading technological sectors, obtaining in this way a more rigorous account of its impact on the economy, but also to consider the influence of additional explanatory variables that might influence the process of restructuring of the economy and its prospects of growth. As previously noted, neo-Schumpeterian literature puts great emphasis in the non-automatic character of diffusion, arguing that the extent to which new technologies are assimilated and developed is strongly dependent on a number of characteristics of the 'receiving' economy, and in particular in its ability to adapt its institutions to the new forms of organization and management of the economic activity required by the new technological paradigm. The socio-institutional frame has thus a decisive influence, which may in some cases accelerate, and in others retard, the processes of technical and structural change. In this context, it seems particularly relevant to take into account the

[65] See, for example, Peneder (2002) and Aguiar and Martins's (2004) findings with respect to the Portuguese economy for the 1985-98 and the 1973-85 periods, respectively, and the comparison of Portuguese results with other European and OECD countries in Peneder (2002).

[66] Technology progressive industries tend to stimulate productivity growth in related industries, through the diffusion of knowledge on new methods of production and by providing new, high quality products and services. Evidence regarding the impact of these spillover effects estimates their influence as being of sizeable importance (see, for example, Stiroh, 2000).

differences in socio-institutional backgrounds correspondent to the specific histories of countries and acknowledge their influence in the processes of structural transformation undertaken and in the overall records of macroeconomic performance. This is done in the last section of Part III, in which a panel-data estimation that considers data from the Portuguese economy together with data from several other countries attempts to elucidate the influence of structural variables in the processes of economic development taking place in the last three decades.

Part II. Long-term economic growth and structural change: the case of Portugal, 1970s-2000s

Section 4. Empirical methods for the analysis of structural change

4.1. Introductory considerations

The last two decades have witnessed a marked rise in applied work on structural change, which, as previously noted, has been growing at a faster pace than fundamental theoretical analysis. The growing concern with the matter has originated considerable progress in the techniques developed to cope with the phenomenon, and most particularly, with the assessment of its impact on economic growth, which constitutes a central purpose of our study. Notwithstanding the prolific production in the field, the different methodological devices can be seen as pertaining to one of the following research lines:

- Pure accounting procedures, generally known as *shift-share* techniques, which provide a descriptive view of the impact of structural change, identified with changes taking place in the composition of output or employment, in the overall productivity growth rate;
- Input-output analysis, which accounts for the interdependencies between sectors in the economic system, and allows for the distinction between the various sources of structural change, such as changes in technology and changes resulting from shifts in the individual components of final demand (domestic consumption, investment and net exports);
- Other methods, which include techniques that are not specifically designed to perform structural analysis, but which can nevertheless be used to this purpose, such as econometric methods.

Shift-share and input-output analyses have an important tradition in the study of structural change. Early applications of shift-share in the study of the relationship between growth and structural change can be found as far back as Fabricant's (1942) and Maddison's (1952) works. Input-output analysis, in its turn, began with Leontief's (1941, 1953) major efforts to build a 'practical extension of the classical theory of general interdependence' (Leontief, 1987: 860), and has stimulated ever since a vast amount of research on the description and interpretation of observable structural relationships.

In recent years, there has been renewed interest in both techniques and, most particularly, in their use in the analysis of the joint impact of structural change and technological progress on the evolution of overall productivity growth. Interest in these issues has also stimulated the use of alternative methodologies, namely econometric methods, which are used in a complementary manner to the more ‘traditional’ tools of structural change analysis.

In the following sections (Sections 4.2.-4.4.) we present a brief description of these methods and of their use in the analysis of structural change, illustrating with recent applications in the field. We also undertake a comparative assessment of their limitations and potentialities, and from this exercise and the appraisal of the work that has already been done relative to the Portuguese case, we define our research agenda and clarify the significance of the present contribution in the study of structural change (Section 4.5.).

4.2. Shift-share analysis

In recent years, there has been renewed interest in shift-share analysis as an empirical tool for the study of the relationship between the economic structure of a country and its productivity growth (e.g., Peneder, 2003; Fagerberg, 2000; Timmer and Szirmai, 2000). This is partly due to the relative simplicity of the technique, since it provides easily interpretable results with relatively low data requirements and little computational effort.

The rationale of shift-share consists in decomposing overall productivity growth into two major parts: one that reflects productivity growth within industries (intra-sectoral component), and the other which is linked to the reallocation of factors between industries (inter-sectoral component or structural change effect). The point of departure for the decomposition consists in expressing a country’s productivity as a whole as the productivity level by industry weighted by the industries’ employment shares:[1]

$$P = \frac{Y}{L} = \sum_{i=1}^{k} \left(\frac{Y_i}{L_i} \right) \left(\frac{L_i}{L} \right) = \sum_{i=1}^{k} \left(P_i S_i \right) \qquad (1)$$

In Equation 1, P represents the labour productivity level, Y and L represent output and employment, subscript i denotes industrial branches (i = 1... k), and S_i represents industry i’s employment share.

[1] As an alternative, some studies use sectoral weights based on labour force shares.

In continuous time, this expression can be rewritten as

$$\Delta P = \sum_{i=1}^{k}\left(\Delta P_i S_i\right)+\sum_{i=1}^{k}\left(P_i \Delta S_i\right) \tag{2}$$

which corresponds in a discrete form to

$$\frac{P^t - P^0}{P^0} = \frac{\sum_{i=1}^{k}(P_i^t - P_i^0)S_i^0}{\sum_{i=1}^{k} P_i^0} + \frac{\sum_{i=1}^{k} P_i^0 (S_i^t - S_i^0)}{\sum_{i=1}^{k} P_i^0} + \frac{\sum_{i=1}^{k}(P_i^t - P_i^0)(S_i^t - S_i^0)}{\sum_{i=1}^{k} P_i^0} \tag{3}$$

in which subscripts 0 and t represent the beginning and the end of period (0, t).

Equation (3) shows that aggregate productivity growth can be decomposed into intra-sectoral productivity growth, that is, productivity growth within the industries (the first term on the right-hand side), and two structural change effects: a static shift effect (the second term) and a dynamic shift effect (the third term). The static shift effect represents the contribution of changes in the allocation of labour between industries to productivity growth, and captures productivity gains caused by a shift of labour towards branches with a higher productivity *level*. The dynamic shift effect measures the interaction between changes in productivity in individual industries and changes in the allocation of labour across industries, and captures productivity gains caused by shifts of labour towards branches with higher productivity *growth*.

Several studies (e.g., Fagerberg, 2000; O'Leary, 2003; Peneder, 2003) have recently used this technique in the investigation of the relevance of structural change on processes of economic growth and convergence.[2] Typically, these studies find that the intra-sectoral component is clearly dominant, whereas the structural change effect (including both the static and the dynamic shift components) plays only a minor role in explaining productivity growth. Indeed, in all the studies listed in Tables 1 and 2 below, the intra-sectoral effect accounts for the largest part of the overall productivity increase within almost all of the periods and industries under study, with the inter-sectoral and the interaction effects providing a relatively small and sometimes even negative

[2] Shift-share analysis can also be used in the assessment of the impact of the economic structure on the productivity gaps among countries (e.g. Bernard and Jones, 1996, van Ark, 1996). In this case, the decomposition of overall productivity growth into the aforementioned effects is usually made with reference to the country that has the highest productivity scores. Mathematically this is done by substituting the subscripts relative to the regions or countries under comparison for the temporal subscripts in Equation 3.

contribution to growth (e.g., Fagerberg, 2000; Timmer and Szirmai, 2000; Peneder, 2003). Looking specifically at the results regarding the Portuguese economy which are described in Table 2, the same conclusion can be drawn, although the evidence found in Lains (2008), Aguiar and Martins (2004) and Peneder (2002), reveals the considerable weight of the inter-sectoral effect in some of the subperiods under analysis.

Table 1: Studies that use *shift-share* analysis in the assessment of the impact of structural change on productivity growth

Author(s)	Aggregate	Technique	Disaggregation level	Period	Sample
Peneder (2003)	Aggregate labour productivity growth	▪ Conventional shift-share analysis	3 sectors	1995-1999	European Union (overall)
	Labour productivity growth in manufacturing	▪ Conventional shift-share analysis	▪ NACE 3-digit manufacturing industries ▪ NACE 3-digit manufacturing industries clustered according to 3 different taxonomies	1985-1998	
O'Leary (2003)	Aggregate labour productivity growth	▪ Conventional shift-share analysis + decomposition of the rate of regional convergence overtime into intra-sectoral and structural change effects	4 sectors (agriculture, manufacturing, distribution and other services)	1960-1996	7 Irish regions
Fagerberg (2000)	Labour productivity growth in manufacturing	▪ Conventional shift-share analysis	24 industries	1973-1990	39 countries (including Portugal)
Timmer and Szirmai (2000)	Labour productivity growth in manufacturing and total factor productivity growth in manufacturing	▪ Conventional shift-share analysis and a modified version that takes into account the Verdoorn effect	13 industries	1963-1993	4 Asian countries (India, Indonesia, South Korea and Taiwan)
Doyle and O'Leary (1999)	Aggregate labour productivity growth	• Conventional shift-share analysis + decomposition of the rate of convergence among countries overtime into intra-sectoral and structural change effects	3 sectors (agriculture, manufacturing, services)	1970-1990	11 European Union Countries (Including Portugal)
Van Ark (1996)	Aggregate labour productivity growth	• Conventional shift-share analysis	10 sectors	1950-73 and 1973-90	9 countries (8 EU countries and US)

Table 2: Summary of results from studies applying shift-share analysis in the assessment of the relevance of structural change on the processes of economic growth/ convergence in the **Portuguese case**

Author(s)	Aggregate	Data source	Disaggregation level	Period	Annual Av. change (%)	(I) Intra-sectoral (%)	(II) Inter-sectoral (5)	(III) Interaction (%)
Lains (2008)	Aggregate labour productivity growth	GGDC Industry Database	56 sectors	1979-1985	0,7	65,2	36,3	-1,6
				1986-1994	3,6	65,1	88,4	-53,5
				1995-2002	2,5	139,3	-0,3	-39,1
Aguiar and Martins (2004)	Aggregate labour productivity growth	Batista *et al.* (1997); Pinheiro (1997); Nunes (1989); INE – Anuário Estatístico de Portugal	3 sectors	1910-50	1,7	85,0	10,0	5,0
				1950-73	5,4	71,7	8,4	19,9
				1973-85	1,0	67,1	52,0	-19,1
				1985-95	3,2	92,2	12,0	-4,2
				1910-95	2,8	84,5	5,8	9,8
	Labour productivity growth in manufacturing	Batista *et al.* (1997); Pinheiro (1997); Nunes (1989); INE – Anuário Estatístico de Portugal	9 sectors	1930-50	-0,3	222,6	-223,6	101,0
				1950-73	6,7	82,7	8,5	8,8
				1973-85	0,5	0,7	90,2	9,1
				1985-2000	4,7	99,6	0,4	0,0
				1930-2000	3,1	68,6	8,8	22,6
Lains (2004)	Aggregate labour productivity growth	Pinheiro (1997)	3 sectors	1953-60	0,7 [1]	77,8	16,6	5,7
				1960-73	1,5 [1]	71,4	16,9	11,7
				1973-79	1,7 [1]	91,9	6,1	2,0
				1979-90	1,9 [1]	94,2	9,9	-4,1
	Aggregate labour productivity growth	Pinheiro (1997)	16 sectors	1953-60	0,7 [1]	60,9	31,6	7,6
				1960-73	1,5 [1]	74,3	23,9	1,8
				1973-79	1,7 [1]	81,4	14,3	4,2
				1979-90	1,9 [1]	101,7	7,8	-9,6
Godinho and Mamede (2004)	Labour productivity gap in manufacturing (relative to a weighted average of productivity levels from 4 EU economies)	STAN OECD Database	2-digit (CAE) manufacturing industries clustered according to the technological OECD taxonomy	▪ 1985		92	8	n.a.
				▪ 1994		96	4	
Peneder (2002)	Aggregate labour productivity growth	EUROSTAT's New Cronos and Egger and Pfaffermayr's data on price deflators	3 sectors	▪ 1995-99	▪ 0,5 [1]	118,2	-8,1	-10,1
	Labour productivity growth in manufacturing	EUROSTAT's New Cronos and Egger and Pfaffermayr's data on price deflators	NACE 3-digit manufacturing industries	▪ 1985-98	▪ 0.4 [1]	123,3	70,7	-93,9
	Labour productivity growth in manufacturing	EUROSTAT's New Cronos and Egger and Pfaffermayr's data on price deflators	NACE 3-digit manufacturing industries clustered according to 3 different taxonomies	▪ 1985-98	▪ 0.4 [1]	111,2	-2,2	-9,0
						98,4	0,9	0,7
						105,9	1,7	-7,6
Fagerberg (2000)	Labour productivity growth in manufacturing	UNIDO Industrial Statistics Database	24 industries	▪ 1973-90	▪ 2,6	147,9	-0,2	-47,7
Doyle and O'Leary (1999)	Aggregate labour productivity growth	OECD International Sectoral Database	3 sectors	▪ 1970-73	▪ 8,4	81	17	2
				▪ 1973-81	▪ 4,7	75	25	0
				▪ 1981-86	▪ 2,9	90	21	-11
				▪ 1986-90	▪ 5,6	80	23	-3
				▪ 1970-90	▪ 5,0	80	22	-2

Notes: (1) Our calculations.

The typical finding of a modest contribution from the structural change components cannot, however, be seen as implying that structural change is insignificant in explaining economic growth.

First of all, as Fagerberg (2000) clearly shows, the results reveal that, *on average*, the reallocation of resources within sectors has made a small contribution to productivity growth, but not that specific structural changes, related in particular with technology-oriented sectors, were insignificant.

Secondly, it is important to bear in mind that the shift-share technique has a number of well-documented shortcomings that advise some caution when interpreting its results. One of those shortcomings has to do with the variability of the outcomes depending on the chosen level of aggregation. In particular, a more aggregated breakdown of the economy tends to be associated with smaller weights for the inter-sectoral effect, since there is a greater possibility of important structural changes occurring at the level of the individual sectors being neglected. At the same time, shift-share analysis does not take into account marginal productivity issues. It assumes that all factors have the same productivity, so that a reallocation of inputs among industries leaves the average productivity levels of the different branches unchanged. Bearing in mind that there may be important pools of relatively low productivity workers in the more traditional sectors of the economy, especially in the earlier phases of development, this may severely underestimate the global impact of structural change on productivity growth.[3]

Another possible source of underestimation of the structural change component is related to the inability of the shift-share technique, as a pure accounting procedure, to capture the indirect productivity gains arising from spillover effects. Technology progressive industries, for example, tend to stimulate productivity growth in related industries, through the diffusion of knowledge on new methods of production and by providing new, high-quality products and services (e.g., Stiroh, 2002). This productivity increase is taken as an intra-sectoral productivity gain and not as a structural change effect.

Apart from spillovers across sectors, the conventional shift-share method also ignores the presence of Verdoorn-type mechanisms (Verdoorn, 1949; Kaldor, 1966, 1975),

[3] In practice, the rise in productivity associated to the transfer of low-productivity workers out from sectors like agriculture or the informal sector of the economy would be accounted for in the intra-sectoral component, rather than in the inter-sectoral one.

which may induce an increase in productivity from an increase in the scale of production.[4] If significant differences in Verdoorn effects within branches exist, and the reallocation of factors favours branches with higher Verdoorn elasticities, shift-share results might underestimate the magnitude of productivity growth due to structural change.

Finally, the notion of structural change addressed by the shift-share technique is a relatively narrow one. Structural change is more than just a mechanic shift of resources towards higher-level or higher-growth productivity industries. In particular, it also involves changes occurring at the demand level, as pointed out by Pasinetti (1981, 1993), which are not duly taken into account by a supply-oriented technique such as shift-share analysis.

Despite the shortcomings mentioned, shift-share analysis remains an important tool for the analysis of differences between sectoral and national growth variables, with several studies attempting to broaden and modify the original version in order to improve the significance and accuracy of results.

A number of recent studies analysing the industrial structure and the export performance of Asian economies (e.g., Wilson, 2000; Kobayashi, 2004; Wilson *et al.*, 2005) use a different version of shift-share analysis, known as 'dynamic shift-share analysis', which was originally developed by Barff and Knight (1988). Unlike conventional shift-share, this latter version allows for the change of the growth rates and industry mixes over time, calculating the different components on an annual basis and then summing up the results over the period under study.[5] This allows for the identification of years of economic transition and the selection of time intervals that are internally consistent, so

[4] Verdoorn's Law (Verdoorn, 1949) is an empirical generalisation that states that there is a positive impact of output growth on productivity growth. Originally, this relation was supported by the existence of static economies of scale, which reflected gains associated to processes of labour division and specialisation, in the ways originally developed by Adam Smith (1776) and subsequently elaborated upon by Allyn Young (1928). Kaldor (1966) added the consideration of dynamic economies of scale to this static effects explanation, which reflect the influence of factors such as 'learning-by-doing' and incremental technical progress. According to the views expressed, a more rapid expansion of output would lead to a faster acquisition of knowledge regarding more efficient methods of production [as in Arrow (1962)], providing, at the same time, a more favourable environment for investment and risk taking.

[5] See Barff and Knight (1988) for a more detailed description of the method.

that the choice of the 'base' period becomes endogenous to the application of the method.[6]

Another reformulation of the shift-share technique can be found in Timmer and Szirmai (2000). Acknowledging the incapacity of the standard approach to take into account productivity gains associated with increases in scale of production, the authors develop a modified version that allows for the consideration of these gains. This is done by estimating by ordinary least squares Verdoorn elasticities for each branch of the economy, and including the resulting estimates in the computation of the structural change effect.[7] The results show that empirical findings based on conventional shift-share are biased, but that they can lead either to an underestimation or overestimation of the magnitude of productivity growth due to structural change.

Recently, several studies within the scope of regional economics have attempted to develop probabilistic forms of shift-share analysis, in order to quantitatively test hypotheses regarding changes in the variables under study. These efforts have been conducted following two alternative routes (Knudsen, 2000), either by representing the shift-share accounting identity in terms of Analysis of Variance (ANOVA) models (e.g., Berzeg, 1984; Patterson, 1991), or by making use of information theoretical models (e.g., Haynes and Phillips, 1982; Haynes and Machunda, 1988). Blien and Haas (2005) present an application of the former approach to the study of processes of structural change in eastern Germany. The use of this method has, however, been restricted to the decomposition by shift-share of the traditional equation considered in regional studies, which involves partitioning change in a regional variable, such as employment, into changes in national trends, industrial sector trends and local conditions, with no application (to our knowledge) to the decomposition used in the analysis of meso-macro levels of the economy.

4.3. Input-output analysis

Input-output analysis, first put forward by Leontief (1941), provides a detailed quantitative description of the structural properties of the components of a given economic system. The production process is illustrated by means of multiple relationships, where certain commodities are generated by other commodities that are

[6] In studies using shift-share analysis with a regional focus this technique presents the additional advantage of reducing the severity of changes in the industrial mix on the results of the analysis (Barff and Knight, 1988).

[7] See Timmer and Szirmai (2000: 384-388) for a more detailed description of the method.

themselves used and consumed in further production. In a standard input-output table, each row and corresponding column represents one particular sector, and each individual entry expresses the amount of the commodity or service produced by the sector (identified in the row) that has been delivered at the sector represented in the corresponding column**.** This structural representation of the economy provides the basis for determining the total sectoral output as well as the magnitude of the inter-sectoral transactions required to satisfy final demands. In particular, it is possible to derive a matrix describing the material input requirements of all producing sectors (matrix of technical input coefficients), which is also used to determine the relationship between the prices of goods produced by the different sectors and the value added payments (expressed in monetary units) made by each industry per unit of its output.

Since its inception, input-output analysis has experienced continuous reformulation and widening of its scope, with several extensions and applications being put forward (see, in this respect, Rose and Myernick, 1989). Given its disaggregated nature, it became a natural tool for the analysis of structural change, which in early applications was done mainly through cross-country comparisons of economic structure, in an attempt to identify regularities in the process of economic development (e.g., Chenery and Watanabe, 1958). More recently, however, the use of I-O analysis in the study of structural change has relied mostly on the comparison of changes in structure in an economy (or a group of economies) over time. This is done with recourse to a relatively new methodology, known as *structural decomposition analysis* (SDA), which permits distinguishing major sources of change in an economy by means of a comparative static exercise.

Like shift-share analysis, SDA is based on splitting an identity into its components. This decomposition may involve a simple tri-partite separation between changes in technology, demand growth and demand composition, or may assume a more detailed identification of sources of change.[8]

In order to illustrate the basic procedure, consider the basic material balance equation of input-output models:

$$X = AX + Y \tag{4}$$

[8] See Rose and Casler (1996) for a comprehensive review on the alternative approaches to deriving SDA equations in order to explore various decompositions of changes in input-output tables.

In Equation (4), $X = (X_1,..., X_n)'$ is the column vector of the sectoral gross outputs, Y is the vector of final demands, and A is the matrix of technical coefficients, where a_{ij} is the quantity of good i that is technologically required per unit of good j.

This relationship can be written as:

$$X = (I - A)^{-1}Y \tag{5}$$

Where I represents the identity matrix and $(I - A)^{-1}$ is the well-known Leontief inverse of direct and indirect input coefficients. Denoting this latter matrix as L, and taking final demand as the sum of private and public consumption (C), investment and changes in stock (I) and net exports (NE), output growth between two points in time (t, t-w) can be decomposed as follows:

$$\frac{X_t - X_{t-w}}{wX_{t-w}} = \frac{(L_t - L_{t-w})Y_t}{wX_{t-w}} + \frac{L_{t-w}(C_t - C_{t-w})}{wX_{t-w}} + \frac{L_{t-w}(I_t - I_{t-w})}{wX_{t-w}} + \frac{L_{t-w}(NE_t - NE_{t-w})}{wX_{t-w}} \tag{6}$$

Equation (6) thus represents the basic identity for the decomposition of output growth into its main constitutive components.[9] The first term on the right-hand side represents the technological component, measuring output growth due to changes in the Leontief matrix of technological coefficients, holding final demand constant. The other three terms represent output changes due to shifts in the individual components of final demand (private and public consumption, investment and net exports), holding the technological matrix constant.

In recent times, a significant and growing literature has used this analytical tool (in a way similar to Equation (6), or by making use of a more complex decomposition scheme), dividing sectoral output change into several parts in order to identify major sources of growth and structural transformation. Table 3 presents a summary description of some of these studies. A common finding within this literature is that the greatest contribution to output or employment change comes from changes in domestic demand (particularly changes in domestic household consumption), with technological change having a positive, albeit much smaller, impact on sectoral output growth (e.g., Korres, 1996; Brus, 1998; Oosterhaven and Hoen, 1998; Andreosso-O'Callaghan and Guokiang, 2002; Sánchez-Chóliz and Duarte, 2006). At the same time, the growth

[9] The components represent average annual growth rates expressed in terms of the average change in percentage points of output relative to the base year.

effects stemming from changes in international trade patterns are generally less pronounced (Oosterhaven and Hoen, 1998; Andreosso-O'Callaghan and Guokiang, 2002; Peneder *et al.*, 2003).[10]

The picture changes somewhat when the analysis is conducted with respect to the more technologically advanced sectors. Oosterhaven and Hoen (1998), for example, find in their study of six EU countries over the period 1975-1985 that modern sectors such as communication, office machinery and electrical goods, which have the larger growth rates of real income, are simultaneously the sectors that experience the most positive impact of technological change. Andreosso-O'Callaghan and Guokiang (2002), in their turn, find for the Chinese economy that the contribution to the rapid growth of high-tech industries such as transport equipment, electronics and communication equipment and instruments in the 1987-1997 period stems mainly from technological change, together with increases in domestic consumption and investment. The same occurs with regard to the more restricted branch of business and knowledge-based services, which has received a great deal of attention in recent studies applying the input-output SDA methodology (e.g., Brus, 1998; Peneder *et al.*, 2003; Franke and Kalmbach, 2005; Savona and Lorentz, 2006).[11] In these sectors, organisational and technological change appears to be a substantial source of growth: Brus (1998) found that the change in input-output coefficients explained 60 percent of structural employment growth in the business services industry in the Netherlands during the 1975-93 period; Oosterhaven and Hoen (1998), in their turn, found that almost half of the real value added growth of 'other market services' (a sector that comes close to the business services industry) was due to changes in the Leontief-inverse matrix of technology coefficients. More recently, Peneder *et al.* (2003) found in their study of seven OECD countries that, apart from being the sector with the highest productivity growth, knowledge-based services are also characterised by a distinct pattern of change, with technological change emerging as a substantial source of growth. This is in marked contrast with manufacturing and other service branches, sectors in which technological and organisational change plays a modest or even negative role in the explanation of sectoral output growth. The same

[10] An exception is found in Franke and Kalmbach's (2005) work, in which the growth contribution from export growth is only slightly lower than the contribution from final domestic demand.

[11] The growing concern with this specific branch of economic activity seems to have been triggered by recent research in the services literature (e.g., Andersen et al., 2000; Miles and Tomlison, 2000, 2005; Petit, 2002), which identifies knowledge intensive based services as one of the main drivers of economic growth today.

pattern is also found in Savona and Lorentz (2006), who show that changes in input-output coefficients accounted for most of the output growth in knowledge intensive based services in a sample of four OECD countries during the late 1960s-1990s period, while they had little influence in other service branches, and even a negative role in some manufacturing branches. Franke and Kalmbach (2005) also find that the highest technological growth contribution occurred in the business-related services, sectors which, once more, exhibit the highest growth rates.

As Rose and Casler (1996) make clear in their critical review of the technique, input-output SDA has a number of strengths, such as enabling the removal of the static features of input-output models. It also represents an alternative to econometric estimation, requiring a much smaller amount of data: it is only necessary to have two input-output tables (one for the initial year and one for the ending year of the analysis), instead of a complete time series covering the entire period. At the same time, SDA allows for a comprehensive account of all inputs of production, making it a very powerful tool for the analysis of resource depletion and pollution problems.

An important analytical limitation to the method is, however, that it is not possible to distinguish between technological, organisational and institutional changes included in the Leontief-inverse matrix of technology coefficients. Organisational and technological change both result in changes of the coefficients in the matrix of intermediary inputs, and as such, they cannot be separated in the decomposition procedure. More precisely, a multitude of factors, including a more efficient use of primary and other inputs, changing technologies, change in vertical integration, quality differences, product innovation, externalities, deregulation, altered industrial relations practices or changing (dis)economies of scale, may be reflected in changes in the Leontief technological matrix, which makes its interpretation problematic.

Minor flaws in the method are related to the non-uniqueness of solutions, as there are several alternative methods to obtain an exact decomposition of the sources of structural change (see in this respect Dietzenbacher and Los, 1998). Furthermore, the method may yield slightly different results according to the base year chosen.[12]

Finally, and in comparison to shift-share techniques, input-output SDA requires a vast amount of data, which is dependent on the determination of government planning

[12] In this respect, Oosterhaven and Hoen (1998) suggest a weighting procedure in which the final year shares and the base year shares are taken for half of the weights.

agencies and central statistical offices, and which represents a major problem in the Portuguese case, given the paucity of available data. Indeed, only recently has Portugal integrated the OECD Input-Output database, more precisely in its last update in 2006, and according to the National Statistics Office (INE), input-output matrices are only available for 1992, 1995 and 1999, the latter of which has been included in the OECD database. This represents a major drawback for the analysis of a relatively long time span, as required by the analysis of the phenomenon of structural change.[13] It may indeed explain the existence of only one study (to our knowledge) focusing on technological progress in the Portuguese economy using input-output analysis (Elmslie, 1994), which makes use precisely of the relatively 'old' ECE input-output tables. All the other studies making use of this methodology are mainly concerned with either environmental issues, focusing on the measurement of carbon dioxide emissions and on its relationship with the international trade of goods (e.g., Cruz, 2002; Barata, 2002; Marques *et al.*, 2006, Cruz and Barata, 2007), and inter-regional trade (e.g., Ramos and Sargento, 2003), or with the application of the input-output model within the framework of the Social Accounting Matrix (SAM) (e.g., Santos, 2004, 2007).

[13] There are some input-output tables for the Portuguese economy for 1959, 1964, 1970 and 1974, which were compiled by the Economic Commission for Europe (ECE). However, those tables are not directly comparable with the more recent ones, as they are based on different assumptions.

Table 3: Studies that use structural decomposition analysis in the quantification of sources of change in output /employment growth

Author(s)	Period	Data	Disaggregation level	Variable	Sources of change
Sánchez Chóliz and Duarte (2006)	1980-1994	Spanish I-O tables for 1980, 1986, 1990 and 1994	▪ 9 sectors (primary, energy, high-tech., medium-high-tech., medium-low-tech., low-tech., construction, high-qualification services, other services	Output growth	▪ Technological change[1] ▪ Demand change
Savona and Lorentz (2006)	End of 1960s-end of 1990s	OECD harmonised I-O tables (Germany, The Netherlands, UK and USA)	▪ 13 sectors	Output growth	▪ Technological change (changes in I-O coefficients) ▪ Changes in the level and in the composition of domestic final demand (comprising changes in public and private consumption and changes in investment outlays) ▪ International trade
Franke and Kalmbach (2005)	1991-2000	German I-O tables for the years 1991-2000	▪ 8 sectors [agriculture, manufacturing export core, other manufacturing, construction, business services (in narrow and broad senses), consumer services, social services]	Output growth	▪ Technological change ▪ Changes in import penetration in intermediate demand ▪ Changes in domestic final demand ▪ Changes in import-export components of final demand
Peneder et al. (2003)	Early 1970s-1990s	OECD harmonised I-O tables; data from national statistical offices from Denmark, France, Germany, Japan, The Netherlands, UK and USA.	5 sectors (manufacturing, distributive services, knowledge-based services, personal and social services, other sectors)	Output growth	▪ Technological change (changes in I-O coefficients) ▪ Changes in the level and in the composition of domestic final demand (comprising changes in public and private consumption and changes in investment outlays) ▪ International trade
Andreosso-O'Callaghan and Guokiang (2002)	1987-1997	Chinese I-O tables for 1987 and 1997	▪ 3 sectors (primary, secondary and tertiary) ▪ 28 sectors	Output growth	▪ Technological change (changes in I-O coefficients) ▪ Changes in the level and in the composition of domestic final demand ▪ International trade
Brus (1998)	1975-1993	CPB I-O tables for the Netherlands	▪ 5 sectors (agriculture, manufacturing, market services, non-market services, government) ▪ 5 subsectors of market services	Employment growth	▪ Technological change (changes in I-O coefficients) ▪ Changes in domestic final demand ▪ Export expansion ▪ Import substitution ▪ Changing labour output coefficients
Oosterhaven and Hoen (1998)	1975-1985	EU-intercountry I-O tables	▪ 25 sectors	Real value-added growth	• Technological change, related with two distinct components: 1) changes in the mix of intermediate inputs (change in the intercountry Leontief inverse); 2) changes in the ratio of primary inputs to intermediate inputs • Changes in trade patterns • Changes in final demand preferences • Changes in the size and composition of macroeconomic demand
Korres (1996)	1960-1980	Greek I-O tables	▪ 9 sectors	Output growth	▪ Technological change (changes in I-O coefficients) ▪ Changes in domestic final demand ▪ Export expansion ▪ Import substitution of final goods ▪ Import substitution of intermediate goods

Notes: (1) The structural decomposition is applied to four linkage components (net backward component, net forward component, internal component and mixed component) in which each sector is previously decomposed. In this sense, SDA provides four technological effects and four demand effects per aggregate sector: three of the technological effects reflect the technological change associated with the activities of the aggregate sector, whereas the fourth reflects technological change in other sectors; two of the demand effects are associated with the demand for inputs produced and consumed by the aggregate sector and the other two with inputs purchased from and sold to other sectors.

4.4. Other methods

Along with shift-share and input-output analyses, other approaches to the study of structural change include the use of descriptive statistics techniques, and the construction of mathematical indexes of structural change. This section makes a brief reference to these methods, and presents a review of the studies that employ econometric techniques in the assessment of the impact of structural change on overall macroeconomic growth.

Mathematical indicators of structural change can be grouped, in broad terms, into two main categories: indices that account for the speed of structural change, such as the Lilien and Nickell indices (Lilien, 1982; Nickell, 1985), and indices that assess the dissimilarity of economic structures across countries (or groups of countries), such as the Krugman specialisation index (Krugman, 1991), and concentration indices. Table 4 presents their mathematical description.

Table 4: Indices for the analysis of structural change

Indices	**Formulae**	**Description**
Nickell index	$I_1 = \sum_i \lvert \Delta x_i \rvert$	x_i represents the proportion of sector *i* in economic activity
Lilien index	$I_2 = \left[\sum_i x_i (\Delta \log x_i)^2 \right]^{1/2}$	x_i represents the proportion of sector *i* in economic activity
Krugman index	$K^k(t) = \sum abs \lvert V_i^k(t) - V^k(t) \rvert$	$V_i^k(t)$ and $V^k(t)$ represent the shares of sector *k* in country *i* and in the reference country (or group of countries) at period *t*
Concentration index	$I_i^k(t) = \dfrac{x_i^k(t) / X^k(t)}{x_i^{'}(t) / X^{'}(t)}$	$x_i^k(t)$ is gross added value at constant prices in country *i* and sector *k*, $X^k(t)$ is gross added value at constant prices in sector *k* in the reference country (or group of countries), $x_i^{'}(t)$ is gross added value at constant prices in country *i* and $X^{'}(t)$ is gross added value at constant prices in the reference country.

Notes: All sectoral shares can be calculated on the basis of employment statistics [as originally developed by Nickell (1985) and Lilien (1982)], or on the basis of value added at constant prices.

As can be readily seen from Table 4, the Nickell index is a measure of the mean deviation of differenced sector shares in economic activity, whereas the Lilien indicator represents a weighted standard deviation measure of changes in sector shares of economic activity. High values for these indicators represent fast structural changes, and in the case of the employment variables being used, a significant reallocation of employment between sectors.

The Krugman and concentration indexes, in their turn, compare the economic structure of a particular country relative to the structure of a reference country (or group of countries). The former ranges in value between zero and two, taking the value of zero if the sectoral structures of the economies under comparison are identical, and taking the value of two if they have completely dissimilar structures. The concentration index compares the share of a sector in a particular country relative to the reference country's sector output, in relation to the share of its whole economy in the output of the reference country (or group of countries). In this case, values around 1 represent a concentration of sectors which is similar to the reference country, whereas values exceeding 1 point to a higher concentration level.

These indexes have been used in a number of studies analysing changes in the economic structure over time. Lilien (1982) developed his indicator in order to demonstrate that most of the unemployment fluctuations in the 1970s within the US economy were due to significant structural shifts. Driver (1990), in his turn, applied the Lilien indicator to the analysis of changes in the capital stock (rather than the labour stock) in a number of English regions during the 1974-85 period. He found that the pace of structural change showed a significant rise in the early 1980s (the Lilien index peaked in 1983/2), remaining thereafter at a high level comparatively to earlier years.

More recently, Barry (2001) used a battery of structural indicators of this type in an attempt to explain the relatively slow convergence of Ireland in the 1960s and 1970s, and its extraordinary performance in the 1990s. Comparing Irish data with data from the other three ‘cohesion countries’ – Portugal, Spain and Greece – Barry calculates Krugman and concentration indices and compares relative shares of modern and traditional industries in overall exports, providing, at the same time, a comparison of the R&D orientation of the economies under study. His main conclusion is that the strong pace of convergence observed in Ireland in the 1990s was caused by a shock in labour demand which was mostly due to an increase in foreign direct investment. This shock, allied with education and infrastructure improvement, macroeconomic stability and a more efficient competition policy, laid the grounds for a profound change in economic structure, with a considerable shift towards high-technology industries.

In a different study, in which a comparative analysis of the Slovakian and EU structures is undertaken (Čutková and Donovai, 2004) there is also a prolific calculation of structural indicators, such as Krugman, Lilien and concentration indices.

The use of these indices, while illustrative of some of the characteristics of the processes of change taking place in the economy, does not offer more than a superficial portrait of those processes. Indeed, they do not allow for the identification of the direction in which structural change is made, and do not provide any indication whatsoever about the nature of the sectoral interdependences in the process. Furthermore, a common criticism to their use is that they are strongly dependent on the chosen level of sectoral aggregation (Driver, 1993). Their calculus at a very broad level of aggregation may neglect important changes taking place at the intra-sectoral level, whereas the use of a very detailed identification of differences across economic activities may make a broad structural change difficult to detect.

An alternative (and more sophisticated) approach to the study of structural change and its impact on economic growth relies on the use of econometric estimation methods. Despite their generalist nature (they are not specifically designed to perform structural analysis), they can nevertheless be used for this purpose, as shown by a number of recent studies that successfully establish a link between the meso and the macro structures of the economy.[14] Peneder (2003), for example, finds a positive relationship between the relative shares in the exports and imports of technology-driven and high-skilled industries and the growth of per capita GDP, using panel-data estimation. Fagerberg (2000) finds changes in the employment share of the electronics industry to be positively related with the manufacturing sector's productivity growth, evidence that is corroborated by Carree (2003), although with a substantial reduction in the estimated spillover effects. Amable (2000), in his turn, in a series of panel-data estimations which include developed countries along with NICs, finds that countries whose foreign trade structure has a comparative advantage in electronics enjoy faster productivity growth. On the whole, these findings suggest the existence of substantial positive spillovers arising from leading technological industries, and in particular from electronic industries. In this context, pure accounting procedures necessarily have to be complemented by other methods, such as econometric methods, in order to obtain a fuller account of structural change as a source of economic growth.

[14] See Table 5 for a more detailed description of these studies.

Table 5: Studies that employ econometric estimation techniques in the assessment of the impact of structural change on productivity growth

Author(s)	Sample	Period	Estimation method	Dependent variable	Structural (independent) variables	Other variables
Peneder (2003)	28 OECD countries	1990-98	Fixed effects panel data estimation	Log of GDP per capita at PPP of 1995	▪ Lagged share of services in total value added ▪ Lagged export share of technology driven industries relative to OECD ▪ Lagged export share of human capital intensive industries relative to OECD ▪ Lagged import share of technology driven industries relative to OECD ▪ Lagged import share of human capital intensive industries relative to OECD ▪ Growth rate of the relative export share of technology driven industries ▪ Growth rate of the relative export share of human capital intensive industries	▪ Log of total population ▪ Log of total population at working age ▪ Employment rate ▪ Lagged employment rate ▪ Year dummies ▪ Log of the lagged value of total investments in the previous period ▪ Growth rate of the log of lagged value of total investments ▪ Lagged level of the average number of years in training or education
	28 OECD countries	1990-98	Panel data estimation – GMM	Δ log of GDP per capita at PPP of 1995[1]	▪ Lagged share of services in total value added ▪ Δ lagged export share of technology driven industries relative to OECD ▪ Export share of technology driven industries relative to OECD (in second differences) ▪ Lagged import share of technology driven industries relative to OECD ▪ Δ lagged export share of human capital intensive industries relative to OECD ▪ Export share of human capital intensive industries relative to OECD (in second differences) ▪ Lagged import share of human capital intensive industries relative to OECD	▪ Δ log of the lagged value of GDP per capita PPP ▪ Δ log of total population ▪ Δ log of total population at working age ▪ Δ employment rate ▪ Δ lagged employment rate ▪ Δ log of the lagged value of total investments in the previous period ▪ Log of total investments (in second differences) ▪ Year dummies
Carree (2003)	20 OECD countries	1972-92, divided into 4 subperiods: 1972-77, 1977-82, 1982-87, 1987-92	OLS	Productivity growth in manufacturing	▪ Employment share of 5 technologically advanced countries at the beginning of each period [2] ▪ Change in the share of each of the 5 industries in total manufacturing employment over each of the subperiods	▪ Initial productivity level ▪ Ratio of gross fixed capital formation to total value added for the manufacturing sector
Fagerberg (2000)	37 countries	1973-90	OLS	Productivity growth in manufacturing	▪ Change in the share of the electrical machinery industry in total manufacturing employment ▪ Change in the share of other high growth industries in total manufacturing employment	▪ Initial productivity level ▪ Enrolment in education (primary and secondary education) ▪ Share of investment in GDP ▪ Size of population ▪ Continent-dummies
Amable (2000)	39 countries	1965-90	Panel data estimation – GMM	Δ log of real GDP per worker	▪ Δ index of inter-industry specialization (Michaeli index) ▪ Δ index of trade dissimilarity ▪ Δ comparative advantage indicator in electronics (as defined by CEPII)	▪ Lagged dependent variable ▪ Δ ratio of investment to capital stock ▪ Δ education variables (either the average years of secondary schooling of the total population or the percentage of 'secondary schooling complete' in the total population, log of 1+ the percentage of 'no schooling' in the total population) ▪ Dummy variables that distinguish the countries in 3 groups (OECD and Israel, Latin American and Asian countries)

Notes: (1) Δ var = variable in the first differences; (2) The industries are: pharmaceuticals (ISIC 3522); office and computing machinery (ISIC 3825); radio, TV and communication equipment (ISIC 3832); Electrical machinery except 3832 (ISIC 383X); professional goods (ISIC 385)

4.5. A critical assessment of the different methods and definition of the empirical research contribution

At the empirical level, the enormous potentialities of structural change analysis in the explanation of the processes of economic growth have recently been explored in a growing number of studies using a variety of techniques. In the previous sections, a brief description of the main methods used was provided, together with an account of their major strengths and weaknesses. Table 6 below provides a comparative summary of the analysis undertaken.

The major tool for the study of structural change at a refined level is, undoubtedly, input-output analysis. Input-output tables provide information regarding industries' interdependencies in terms of the structure of the costs of production and the value added that is generated in the production process, allowing for the identification of the major sources of growth and structural transformation. Unfortunately, the use of this technique requires a vast amount of data, which is not available for a sufficiently long time span in the Portuguese case. We thus revert to the use of alternative (although complementary) methods, in order to analyse the process of structural transformation that has taken place in Portugal over the last thirty years.

Shift-share analysis has a number of well-known shortcomings, but it has proved to be a useful tool to investigate how aggregate growth is linked to differences in productivity growth within industries, and with the reallocation of factors between industries, requiring much less data. Furthermore, some of the recent developments of the technique have improved the accuracy of its results, providing easily interpretable policy orientations concerning the economy's pattern of specialisation. Looking at the evidence that has been produced so far for the Portuguese economy using this methodology, there seems to be scope for further improvement.

First of all, all the studies developed until now have restricted their analysis to the investigation of the relationship between labour productivity gains and the reallocation of labour across sectors, disregarding the impact of capital transfers on the global process of structural change. This oversight may have had important consequences in terms of understating the overall importance of structural change. Indeed, according to the overwhelming evidence regarding the Portuguese growth experience in the last few decades (see, for example, Afonso (1999) and Lains (2003)), Portuguese economic growth has been mostly triggered by capital accumulation, and in this context, it seems reasonable to expect the reallocation of capital across sectors to have had an important effect on the process.

Secondly, the studies focusing explicitly on the Portuguese economy have tended to restrict the analysis to a very high level of aggregation.[15] While providing an illustrative picture of the overall evolution of the Portuguese economy, such a broad sectoral breakdown seems to be insufficient to get a rigorous account of the impact of technological progress and structural change in productivity growth. Furthermore, the work in this field has been exclusively centred on the assessment of the relative contribution of the three macro-sectors (primary, manufacturing and services), and on the analysis of the contribution of manufacturing industries to aggregate productivity growth. The service sector is taken as a whole, seemingly at odds with recent developments in the services literature, which emphasises the increasing relevance of some service subsectors, and particularly those more intimately related to ICT technologies, to aggregate productivity growth (e.g. Peneder *et al.*, 2003; Savona and Lorentz, 2006).

Finally, some of the studies that use a higher disaggregation level when measuring the impact of structural change on Portuguese productivity growth (Fagerberg, 2000; Peneder, 2003) consider a relatively short time-span, that does not allow for a comprehensive analysis of the overall process of structural change, which is by nature a long-term phenomenon, and does not take into account the specificities of Portuguese economic growth when choosing the temporal span under study.

All things considered, it is our purpose to provide a broader understanding of the interaction between structural change and Portuguese economic growth, which is accomplished on the basis of the following improvements in relation to previous studies:

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[15] Although Peneder (2002) and, to a lesser extent, Fagerberg (2000), provide results for the structural decomposition of productivity growth in Portugal with greater detail, they do not interpret those results in light of the overall process of development of the Portuguese economy. Indeed, in both cases, the calculus is made in parallel with a number of other countries in order to get a sufficient amount of evidence to account for 'stylised facts' concerning the influence of industrial structure on aggregate growth.
Recently, Lains (2008) used shift-share analysis for a total of 56 sectors. This study, however, does not take into account capital transfers across industries, and does not directly address the relationship between structural change and technology.

i. Adopting a wider perspective on the measurement of structural change effects, by considering a more complete measure that simultaneously accounts for shifts in labour and capital;

ii. Using a relatively high sectoral disaggregation level, extending the higher breakdown of economic activity to the services sector;

iii. Applying shift-share analysis to a relatively long time-span that covers the last thirty years, taking into account the different phases of growth of the Portuguese economy;

iv. Addressing explicitly the connection between technological progress and structural change by using industrial taxonomies that take into account the technological and innovativeness features of industries;

v. Improving the accuracy of results, taking into account Verdoorn effects in the measurement of the overall impact of structural change on total factor productivity growth.

This exercise will hopefully provide a more rigorous assessment of the relationship between structural change and the macroeconomic performance of the Portuguese economy, which is complemented in Part III with econometric estimation methods. As indicated earlier, because of the essentially accounting nature of the shift-share technique, spillover effects between industries are not duly taken into account, and the analysis of causality chains cannot be developed. We thus use econometric methods in the final part of the current work, in order to overcome these shortcomings and explore the existence of causality links between the meso and the macro structures of the economy.

Table 6: Comparison of the methods used in the empirical analysis of structural change

Method	Brief description of method	Main strengths	Main weaknesses	Typical findings	Recent applications
Shift-share analysis	Pure accounting technique that, when applied to the study of structural change, allows for the decomposition of productivity or employment growth into three major components: intra-sectoral, static and dynamic structural change effects.	• Requires a relatively small amount of data and little computational effort • Provides easily interpretable results.	• Sensitivity of the outcomes depends on the chosen level of aggregation • Does not take into account marginal productivity issues. • Does not capture spillover effects • The traditional procedure ignores the presence of Verdoorn-type mechanisms. • Adopts a relatively narrow notion of structural change. • Despite being useful as a preliminary step in identifying the factors driving structural change, it does not explain the economic forces behind those changes	Commonly, studies relying on shift-share analysis find that the intra-sectoral component is clearly dominant, whereas the structural change effect (including both the static and the dynamic shift components) plays only a minor role in explaining productivity growth.	• Aguiar and Martins (2004) • Lains (2004) • Godinho and Mamede (2004) • Peneder (2003) • O'Leary (2003) • Fagerberg (2000). • Timmer and Szirmai (2000)
Input-output analysis	I-O SDA allows for the decomposition of input-output relations between any two points in time, as a sum of effects associated with each of the individual sources of change. This decomposition may involve a simple tri-partite separation between changes in technology, demand growth and demand composition, or may assume a more detailed identification of sources of change.	• Provides a detailed description of the economic structure • The sectoral scheme of the I-O table facilitates data collection, and its matrix representation facilitates data organisation • Simplicity and transparency of the table • Allows for a bottom-up determination of aggregates • Represents a comprehensive means of assessing economic impacts	• Sensitivity of the outcomes depends on the chosen level of aggregation • Requires a vast amount of data, • Changes in input-output coefficients can be the result of a whole array of technologic, organisational and institutional changes. • It does not explain the economic forces behind structural changes.	Typically, I-O SDA results show that the greatest contribution to output growth comes from changes in domestic demand, where the growth effects stemming from other sources of changes are generally less pronounced. Technologically advanced sectors and particularly business-related sectors show a distinct pattern of change, with an important (and sometimes predominant) contribution stemming from technological change	▪ Sánchez Chóliz and Duarte (2006) ▪ Savona and Lorentz (2006) ▪ Franke and Kalmbach (2005) ▪ Peneder et al. (2003) ▪ Andreosso-O'Callaghan and Guokiang (2002)
Indices of structural change	Represent relatively simple descriptive statistics, which can account for the speed of structural change (Lilien and Nickell indices), and assess the dissimilarity of economic structures across countries (Krugman specialisation index, concentration indices).	• Require a relatively small amount of data and little computational effort • Provide easily interpretable results.	• Provide only a superficial (and partial) portrait of the processes of structural change. • Results are strongly dependent on the chosen level of sectoral aggregation	-	▪ Čutková and Donovai, 2004 ▪ Barry (2001)
Regression analysis	Regression analysis has been used both in terms of simple time-series OLS estimation, and panel-data estimation.	• In contrast with other methods, econometric analysis can be used to analyse causality chains and perform statistical tests regarding the probable causes (and consequences) of structural change • Also permits taking into account spillover effects among industries. • Provides easily interpretable results.	• Although hypotheses concerning the impact of some aspects of structural change in economic growth can be statistically explored, it does not provide a complete and detailed overview of the structural change process, as in other techniques, such as input-output analysis, which are specifically designed for the study of structural change.	The surveyed studies are successful in establishing a link between the meso and the macro structures of the economy. Generally, a positive relationship is found between the relative shares of technologically advanced industries and economic growth. This suggests the existence of substantial positive spillovers arising from leading technological industries.	▪ Peneder (2003) ▪ Carree (2003) ▪ Fagerberg (2000) ▪ Amable (2000)

Section 5. Measurement of capital stock and total factor productivity

5.1. Introductory considerations

Multifactor productivity (MFP) – or total factor productivity (TFP) – measures are fundamental instruments to identify the relative importance of different sources of growth, permitting that growth contributions from labour, capital, and technology to be disentangled. Despite their major importance in the analysis of growth patterns and in the assessment of a country's potential for future economic growth, only a few studies have approached these issues for the Portuguese case (e.g., Teixeira and Fortuna, 2008; Lains, 2008, 2003; Mendi, 2007). Furthermore, to our knowledge, those studies have focused only on the measurement of MFP at the aggregate level, putting aside the estimation of this measure by type of economic activity. Lack of information is probably the main factor accounting for this. Indeed, MFP measures call for information on capital measures, which, in turn, require a vast amount of data – such as a long time-series of investment, price deflators to revalue investment to constant base year, estimates of service lives or rates of depreciation, and a benchmark level of capital stock for at least one year –, requirements that are naturally multiplied when several economic sectors or activities are accounted for.

In this section an attempt is made to fill this gap, by calculating multifactor productivity growth for a number of economic branches. As indicated earlier, this procedure is an intermediate step to reach our main research goal: assess the impact of structural change in Portuguese economic growth in the past thirty years and identify the main sectors responsible for the observed productivity trends. For this purpose we rely on a growth accounting framework – a non-parametric technique – examining how much of the observed rate of change of an industry's output can be explained by the rate of change of combined inputs, and evaluating MFP growth residually.[16] In order to do so, we first estimate flows of capital services (the contribution of capital to production) by type of activity and by asset type.[17] In the absence of directly observable flows of capital

[16] Under this approach MFP is identified as a 'residual' resulting from the difference in the growth of output and the contribution of inputs, weighted at their respective factor shares in value added.

[17] Although some studies use gross capital stock as a capital input, this is not the appropriate measure of capital to be used when assessing multifactor productivity growth. The first and most obvious reason is that all the other variables in the growth accounting model are flows, rather than stocks. At the same time, the use of capital stocks (whether gross or net) does not take into account the productive efficiency of capital assets. An additional reason is related to the weighting procedure used in the calculus of gross and net capital stocks, which is based on market values. This procedure provides erroneous information on the

services, these are approximated as a proportion of the productive capital stock, which is obtained by converting the gross capital stock derived from the perpetual inventory method (PIM) into standard efficiency units. The standard efficiency units of different types of assets are then combined into an overall index – volume index of capital services (VICS) –, taking the user costs of capital of the different types of assets as weights.

5.2. Data sources

In order to measure MFP growth using the growth accounting methodology, data on output, labour and capital inputs at constant prices are required. Data on output and labour variables regarding the 1979-2003 period can be directly obtained from the Groningen Growth and Development Centre (GGDC) Database.[18] This database provides data on current value added, value added deflators and hours worked for 56 industries in the 1979-2003 period for several countries, including Portugal. We extend the output data to include 1977 and 1978, considering the statistics available in the OECD STAN Database.[19] The data provided by this source for the 1977-1978 period is, however, available in more aggregate terms, by grouping together the information on some of the economic branches of our sample, such as DB and DC, DK and DL, and GG and HH, respectively.[20] In order to discriminate among sectors, we use the sectoral output proportions data provided by the Portuguese National Statistics Office (INE) for 1977 and 1978. Furthermore, data on CA+CB output and VAB deflators was not available in the OECD STAN Database and, therefore, it had to be estimated by applying backwards the corresponding growth rates available at INE to the 1979 value. The number of hours worked per employee regarding 1977 and 1978 was obtained by applying backwards the annual variation rates of employment provided by INE. During the 1977-1979 period there were no changes in the number of established working days and in the total number of hours worked per day.[21] It seems reasonable therefore to expect that the variation of the total number of hours worked should follow closely the employment variation rates in each sector.

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contribution of the different assets to production, undervaluing the contribution from short-lived assets and overvaluing that from long-lived assets (OECD, 2001a, 2001b).

[18] Available on-line at http//: www.ggdc.net.

[19] This is the same source used by GGDC in the compilation of Portuguese output and output deflators data.

[20] See Section 5.3.1. below.

[21] See in this respect, Leite and Almeida (2001) and Barreto (1990:. 57-117).

Greater difficulties arise with respect to capital input estimates, which are not directly available at the sectoral level for the Portuguese case. We had thus to start by measuring capital services by type of activity, which required information on two basic inputs: investment series by industry, cross-classified by type of asset, and producer price indices of investment goods to deflate investment expenditure series.

Regarding investment, our data source is INE. For the period under analysis (1977-2003), INE provides annual nominal gross investment data disaggregated by type of activity and further subdivided into the categories land (*animais e plantações*), machinery and equipment (*máquinas e aparelhos*), transport equipment (*material de transporte*), buildings (*construção*) and other investment (*Outros*).

Since it is our purpose to estimate a measure of capital input and land is a non-produced asset, this category of investment is not included in our computations.[22] Furthermore, we consider the broad 'buildings' category, although ideally owner-occupied residential capital should be excluded from our calculus.[23] However, such a distinction within the 'buildings' category would be problematic in the Portuguese case, since building investment made by sole proprietorship firms (which represent a very significant part of total Portuguese firms) is included within the households' residential investment. It was therefore necessary to consider all buildings, irrespective of the institutional nature of the investor, in the measurement of capital input.

During the period under study, INE changed the calculus procedure of the GFCF series, which were computed under different conceptual schemes. The most relevant change took place in 1995, when some adjustments were made in order to accommodate for the requirements stipulated by the European System of National and Regional Accounts (SEC 95). For the 1995-2003 period, INE provides a fully integrated GFCF series, but unfortunately the same does not apply for the preceding years. Thus, we had to remove discontinuities relative to the previous period, by applying backwards the growth rates implicit in the earlier temporal series. This allowed us to get an overall picture of the dynamics of the investment flows at current prices in the period under study, which is depicted in Figure 1.

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[22] In this respect we follow the OECD (2001a) recommendations, which acknowledge that in general terms land should not be treated as gross fixed capital formation (GFCF) in the measurement of productivity (see OECD, 2001a: 76). Furthermore, in our case, this asset constitutes only a negligible part of the GFCF, never exceeding 2% of its total value during the whole period under study.

[23] Given our purpose of analysis – the measurement of TFP growth – the only relevant part of residential investment is the investment carried out by specialised producers of market services (OECD, 2001a).

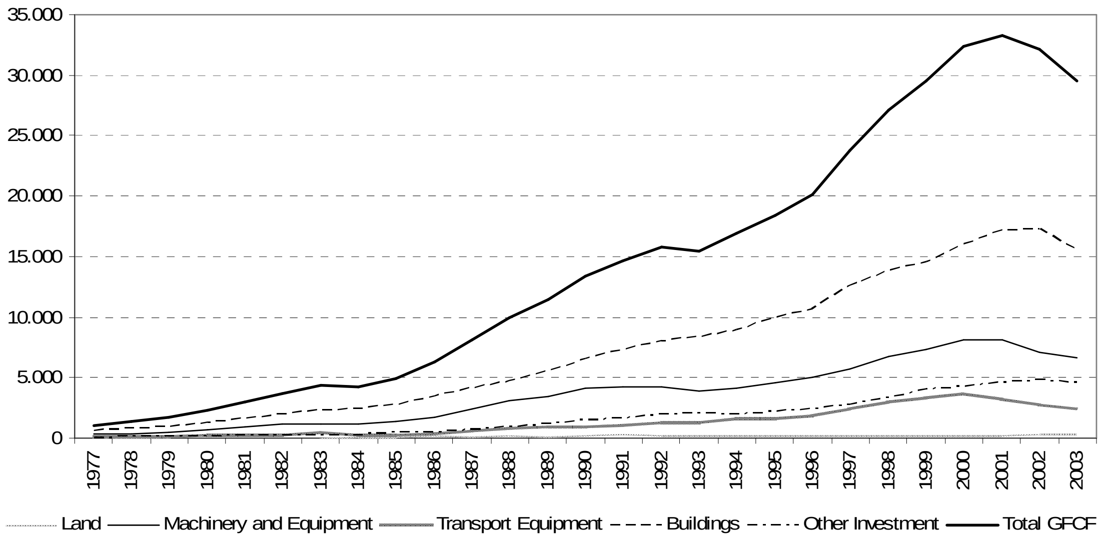


Figure 1: Portuguese GFCF, current prices 1977-2003 (10^6 euros)

Note: Author's computations based on data from INE

In order to deflate the investment expenditure series, the deflators from Banco de Portugal for the 1977-1995 period were applied,[24] and for the subsequent years, the deflators from INE. Deflators from Banco de Portugal consider only the breakdown of the GFCF by type of asset for the whole economy, whereas INE provides investment deflators that consider simultaneously the industry and asset types in which the investment was made. To avoid the introduction of (possible) noise from the consideration of a different detail level in the deflators used, we opted for deflators discriminated only by asset type in the estimation of constant prices investment series, taking 1977 as the base year.[25]

Taking into account price deflators, the evolution of the total GFCF and of the individual investment series on the different assets between 1977 and 2003 is as shown in Figure 2.

[24] This information is available on-line at http://www.bportugal.pt.
[25] The list of deflators considered can be consulted in Annex 1

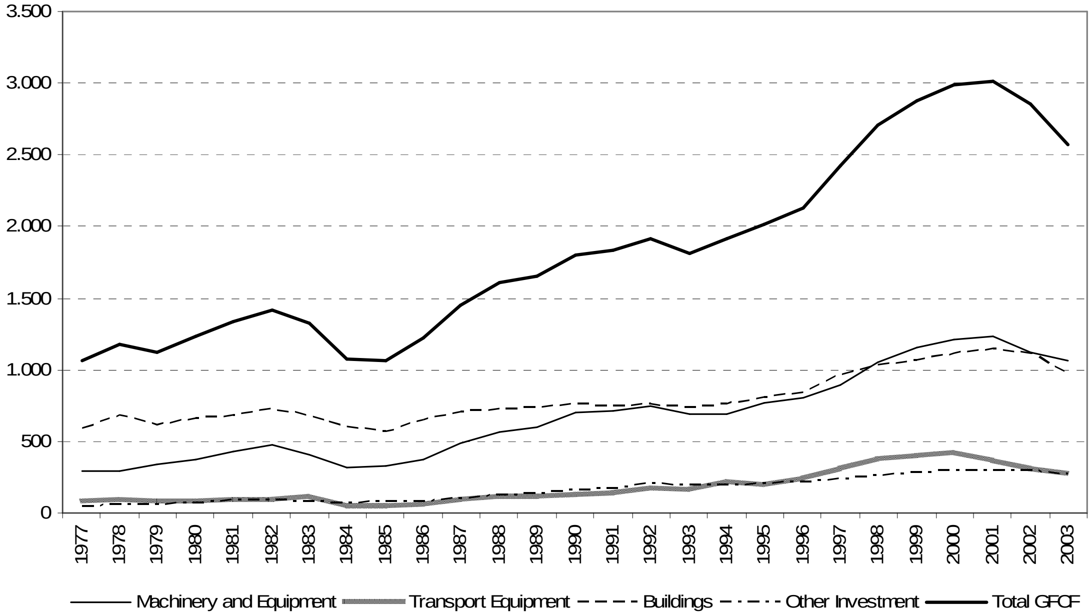


Figure 2: Portuguese GFCF at constant 1977 prices (10^6 euros).

Note: Author's computations based on data from INE and Banco de Portugal

Figures 1 and 2 show a general trend towards an increase in investment flows up to 2001, which is particularly intense between 1996 and 2000. The more recent years (2002 and 2003) reveal, however, an opposite tendency, due to the situation of economic recession that has since then affected the Portuguese economy (e.g., Blanchard, 2006). This evolution is also present when investment in individual assets is considered, with more pronounced increases in investment flows occurring in the machinery and equipment category.

Along with changes in conceptual terms, INE also changed the classification scheme of economic activities, using *NCN 86* (*Nomenclatura das Contas Nacionais 1986*) between 1977 and 1995, and *NCN 95* (*Nomenclatura das Contas Nacionais 1995*) in the subsequent period. In order to harmonise both classifications and obtain an integrated investment series for the different branches of the economy, we used INE's table of correspondences between branches under the two categorisations.[26] This procedure was applied to the GFCF sectoral series obtained by applying backwards the growth rates implicit in the 1977-1995 period, allowing us to get consistent investment series for the set of individual branches for the whole period under study.[27]

[26] This table can be found in Annex 2.

[27] Annexes 3 and 4 show the sectoral evolution of the GFCF in nominal and real terms.

5.3. Measurement of the capital input

5.3.1. Level of sectoral breakdown

In general terms, the more detailed the activity breakdown used, the more informative the capital statistics obtained for productivity purposes. The choice of the breakdown activity level is, however, constrained by the sectoral delimitation used in the collection of fixed capital formation.

As indicated earlier, the sectoral classification scheme used by INE changed during the period under study, from 49 up to 59 sectors under the (new) NCN 95 classification scheme. The harmonisation of nominal investment series during the period under study led to the initial consideration of 31 branches. However, it was necessary to take into account additional factors in the definition of the full range of economic branches to be included in the analysis. First of all, and given our purpose of analysing the relationship between structural and technological change, the selection of sectors had to reflect, even if in approximate terms, the technological taxonomies taken into account (see Section 6.2. below). Furthermore, we also had to bear in mind that a very fine breakdown level could be problematic, since transfers of used assets between producers in different types of activities could affect the reliability of the capital estimates (OECD, 2001b). In the end, 26 industries (cf. Table 7) were considered, including activities from agriculture, manufacturing and services.

Table 7: Industries considered in the measurement of capital stock statistics

NACE rev 1 categories	ISIC rev 3 categories	Industries
AA + BB	01-05	Agriculture, hunting, forestry and fishing
CA + CB	10-14	Mining and quarrying
DA	15-16	Manufacture of food products; beverages and tobacco
DB	17-18	Manufacture of textiles and textile products
DC	19	Manufacture of leather and leather products
DD	20	Manufacture of wood and wood products
DE	21-22	Manufacture of pulp, paper and paper products; publishing and printing
DF	23	Manufacture of coke, refined petroleum products and nuclear fuel
DG	24	Manufacture of chemicals, chemical products and man-made fibres
DH	25	Manufacture of rubber and plastic products
DI	26	Manufacture of other non-metallic mineral products
DJ	27-28	Manufacture of basic metals and fabricated metal products
DK	29	Manufacture of machinery and equipment n.e.c.
DL	30-33	Manufacture of electrical and optical equipment
DM	34-35	Manufacture of transport equipment
DN	36-37	Manufacturing n.e.c.
EE	40-41	Electricity, gas and water supply
FF	45	Construction
GG	50-52	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods
HH	55	Hotels and restaurants
II	60-64	Transport, storage and communication
JJ + KK	65-74	Financial intermediation, real estate, renting and business activities
LL	75	Public administration and defence; compulsory social security
MM	80	Education
NN	85	Health and social work
OO+ PP	90-95	Other community, social and personal service activities; Private households with employed persons

5.3.2. Methodology used

In the estimation of capital services we follow the method pioneered by the United States Bureau of Labor Statistics (BLS) and currently also in use by the Australian Bureau of Statistics (ABS). In contrast with the traditional approach, which consists in estimating the gross capital stock using the perpetual inventory method (PIM) and then applying a depreciation function to get net capital stock, this procedure does not require the direct estimation of depreciation. It starts from the estimation of age-efficiency profiles for each type of asset, which are then used to generate age-price profiles for the assets. These are in turn applied in the estimation of the net capital stock from which depreciation is obtained indirectly. The new methodology consists therefore in an integrated approach, in which all capital measures are consistently calculated on the basis of the same set of assumptions. This constitutes an important advantage relative to the traditional application of PIM.[28]

Under this new methodology, the flows of capital services are approximated as a proportion of the stock of capital converted into standard efficiency units. Therefore, an intermediate step towards the estimation of the capital input consists in estimating the capital stock in efficiency units for each type of asset. This is shown in Equation (7):

$$S_t^i = \sum_{\tau=1}^{T^i} \left(\frac{IN_{t-\tau}^i}{q_{t-\tau,0}^i} \right) h_\tau^i F_\tau^i \qquad (7)$$

In this expression, the capital stock of asset *i* at period *t* is represented as the sum of all (nominal) vintage investment in the asset ($IN^i_{t-\tau}$) deflated by the purchase price of new capital goods in year *t* ($q^i_{t-\tau,0}$). This value is corrected for the loss of productive efficiency over time, by considering an age-efficiency function h^i_τ, and also for the probability of retirement of capital goods (F^i_τ).[29] T^i is the maximum service life of the asset in years (t = 1, 2,…, T).

After getting capital stocks converted to standard efficiency units for each type of asset, the next step consists in aggregating the stocks to obtain overall measures of capital services for different types of activities. This is done by considering the user costs of capital as the appropriate weights. User costs are prices for capital services (which represent quantities) and may be seen as reflecting the marginal productivity of the

[28] See OECD (2001b) for a more detailed description of both methods.
[29] F^i_τ gives the cumulative value of the retirement distribution, describing the probability of survival over the capital vintage's life span.

different assets under the usual assumptions regarding competitive markets.[30] More precisely, user costs of capital (μ_{it}) measure the cost of financing the asset, corresponding to the sum of depreciation (d_{it}) and the real cost of financial capital (r_{it}), minus the nominal capital gain (or loss) from holding the asset for each accounting period $(p_{it} - p_{i,t-1})$.[31]

$$\mu_{it} = r_{it} \cdot p_{i,t-1} + d_i \cdot p_{it} - (p_{it} - p_{i,t-1}) \tag{8}$$

This expression is derived from the equilibrium condition according to which an investor is indifferent in relation to two alternatives: earning a nominal rate of return r on a different investment q or buying one unit of capital, collecting a rental p and then selling the depreciated asset $(1-d).p$ in the next period.

After user costs have been derived, the next step is to combine the stocks of each asset type to obtain volume indices of capital services for activity types. This is usually done with recourse to a superlative index number such as the Törnqvist index:[32]

$$\ln\left[K_t / K_{t-1}\right] = \sum_i \bar{v}_i \ln\left[K_{it} / K_{i,t-1}\right] \tag{9}$$

In which $K_{i,t}$ represent the estimates of the productive capital stock for different types of assets and $\bar{v}_i = 0{,}5\left(v_{i,t} + v_{i,t-1}\right)$, where $v_{i,t} = \dfrac{\mu_{i,t} K_{i,t}}{\sum_i \mu_{i,t} K_{i,t}}$.

Once aggregation is made, an estimation of the volume index of capital services for each sector is obtained, which constitutes a measure for the potential flow of productive services of capital assets in that sector. This measure is used to approximate the flow of capital services in the measurement of total factor productivity growth.

[30] By weighting the stocks of different assets by their relative productivity in production, the overall productive stock will then constitute a measure of the potential flow of productive services that all fixed assets can deliver in production.

[31] p_{it} is the market price of a new asset.

[32] The use of this index is based on its approximation to general functional forms of the production function [see in this respect OECD (2001b)].

5.3.3. Assumptions considered in the estimation of capital services

Age-efficiency profile

OECD (2001b) refers to the existence of (at least) five distinct age-efficiency profiles: the ‘one-hoss shay’ pattern, in which the asset keeps its efficiency intact throughout its service life; the geometric and linear patterns, where efficiency declines at a constant rate or by a constant amount each year, respectively; the hyperbolic profile, which assumes that capital services fall by small amounts initially and by larger amounts as the asset ages; and, finally, the two-step age-efficiency profile, which shows a combination over time of efficiency profiles and which is characteristic of assets incorporated into integrated production systems in manufacturing industries.

The most widely used patterns are the geometric and hyperbolic.[33] Despite the greater analytical tractability of the former, the hyperbolic pattern seems to provide a more realistic account of the loss of productive capacity of capital goods as they age. Indeed, in most cases, the loss of the relative efficiency occurs at a relatively low rate in the first years of utilisation, increasing the rate of decline in later stages. This age-efficiency profile was therefore considered in our calculations.[34]

The hyperbolic profile can be calculated by a function in the following form:

$$h_{\tau}^{i} = \left(T^{i} - \tau\right) / \left(T^{i} - \beta\tau\right) \tag{8}$$

In this expression β is the slope-coefficient: the higher its value, the slower the loss of efficiency of the capital asset. In fixing β’s value for each asset, we follow BLS and ABS practices, setting β at 0.5 for machinery and equipment, and 0.75 (a higher value corresponding to a slower rate of efficiency loss) for buildings and structures.[35]

[33] Both the US Bureau of Labor Statistics (BLS) and the Australian Bureau of Statistics (ABS) assume a hyperbolic pattern in their capital services measures. The geometric age-efficiency pattern is employed by Statistics Canada, and by Jorgenson and his collaborators in a vast number of studies (e.g., Jorgenson et al., 1987; Jorgenson, 1989; Jorgenson and Stiroh, 2000).

[34] A similar understanding is provided by Brito (2005), in her study of the application of age-efficiency profiles in the measurements of capital in the Portuguese case.

[35] It is worth mentioning that there is relatively little scientific basis for defining β values. ABS follows BLS practices, which, in turn, sets their values in order to yield age-price profiles similar to the ones implicit in BEA’s (Bureau of Economic Analysis) estimates on wealth.

Service lives of assets

An additional set of assumptions refers to the service lives of the assets, that is, the period in which assets are retained in the capital stock, whether in first or second-hand usage.

A possible source for obtaining service lives relies on the estimates provided by the tax authorities in the definition of legal rates of depreciation. The estimates originating from this source are, however, frequently biased by political agendas, such as the encouragement of investment, which undermines their usage as an accurate measure of the time span of capital assets. Additional sources for obtaining service life estimates can be found in company accounts, statistical surveys and expert advice. However, none of these sources seem to be available in the Portuguese case, at least with the necessary detail and ample coverage that is required in the present work. In these circumstances, we had to rely on an alternative source, namely, service life estimates developed by other countries.[36] In this respect, the OECD manual for the measurement of capital (OECD, 2001b) identifies four countries which present service life estimates that seem to be based on more reliable information than that usually available in other countries. They are the United States, Canada, the Czech Republic and the Netherlands. In the present study, the Dutch classification scheme seemed to be the most appropriate given its similarities with the Portuguese case in terms of both the capital asset categories and the breakdown level of economic activity. It thus comprised the basis for the average service lives considered in our work (see Table 8 below).[37] Estimates of mean service lives from Statistics Netherlands constitute a compilation of 'best source' estimates, obtained by different methods. With respect to manufacturing branches, they are the result of the estimation of a Weibull distribution based on data gathered on discards and capital stock in Dutch manufacturing.[38] The computations derived for the asset category 'Machinery' include, however, installations along with machinery (see Meinen, 1998), which results in very large mean asset lives when compared with estimates from other

[36] We realise that considering service lives from other countries does not capture the specificities of the Portuguese case, jeopardising the accuracy of the estimates obtained. The determination of service lives specific to the Portuguese case would imply, however, an extensive amount of work which would go far beyond the scope of the present investigation. Such an effort can be seen as an important improvement to be carried out in future research.

[37] Annex 5 presents the service lives used by *Statistics Netherlands*.

[38] See, in this respect, Meinen (1998) and Meinen et al. (1999).

countries.[39] Because Portuguese data includes only machinery equipment in the homologous category and does not provide an autonomous calculation of investment in computers, which have a shorter economic life, we replaced the original Dutch information regarding this category for manufacturing branches with the Czech Republic's corresponding figures.[40] We also considered a mean service life of 10 years for the residual category 'Other investment' in manufacturing branches, the same value presented for the other sectors in the Dutch service life estimates, and which is close to the average value set by BLS (7 years). Furthermore, for the industries not explicitly taken into account under the Dutch or Czech classification schemes, we considered the available figures in the closest economic branches.[41]

[39] See, for example, the estimates presented by the US, Canada and the Czech Republic included in the OECD (2001b), and the estimates used by ABS, available on line at http://abs.gov.au/AUSSTATS.
[40] Annex 6 presents the service lives used by the Czech Republic in the estimation of capital statistics.
[41] For example, we assumed the mean asset lives of the rubber and plastics industry to be similar to the ones regarding the chemicals industry.

Table 8: Service lives of assets considered in the measurement of capital stock statistics

Industries	Buildings	Transport Equipment	Machinery and Equipment	Other Investment
Agriculture, forestry and fishing	45	12	15	10
Mining and quarrying	40	10	20	12
Food, beverages and tobacco	43	10	16	10
Textiles and clothing	47	10	18	10
Leather and footwear	47	10	18	10
Wood and wood products	55	10	18	10
Pulp, paper and paper products, printing and publishing	55	10	18	10
Coke, refined petroleum products and nuclear fuel	46	10	18	10
Chemicals and chemical products	39	10	18	10
Rubber and plastics	39	10	18	10
Non-metallic mineral products	47	10	18	10
Basic metals and fabricated metal products	47	10	18	10
Machinery and equipment n.e.c	47	10	18	10
Electrical and optical equipment.	47	10	18	10
Transport equipment	47	10	18	10
Manufacture n.e.c.	47	10	18	10
Electricity, gas and water supply	47	10	18	10
Construction	47	10	20	10
Wholesale and retail trade	60	8	15	10
Hotel and restaurant services	60	8	15	10
Transport, storage and communication	60	25	15	10
Financial intermediation, real estate, renting and business activities	60	8	15	10
Public administration and defence; compulsory social security	60	8	15	10
Education	60	8	15	10
Health and social work	60	8	15	10
Other community, social and personal services	60	8	15	10

Retirement function

Other assumptions relate to the distribution of retirements around the average service life. Most studies consider bell-shaped retirement patterns, although other profiles are also available (e.g., simultaneous exit, linear and delayed linear patterns).[42] The greater adherence to reality of the bell-shaped profile, which assumes a gradual increase of retirements in the early years until a peak is reached around the average service life, followed by a gradual slowdown in subsequent years, seems to explain the preference.

[42] See OECD (2001b) for details on these profiles.

Several mathematical functions can be used to provide such a bell-shaped pattern (e.g., gamma, quadratic, Weibull, Winfrey and lognormal functions). The present study follows the method outlined by Shreyer (2003), assuming a normal distribution with a standard deviation of 25 percent of the average service life, and truncating the distribution at an assumed maximum service life of 1.5 times the average service life.

Benchmark capital stocks

The use of PIM in the estimation of capital stocks requires additionally an initial benchmark estimate of the capital stock. In this case, because investment series start in 1977 and we consider 26 sectors with four different types of capital assets, 104 initial estimates are required for the beginning of 1977.

The estimation of an initial benchmark capital stock can be obtained directly, using information provided by sources such as population censuses, fire insurance records, company accounts and administrative property records. However, reliable information of this type is very hard to find (particularly for the Portuguese case), and therefore most studies (e.g., Osada, 1994; Timmer, 1999; Kamps, 2006) rely on indirect shortcut methods for this purpose. The use of these methods may naturally introduce some bias in the estimation, but the importance of the errors tends to diminish over time as the initial capital stock wears out.

Timmer (1999), for example, employs a method similar to Osada (1994), estimating the average of incremental capital-value added ratios for the three years subsequent to the beginning of the investments series (1975), allowing for a one-year lag average. The estimated value is then applied to gross value added in 1975 in order to get a benchmark capital stock for that year. Jacob *et al.* (1997), in their turn, construct estimated stock series for the several sectors under study, based on the assumption that capital stock was zero thirty years before the beginning of the investment series (1970) and that gross investment grew linearly from that date to its observed level in 1970. A similar procedure is used by Kamps (2006) and Pina and St. Aubyn (2005). In both cases, an artificial investment series starting a hundred years before the beginning of the investment series is computed, assuming an initial value of capital stock at zero and a constant rate of investment increase until the beginning of the period considered is reached.

In the present study we follow these latter examples, constructing artificial investment series starting in 1877 by assuming a 4% real annual growth from that year to the values observed in 1977. The choice of the 4% rate, similarly to Kamps (2006) and Pina and St. Aubyn (2005), is justified on the grounds that it is a reasonable order of magnitude for a long-term macroeconomic series.

Setting the initial values of capital stocks at zero, and considering the previously indicated assumptions regarding efficiency decay, the shape of the survival function and asset lives, we obtained the initial capital stock estimates presented in Table 9.[43] Despite being based on relatively *ad-hoc* assumptions, we believe that this procedure does not imply a considerable impact on the dynamics of the resulting capital stock series, providing reliable estimates of the capital input.[44]

[43] In 7 of the 104 cases, all regarding the residual category 'Other Investment', we assume an initial capital stock of zero, since the 1977 GFCF value is negative.

[44] Kamps (2006) develops a sensitivity analysis, showing that the assumption regarding the initial capital stock does not influence significantly the dynamics of the resulting capital stock series. Furthermore, its importance diminishes over time as the initial capital stock wears out, and we have considered a considerably distant starting year in the estimation of artificial GFCF time series.

Table 9: Initial capital stocks (10^6 euros; constant 1977 prices)

Industries	Buildings		Transport Equipment		Machinery and Equipment		Other Investment	
	GFCF 1977	Initial stock	GFCF 1977	Initial stock	GFCF 1977	Initial stock	GFCF 1977	Initial stock
Agriculture, forestry and fishing	4,37	80,76	7,25	53,10	18,99	166,93	0,20	1,27
Mining and quarrying	0,75	13,22	0,55	3,48	0,94	10,16	-0,03	0[1]
Food, beverages and tobacco	5,02	91,13	2,94	18,55	19,34	177,52	0,16	0,99
Textiles and clothing	4,17	78,58	1,00	6,30	19,81	198,27	0,17	1,06
Leather and footwear	0,39	7,29	0,16	1,02	1,56	15,59	0,06	0,39
Wood and wood products	1,03	20,49	1,02	6,45	3,04	30,38	0,00	0
Pulp, paper and paper products, printing and publishing	1,75	34,88	0,58	3,67	14,21	142,22	-0,03	0[1]
Coke, refined petroleum products and nuclear fuel	1,62	30,20	0,01	0,06	32,16	321,91	0,01	0,07
Chemicals and chemical products	8,49	141,45	0,77	4,86	19,90	199,14	-0,22	0[1]
Rubber and plastics	0,67	11,11	0,34	2,13	2,42	24,22	0,01	0,07
Non-metallic mineral products	5,56	104,76	2,66	16,74	11,07	110,75	0,004	0,02
Basic metals and fabricated metal products	6,48	121,99	1,42	8,92	10,10	101,15	0,74	4,65
Machinery and equipment n.e.c	1,61	30,31	0,43	2,73	3,77	37,71	0,10	0,62
Electrical and optical equipment.	0,73	13,82	0,28	1,79	3,56	35,66	0,02	0,15
Transport equipment	4,07	76,53	0,63	3,96	2,19	21,94	0,14	0,88
Manufacture n.e.c.	1,53	28,83	0,77	4,84	4,89	48,93	0,06	0,37
Electricity, gas and water supply	53,55	1008,16	0,25	1,56	5,48	54,8	-0,23	0[1]
Construction	36,30	683,28	9,58	60,34	26,39	284,49	1,63	10,29
Wholesale and retail trade	8,02	164,5	11,53	58,98	31,44	276,35	2,46	15,52
Hotel and restaurant services	1,52	31,17	0,13	0,68	2,66	23,37	-0,04	0[1]
Transport, storage and communication	41,85	858,74	45,33	563,02	24,16	212,40	3,58	22,56
Financial intermediation, real estate, renting and business activities	313,20	6426,54	1,29	6,62	5,01	44,01	39,37	247,99
Public administration and defence; compulsory social security	56,82	1165,88	2,65	13,53	13,66	120,08	-0,73	0[1]
Education	13,29	272,64	0,07	0,34	7,07	62,13	0,05	0,34
Health and social work	5,51	113,12	0,08	0,39	4,47	39,30	-0,05	0[1]
Other community, social and personal services	7,99	163,85	0,32	1,66	1,87	16,43	0,41	2,61

Notes:1) Initial stocks were set at zero because the 1977 GFCF values were negative; 2) Author's computations based on data from INE and Banco de Portugal

5.3.4. Capital services estimates

Having defined the set of assumptions, the calculus of capital services by sector and asset type was performed using the methodology described in Section 5.3.2.. Table 10 provides a summary of the results.[45]

Table 10: Volume growth of capital services by sector and asset type (compound annual percentage changes)

Industries		Machinery	Transport	Construction	Other Investment
AAeBB	1977-1985	9.58	4.73	2.94	16.20
	1986-1994	2.91	-0.51	6.10	13.84
	1995-2003	2.50	0.28	1.73	-8.84
	1995-2000	2.97	0.21	1.72	-7.58
	2001-2003	1.56	0.40	1.76	-11.30
CAeCB	1977-1985	15.82	8.86	5.58	-25.12
	1986-1994	5.58	3.36	3.96	-40.98
	1995-2003	12.36	2.52	3.34	1.28
	1995-2000	14.32	3.70	3.83	5.71
	2001-2003	8.54	0.21	2.37	-7.03
DA	1977-1985	8.68	8.56	5.70	17.96
	1986-1994	6.03	2.44	5.49	29.34
	1995-2003	2.65	10.25	4.44	0.95
	1995-2000	2.55	11.50	4.58	0.29
	2001-2003	2.83	7.80	4.15	2.28
DB	1977-1985	9.81	10.77	7.75	16.35
	1986-1994	5.17	6.11	3.91	21.47
	1995-2003	0.44	3.97	3.09	-4.02
	1995-2000	1.70	5.62	3.61	-3.70
	2001-2003	-2.03	0.74	2.07	-4.66
DC	1977-1985	29.41	15.86	7.31	3.15
	1986-1994	7.71	4.36	7.43	32.69
	1995-2003	0.58	1.34	4.20	-15.62
	1995-2000	2.24	2.73	5.51	-12.38
	2001-2003	-2.65	-1.40	1.62	-21.74
DD	1977-1985	8.16	6.56	7.28	-92.91
	1986-1994	4.55	2.03	3.53	29.77
	1995-2003	4.87	0.18	6.88	-10.70
	1995-2000	5.18	1.51	6.72	-9.84
	2001-2003	4.25	-2.42	7.21	-12.40
DE	1977-1985	12.14	13.38	9.83	-40.31
	1986-1994	5.75	3.92	5.73	45.62
	1995-2003	0.47	11.32	5.61	8.76
	1995-2000	1.83	9.99	5.20	4.29
	2001-2003	-2.19	14.03	6.44	18.26
DF	1977-1985	2.49	25.63	0.83	-44.61
	1986-1994	0.21	-1.10	2.05	-3.23

[45] By their very nature, capital service flows are presented as rates of change or indices, and not as levels of stocks as is the case for measures of net and gross stocks. At the level of individual assets, the rate of change of capital services is equal to the evolution of the productive stock.

	1995-2003	0.73	6.44	11.14	0.19
	1995-2000	-0.15	-179.,15	10.70	-1.59
	2001-2003	2.50	-292.49	12.02	3.86
DG	1977-1985	7.67	11.63	6.25	-19.02
	1986-1994	-0.94	0.80	0.68	30.69
	1995-2003	3.39	9.61	2.54	-1.10
	1995-2000	2.58	13.55	2.88	-0.72
	2001-2003	5.03	2.15	1.86	-1.85
DH	1977-1985	11.39	9.84	7.23	2.16
	1986-1994	3.20	-0.36	3.72	58.61
	1995-2003	10.16	12.40	9.55	-2.86
	1995-2000	11.63	12.45	8.84	-4.15
	2001-2003	7.27	12.29	11.00	-0.24
DI	1977-1985	9.02	7.17	4.80	73.49
	1986-1994	2.77	0.26	3.14	27.03
	1995-2003	3.98	3.68	3.46	-16.60
	1995-2000	5.28	5.52	3.75	-14.67
	2001-2003	1.42	0.08	2.88	-20.35
DJ	1977-1985	9.00	7.85	3.25	2.28
	1986-1994	3.27	-1.02	2.27	16.30
	1995-2003	2.48	2.86	2.25	-6.99
	1995-2000	2.35	5.39	2.17	-5.83
	2001-2003	2.73	-2.03	2.40	-9.27
DK	1977-1985	10.47	10.56	5.79	6.56
	1986-1994	3.73	0.21	2.71	26.52
	1995-2003	7.37	6.56	4.99	-11.42
	1995-2000	8.80	9.60	4.93	-9.67
	2001-2003	4.57	0.74	5.12	-14.81
DL	1977-1985	13.86	7.47	9.85	-3.30
	1986-1994	3.69	7.21	5.20	-54.53
	1995-2003	12.44	9.63	9.57	-6.24
	1995-2000	12.97	11.08	9.62	-5.19
	2001-2003	11.37	6.79	9.49	-8.29
DM	1977-1985	18.99	13.47	675	0.35
	1986-1994	4.79	-2.54	1.82	23.56
	1995-2003	11.19	13.01	3.74	0.81
	1995-2000	12.50	16.64	4.30	1.06
	2001-2003	8.61	6.09	2.64	0.33
DN	1977-1985	7.71	7.84	6.30	9.71
	1986-1994	2.64	1.81	2.75	26.08
	1995-2003	-0.08	-1.28	3.27	-11.82
	1995-2000	0.59	-1.41	3.50	-7.66
	2001-2003	-1.40	-1.02	2.82	-19.58
EE	1977-1985	5.55	15.99	6.60	34.23
	1986-1994	7.95	0.55	0.40	-11.89
	1995-2003	12.17	8.36	1.84	-8.22
	1995-2000	10.42	15.56	1.38	-11.21
	2001-2003	15.75	-4.72	2.77	-1.93
FF	1977-1985	6.14	6.48	2.21	7.20
	1986-1994	6.44	3.32	0.76	7.24
	1995-2003	4.27	3.28	0.90	-6.04
	1995-2000	5.43	3.00	0.84	-5.17
	2001-2003	1.98	3.85	1.02	-7.76
GG	1977-1985	7.61	9.58	7.31	8.29

	1986-1994	2.72	4.49	5.34	23.92
	1995-2003	3.60	6.05	6.34	-1.88
	1995-2000	3.73	8.03	7.07	-1.80
	2001-2003	3.35	2.19	4.89	-2.03
HH	1977-1985	10.76	21.34	9.45	-49.03
	1986-1994	10.16	2.41	5.96	35.60
	1995-2003	11.57	18.71	6.88	12.86
	1995-2000	12.21	27.10	7.92	13.67
	2001-2003	10.32	3.56	4.82	11.26
II	1977-1985	7.17	4.89	3.70	-6.50
	1986-1994	8.66	2.55	2.15	20.19
	1995-2003	2.96	5.23	4.81	4.56
	1995-2000	2.71	5.94	4.56	6.47
	2001-2003	3.47	3.84	5.30	0.85
JJeKK	1977-1985	15.33	10.38	3.80	12.42
	1986-1994	20.67	32.47	3.88	2.45
	1995-2003	2.17	8.09	2.87	4.90
	1995-2000	3.65	12.50	3.00	5.83
	2001-2003	-0.73	-0.23	2.61	3.06
LL	1977-1985	9.05	10.74	5.63	-20.81
	1986-1994	7.48	1.18	5.15	104.13
	1995-2003	5.82	14.94	5.23	-164.9
	1995-2000	6.91	21.89	5.58	-13.35
	2001-2003	3.68	2.22	4.52	-136.37
MM	1977-1985	14.67	18.46	5.43	8.81
	1986-1994	13.56	14.36	3.66	47.13
	1995-2003	16.44	23.97	4.15	11.95
	1995-2000	15.20	31.48	4.38	13.87
	2001-2003	18.96	10.21	3.71	8.22
NN	1977-1985	10.71	21.69	5.72	40.46
	1986-1994	8.02	5.66	4.59	-23.06
	1995-2003	12.92	24.05	4.58	14.50
	1995-2000	13.61	33.92	4.37	20.95
	2001-2003	11.54	6.44	4.99	2.63
OO	1977-1985	13.16	15.14	4.82	-8.54
	1986-1994	22.36	36.59	4.80	34.35
	1995-2003	8.89	-11.05	3.89	32.75
	1995-2000	11.48	-9.05	3.55	44.91
	2001-2003	3.89	-14.91	4.58	11.40

Note: Author’s computations based on data from INE and Banco de Portugal

The capital services series by sector and asset type show an increasing trend over most of the time period under study. The rise in capital services is particularly intense in most of the sectors/assets in the mid-1990s, which reflects the aforementioned acceleration of investment flows in this period. The more recent years (2001-2003), however, are characterised by a decrease in the growth rate of the capital services in a significant part of the sectors/assets considered, which is related with the overall decline of the macroeconomic environment during this period. The ‘Other Investment’ capital services series exhibit very volatile growth rates, which are explained by the residual nature of this category.

After getting capital stocks converted to standard efficiency units for each type of asset, the next step consists in aggregating the stocks to obtain overall measures of capital services for different types of activities. This is done by considering the user costs of capital as the appropriate weights (cf. Section 5.3.2.).

As indicated earlier, the determination of user costs of capital requires information on depreciation rates, on the net return of capital, and on the nominal capital gain (or loss) from holding the asset for each accounting period (see Equation (8)). Following the literature (e.g., OECD, 2001b; Schreyer *et al.*, 2003; Oulton and Srinivasan, 2003), we assume that the rate of return of capital is the same in all types of assets, considering implicitly that the firms' behaviour is consistent with profit maximisation. Its value is obtained by considering the gains from capital in total available income as reported in the national accounts provided by INE.[46] The rates of change in the price of asset type *i* are taken from the data used to estimate the capital stocks of individual assets. Finally, and following Schreyer *et al*. (2003), we define the rate of depreciation as the ratio of the purchase price of a one-year old asset over that of a new asset:[47]

$$d_{t,0} = 1 - \frac{q^i_{t,1}}{q^i_{t,0}}$$

With the general expression of the rate of vintage prices being given by:

$$\frac{q^i_{t,s+1}}{q^i_{t,s}} = \frac{\sum_{\tau=0} \frac{h^i_{s+\tau+1}}{\left[(1+r)/(1+\xi^i)\right]^{\tau+1}}}{\sum_{\tau=0} \frac{h^i_{s+\tau}}{\left[(1+r)/(1+\xi^i)\right]^{\tau+1}}}$$

Where the *h* terms represent the hyperbolic age-efficiency profile, *s* is the capital vintage, and $(1+r)/(1+\xi^i)$ is a real interest rate, where ξ^i is an asset-specific price index.[48] OECD (2001b) sets this interest rate at 4%, considering it to be a reasonable value for a long-term real interest rate. We follow the OECD standard procedure setting $(1+r)/(1+\xi^i)$ at 1.04.

[46] The graphic representation of these estimates can be found in Annex 7.
[47] Differences in tax treatment between asset types have not been considered due to lack of data.
[48] ξ^i is the expected rate of change of nominal user costs.

The estimates of the annual deterioration rates by sector and asset type are presented in Table 11.

Table 11: Estimates of annual deterioration rates (%)

Industries	Buildings	Transport Equipment	Machinery and Equipment	Other Investment
Agriculture, forestry and fishing	0.95	7.39	5.58	9.03
Mining and quarrying	1.16	9.03	4.06	7.39
Food, beverages and tobacco	1.02	9.03	5.31	9.03
Textiles and clothing	0.88	9.03	4.62	9.03
Leather and footwear	0.88	9.03	4.62	9.03
Wood and wood products	0.68	9.03	4.62	9.03
Pulp, paper and paper products, printing and publishing	0.68	9.03	4.62	9.03
Coke, refined petroleum products and nuclear fuel	0.92	9.03	4.62	9.03
Chemicals and chemical products	1.19	9.03	4.62	9.03
Rubber and plastics	1.19	9.03	4.62	9.03
Non-metallic mineral products	0.88	9.03	4.62	9.03
Basic metals and fabricated metal products	0.88	9.03	4.62	9.03
Machinery and equipment n.e.c	0.88	9.03	4.62	9.03
Electrical and optical equipment.	0.88	9.03	4.62	9.03
Transport equipment	0.88	9.03	4.62	9.03
Manufacture n.e.c.	0.88	9.03	4.62	9.03
Electricity, gas and water supply	0.88	9.03	4.62	9.03
Construction	0.88	9.03	4.06	9.03
Wholesale and retail trade	0.59	11.46	5.58	9.03
Hotel and restaurant services	0.59	11.46	5.58	9.03
Transport, storage and communication	0.59	3.02	5.58	9.03
Financial intermediation, real estate, renting and business activities	0.59	11.46	5.58	9.03
Public administration and defence; compulsory social security	0.59	11.46	5.58	9.03
Education	0.59	11.46	5.58	9.03
Health and social work	0.59	11.46	5.58	9.03
Other community, social and personal services	0.59	11.46	5.58	9.03

Note: Author's computations.

As would be expected, deterioration rates are higher in the case of transport equipment, and lower in the longest-lived assets (buildings). A similar pattern is found in the studies by Jorgenson and Stiroh (2000) and Oulton and Srinivasan (2003), although the transport equipment deterioration rate assumes relatively higher values. It is important to recall, however, that the rates used in these latter works are obtained by considering a geometric decay efficiency profile and generally lower asset lives.

The results of the estimation of aggregate indices of capital services are presented in Figures 3 to 7.[49]

Taking the economy as a whole, our findings suggest the existence of five distinct phases during the period under study, which follow very closely the observed fluctuations of Portuguese macroeconomic growth.[50] Between 1977 and 1984, most industries show a considerable decline in the rate of capital accumulation, which is followed by a phase of recovery during 1986-1990. Subsequently, there is a new period of decay which lasts up to 1994. The second half of the 1990s is characterised by an increase in the rate of (productive) capital accumulation and capital services, but the more recent years reveal a consistent pattern of decline in the large majority of the industries considered, and at the overall economic level.

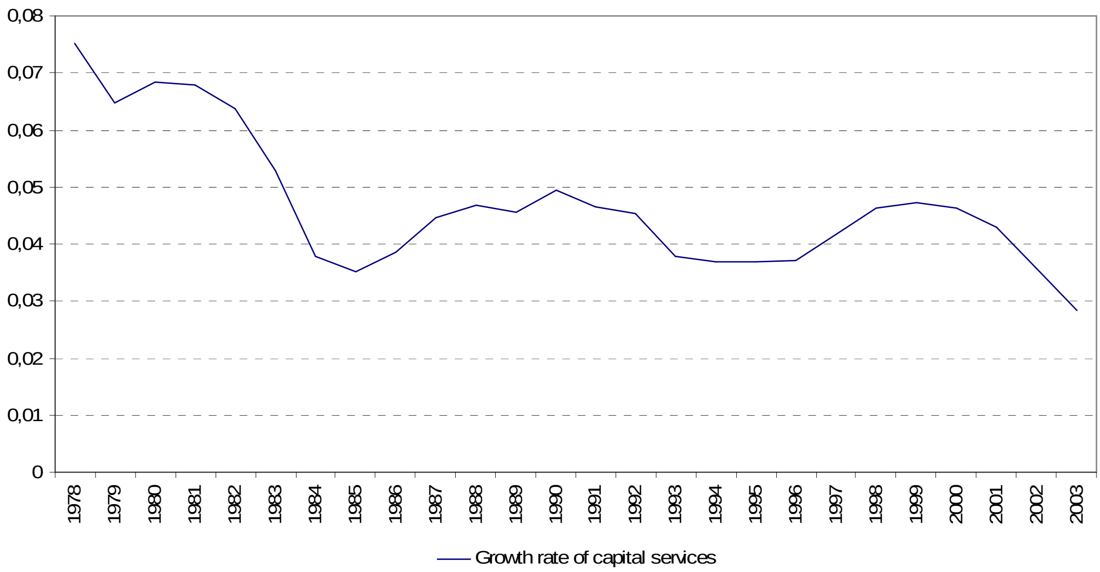


Figure 3: Growth of capital services, total economy (1977-2003).

Note: Author’s computations based on data from INE and Banco de Portugal

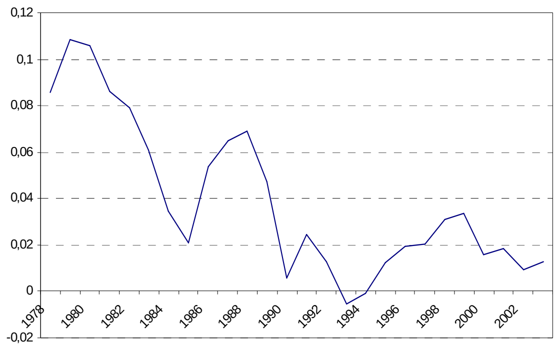
The observed chronological regularities are, however, accompanied by considerable differences across industries. Some industries, included in what we label Group 1, show a general tendency of decline in capital accumulation rates over the whole period analysed. This group is significantly represented by the so-called ‘traditional’ industries,

[49] The full list of results, with the estimates of the volume index of capital services by sectors can be found in Annex 8.
[50] See Lopes (1996), and more recently Lains (2003).

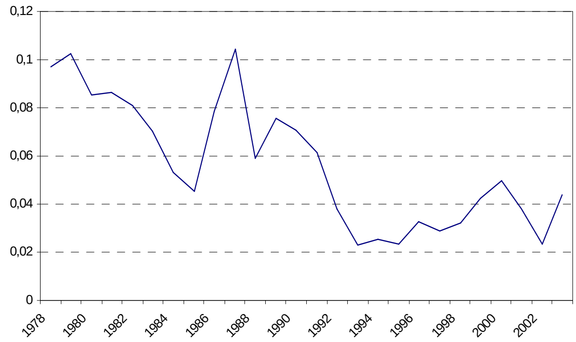
such as textiles and clothing, leather and footwear, pulp, paper and paper products, and non-metallic mineral products.

Group I:

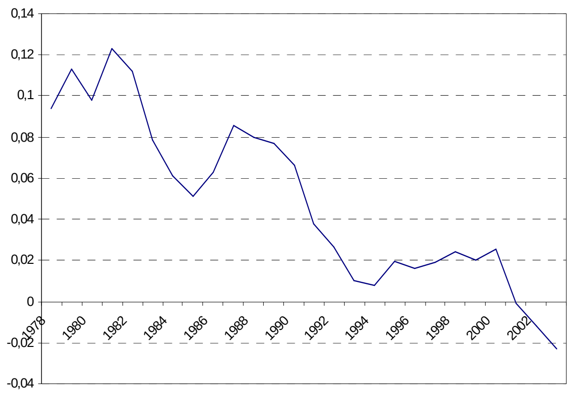
Agriculture, forestry and fishing



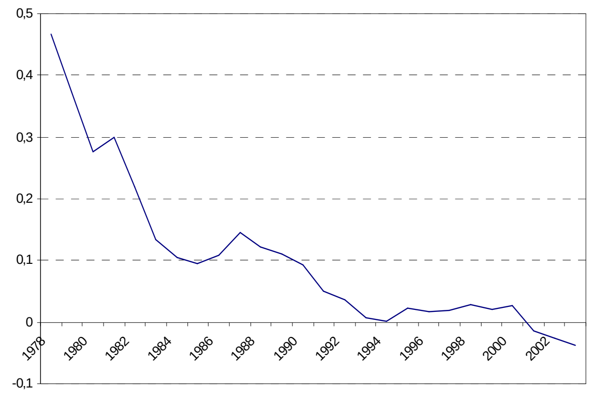
Food, beverages and tobacco



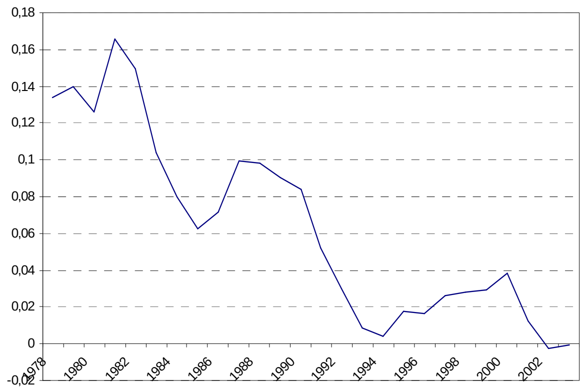
Textiles and clothing



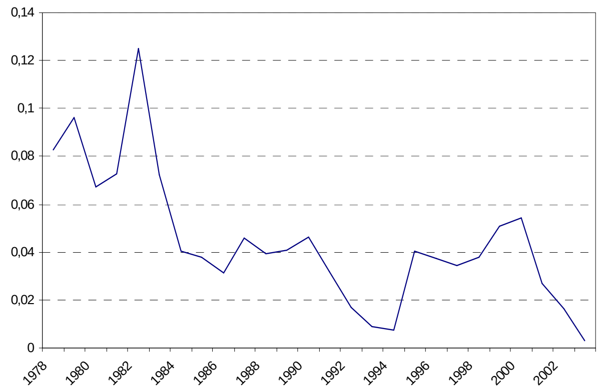
Leather and footwear



Pulp, paper and paper products, printing and publishing



Non-metallic mineral productsl



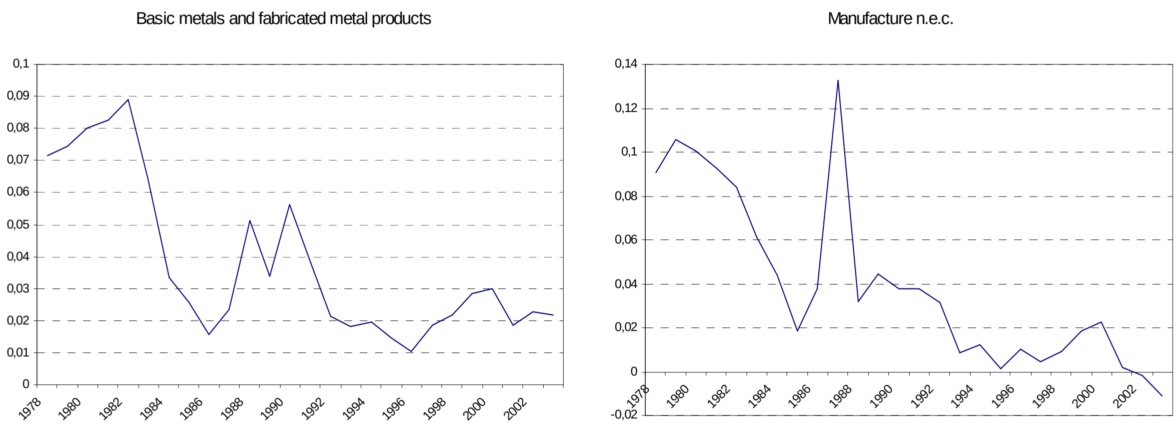
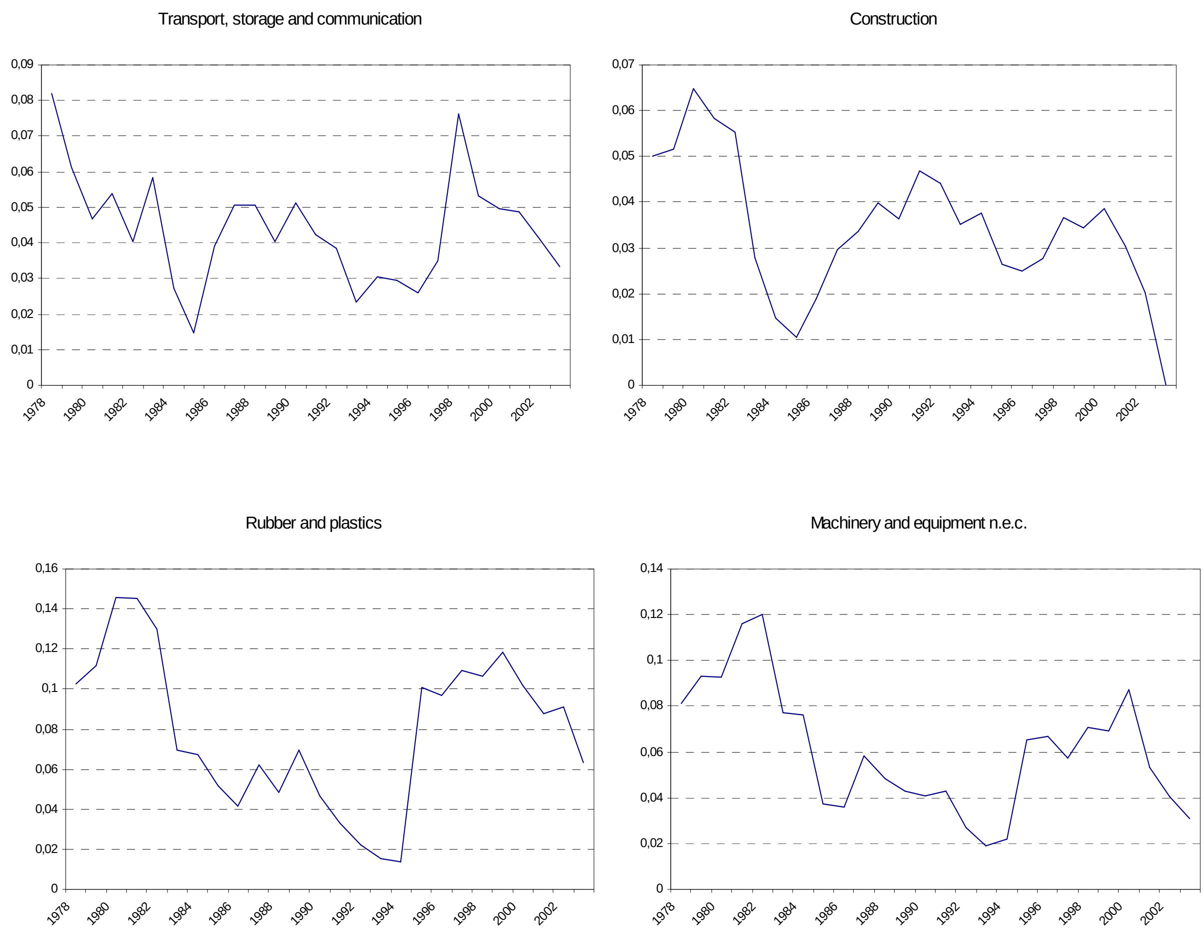


Figure 4: Growth of capital services in Group I of industries (1977-2003).

Note: Author's computations based on data from INE and Banco de Portugal

Other industries, such as construction, transport, storage and communication, and rubber and plastics, present considerable signs of recovery during the recent periods of economic expansion (1986-1990 and 1996-2000), experiencing, however, a considerable decline in the rate of growth of capital services between 2001 and 2003.

Group II:



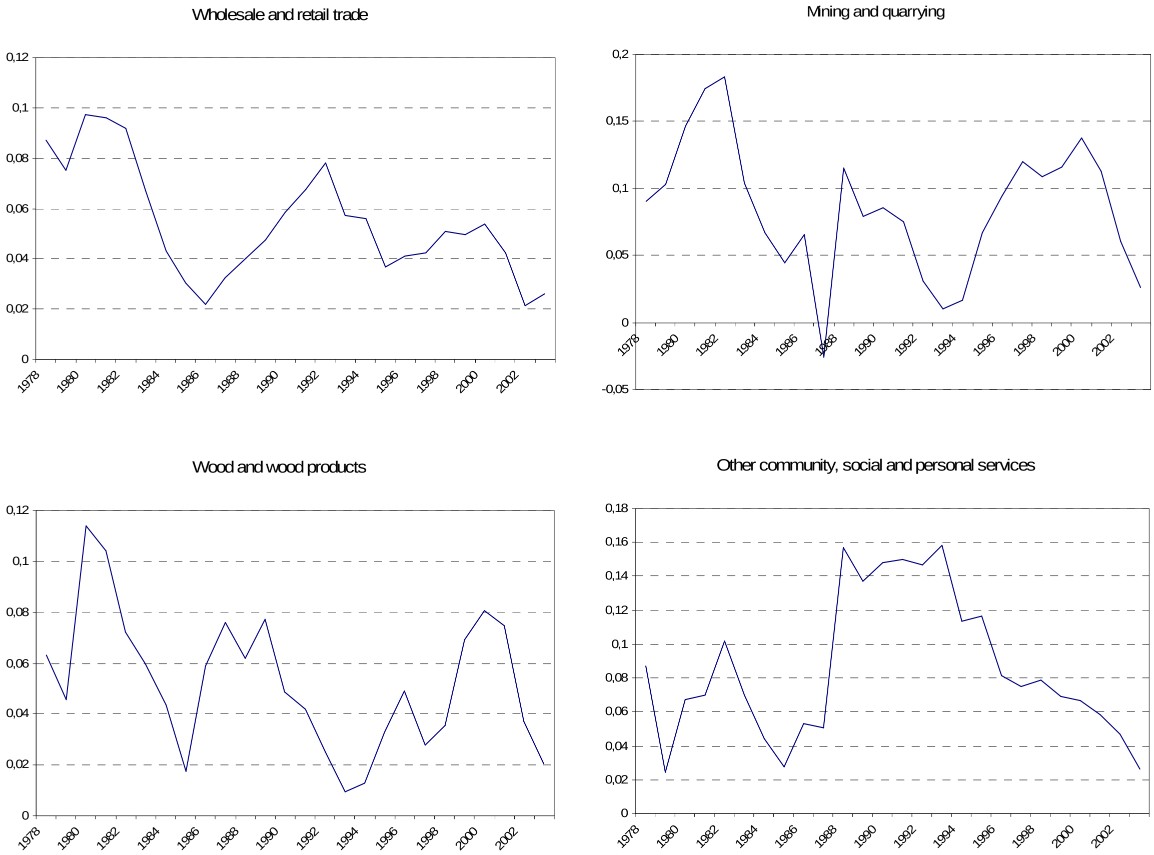
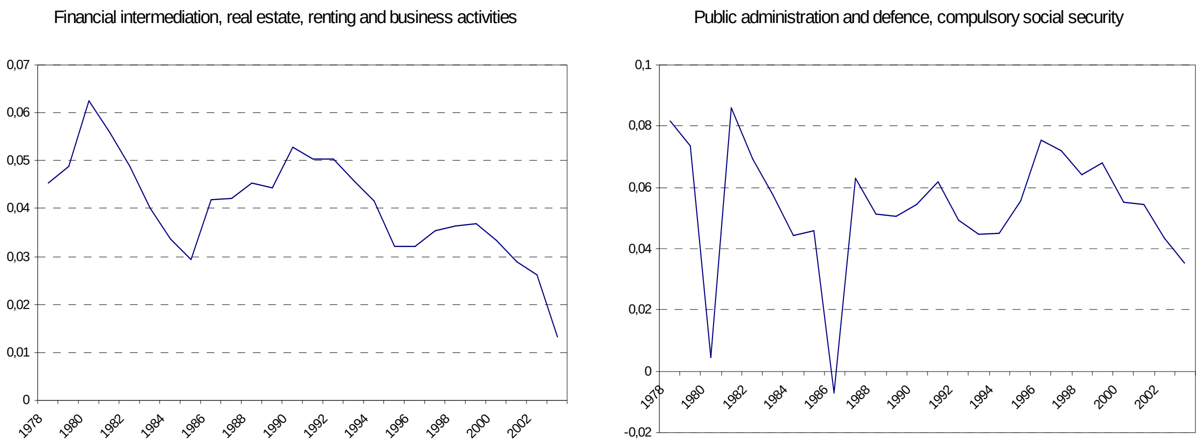


Figure 5: Growth of capital services in Group II of industries (1977-2003).

Note: Author's computations based on data from INE and Banco de Portugal

Another group of industries (financial intermediation, real estate and business activities, public administration and defence, education, health and social work, transport equipment, hotel and restaurant services) shows relative stability of productive capital growth rates during most of the period under study, experiencing a decline in these rates between 2001 and 2003.

Group III:



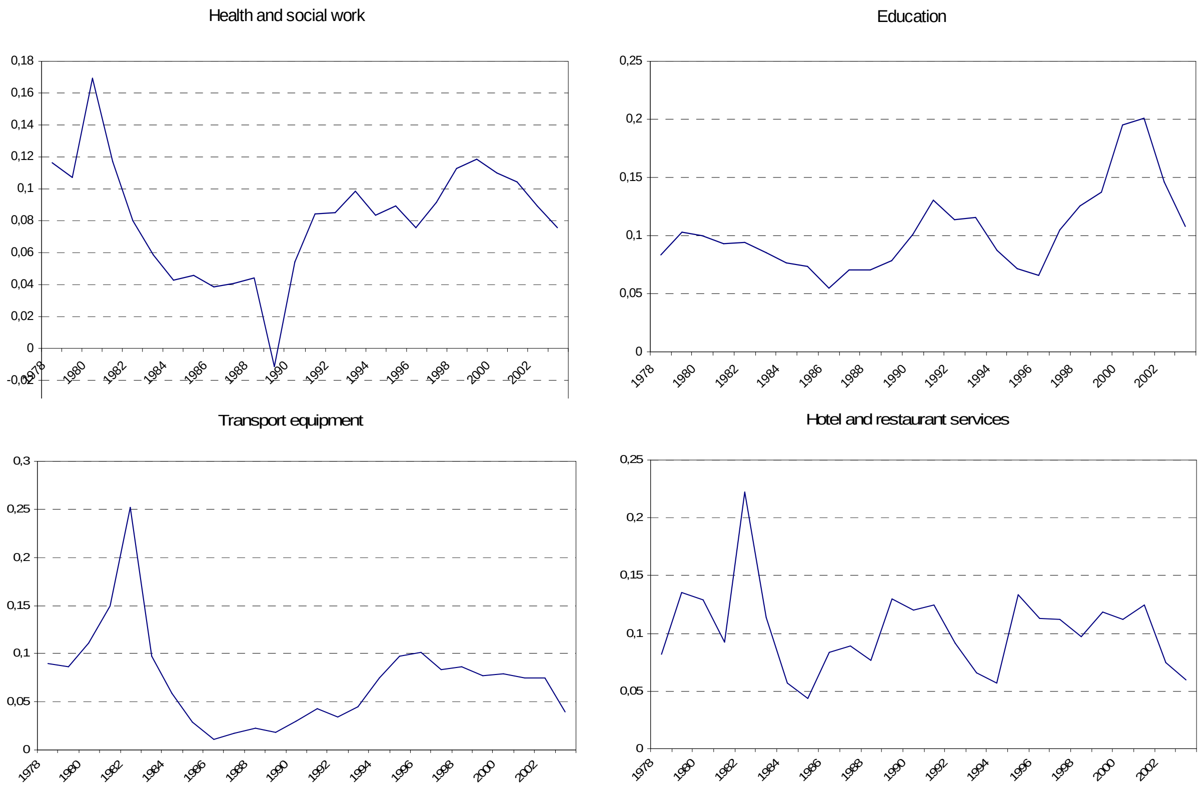
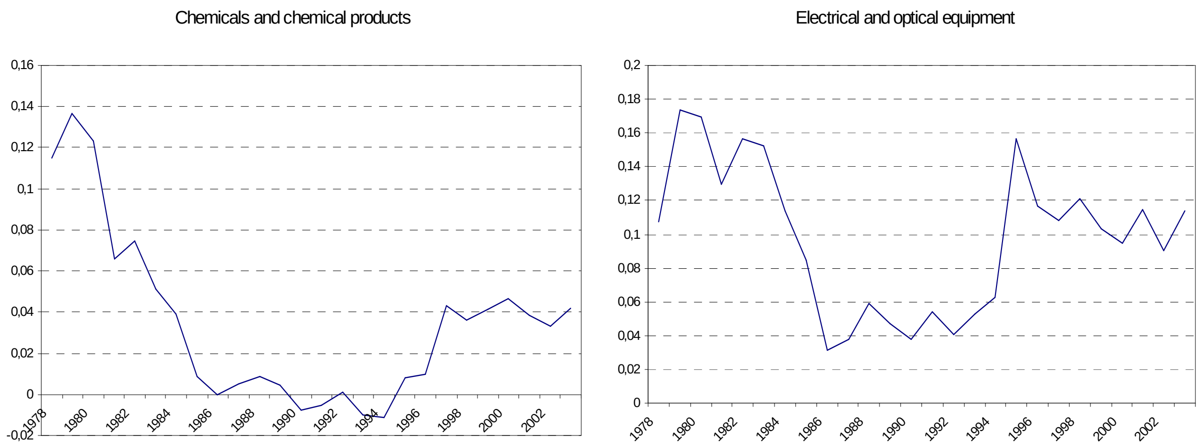


Figure 6: Growth of capital services in Group III of industries (1977-2003).

Note: Author's computations based on data from INE and Banco de Portugal

Finally, and in contrast with the evidence found in the overwhelming majority of industries, a fourth group is characterised by a significant recovery from the mid-1990s onwards, after a period of marked decline, with no signs of deterioration in the more recent years. This is the case of electrical and optical equipment, chemical and chemical products, electricity, gas and water supply, and coke, refined petroleum products and nuclear fuel.

Group IV:



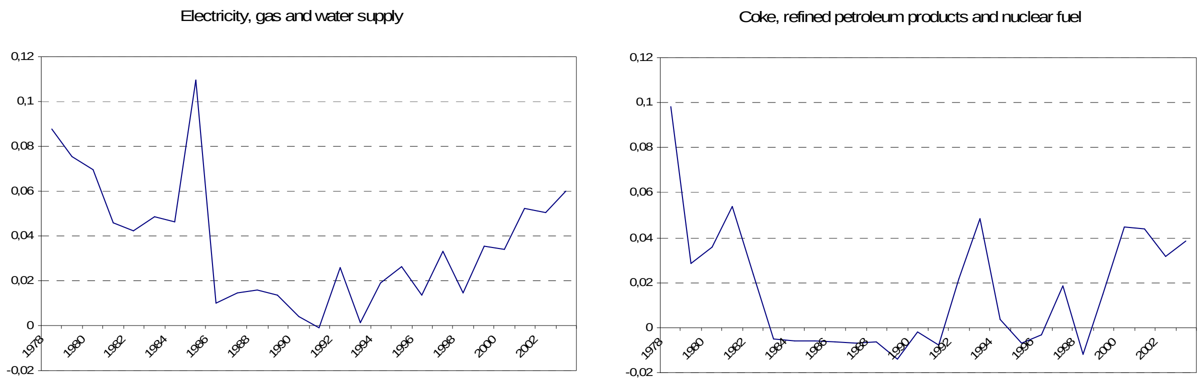


Figure 7: Growth of capital services in Group IV of industries (1977-2003).

Note: Author’s computations based on data from INE and Banco de Portugal

The steady decline in the rate of accumulation of physical capital in the more traditional industries, together with the recent improvement in the corresponding rates associated with more technology-intensive industries suggests that a process of structural change towards the latter industries has been taking place during the last thirty years, expressed at least with respect to the capital factor. The global significance of this process has, however, to be established in conjunction with the labour shifts among sectors, a task that is pursued in the following sections.

5.4. Total factor productivity growth estimates

5.4.1. Methodology

As indicated before, we rely on a growth accounting framework to estimate TFP growth. This approach, originally developed by Tinbergen (1942) and Solow (1957), and later elaborated upon by authors such as Jorgenson and Griliches (e.g., Jorgenson and Griliches, 1967; Griliches, 1990; Jorgenson, 1995), identifies TFP as a 'residual' correspondent to the difference in the growth of output and the contribution of inputs, weighted at their respective factor income shares.[51]

We estimate TFP growth using the Törnqvist TFP indices based on a translog value added production function. TFP growth is given by the following expression: [52]

$$T\hat{F}P_t = \hat{Y}_t - \alpha_t \hat{L}_t - (1-\alpha_t)\hat{K}_t \quad (9)$$

Where L and K are the labour and capital inputs, respectively, $\alpha_t = 1/2(v_t + v_{t-1})$, and v_t is the share of labour in value added.

As is apparent from Equation (9), the growth accounting framework is entirely based on the production function approach, which is firmly grounded on the neo-classical (equilibrium) tradition. As indicated earlier (cf. Part I), it is difficult to reconcile the use of an equilibrium approach with the view according to which the overall transformation processes, and most particularly the processes of technological change, are essentially non-equilibrium conceptions (e.g., Nelson and Winter, 1982; Dosi, 1988). Furthermore, the growth accounting construction is based on a number of simplifying assumptions, such as rational behaviour on the part of the producers, perfect competition and constant returns to scale, which naturally may not match reality. But even with these shortcomings, this technique provides a very useful and simple way to disentangle the growth contributions from labour, capital and technology, allowing for the analysis of past growth trends, and for the anticipation of future growth prospects.[53] Of course,

[51] Under the assumption of constant returns to scale, the factor shares represent the marginal productivities of labour and capital.
[52] This expression is obtained considering the traditional Cobb-Douglas production function differentiated with respect to time.
[53] It is important to bear in mind, however, that along with technological change, the residual is influenced by an array of factors such as changes in market structure, reallocation of resources, pure efficiency changes, scale and cyclical effects, changes in the organisation of production, and measurement errors, which hinders the precise identification of the main causes generating the observed productivity patterns.

accounting is not explaining, and therefore the evidence found has to be read within the specific historical and institutional context in which it arises. Otherwise, it would be impossible to achieve a global understanding of the underlying causes of growth.

5.4.2. TFP growth estimates

Figure 8 presents trends in output per hour worked and per unit of capital services (labour and capital productivity, respectively), capital intensity and TFP growth for the Portuguese economy between 1977 and 2003. The picture does not change much over the whole period under study, which is characterised by a significant mismatch between the rapid increase in the capital input and the (lower) increase in labour input.[54] The strong shift towards more capital-intensive production (by 2003, capital deepening had increased more than three times in relation to the 1977 level), allowed labour productivity to grow at a faster rate than multifactor productivity, which increased at a much more modest rate (about 0.8% a year, whereas labour productivity grew at 2.7%). TFP growth, relatively stable between 1977 and 2003, is punctuated by moments of absolute decline, which coincide with the periods of more severe deterioration in the economic cycle, such as 1984, 1993, and more recently, 2003.

[54] In ideal terms, the measure of labour input should be adjusted for the effects of changing labour composition. Unfortunately, there is no information regarding changes in labour quality for the Portuguese case at the sectoral level for the whole period under study (the only available sources are the General Population Censuses, which are conducted every ten years, and *Quadros de Pessoal*, which have information only from the end of the 1980s onwards). We believe, however, that our estimates would not be significantly affected by the additional consideration of changes in the composition of the labour force. According to the evidence found in studies investigating human capital trends in Portugal in the last few decades, the rate of increase in this factor has been relatively low [see Teixeira and Fortuna (2004) and Teixeira (2006)]. Furthermore, according to the last Population Census, from 2001, the large majority of the Portuguese workforce still has a very low level of schooling, which is apparent from the huge percentage of individuals who do not possess more than six years of formal education (about half of the total labour force), and from the small percentage of those who have a university diploma (only 12%).

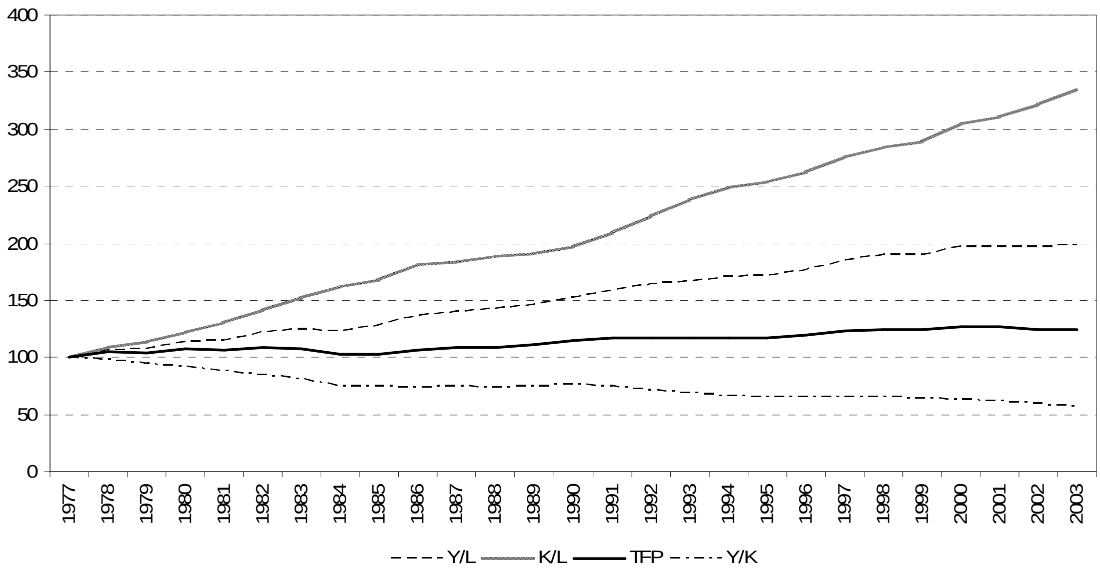


Figure 8: Labour productivity, capital productivity, capital intensity and TFP growth Portuguese Economy: 1977-2003 (1977 = 100).

Note: Author's computations

Our estimates of aggregate TFP growth are not very far from the ones found in previous studies regarding the Portuguese economy (cf. Table 12). The overall TFP growth series shows, furthermore, relatively similar trends to the ones described in Teixeira and Fortuna (2004) over the 1977-2001 period, although presenting globally more pessimistic estimates. Our approach is based, however, on a more refined calculus procedure of the physical capital stock. In particular, indices of net and gross capital stock, used in Teixeira and Fortuna's work, tend to rise at a slower rate than measures of capital services, and therefore they tend to understate the contribution from capital to output growth and to overstate the productivity residual.

Table 12: Summary results of growth accounting for the Portuguese economy in previous studies

		Annual growth rate (%)s					As percentage of output growth			
Author	**Period**	**Labour**	**Capital**	**Human capital**	**TFP**	**Output**	**Labour**	**Capital**	**Human capital**	**TFP**
Lains (2003)	1973-90	0.02	1.74	1.61	0.56	3.93	0.5	44.3	41.0	14.2
Afonso (1999)	1974-85	0.69	1.51	-	0.16	2.36	29.2	64.0	-	6.8
	1986-93	0.17	1.46		1.30	2.93	5.8	49.8	-	44.4
Lopes (1996)	1974-92	1.80		-	0.60	2.40	75.0		-	25.0
Neves (1994)	1974-79	0.94	1.79	-	0.72	3.45	27.2	52.0	-	20.9
	1980-91	0.82	1.51	-	0.12	2.45	33.5	61.6	-	4.9

At the sectoral level (cf. Table 13), there is also a clear prevalence of relatively low TFP growth, although the results show some variation across industries. There are even some cases, such as Chemicals, Machinery and equipment, and Hotel and restaurant services, which show a decline in TFP levels between 1977 and 2003.

TFP growth in services is lower than that for the economy as a whole, similarly to the evidence found for other European countries (e.g., Sakurai *et al.*, 1997; O'Mahony, 1999; van Ark *et al.*, 1999). In agreement with these latter studies we also find the relatively poor performance of financial intermediation activities, which seems to be primarily related with the severe measurement problems affecting the sector.[55]

Table 13: Average annual TFP growth by sector, 1977-2003 (%)

Industries	1977-81	1982-85	1986-90	1991-95	1996-2000	2001-03	1977-2003
Agriculture, forestry and fishing	3.4	4.6	2.0	2.8	1.1	-0.5	**2.3**
Mining and quarrying	3.4	-9.9	5.6	1.0	1.1	8.0	**1.3**
Food, beverages and tobacco	1.2	-4.1	-2.6	-0.5	2.0	-1.3	**-0.8**
Textiles and clothing	2.7	-1.5	-0.6	-0.6	0.6	0.5	**0.1**
Leather and footwear	-0.9	-0.5	-0.5	1.4	0.4	-4.6	**-0.5**
Wood and wood products	-4.1	-4.6	5.0	0.8	2.8	1.4	**0.4**
Pulp, paper and paper products, printing and publishing	-1.9	-3.1	-3.1	3.1	0.7	1.1	**-0.5**
Coke, refined petroleum products and nuclear fuel	18.5	-11.0	10.9	0.2	6.9	-0.6	**4.1**
Chemicals and chemical products	-11.0	1.6	3.0	-0.4	3.1	-4.3	**-1.0**
Rubber and plastics	8.4	-11.9	-4.9	-4.2	0.2	5.8	**-1.8**
Non-metallic mineral products	-7.5	-0.8	2.8	1.9	6.0	-4.1	**0.2**
Basic metals and fabricated metal products	0.4	-7.2	8.0	-1.9	0.8	2.4	**0.5**
Machinery and equipment n.e.c	-13.4	-6.9	-4.5	-1.1	-1.4	4.9	**-4.1**
Electrical and optical equipment.	6.1	-5.0	3.6	2.9	5.0	-2.2	**2.1**
Transport equipment	0.6	-14.2	6.4	1.9	8.1	0.0	**0.8**
Manufacture n.e.c.	-1.0	-3.4	0.1	4.2	3.9	-0.4	**0.8**
Electricity, gas and water supply	-13.8	10.5	1.1	6.3	5.1	0.8	**1.7**
Construction	3.0	-3.4	2.7	1.2	1.0	-4.3	**0.3**
Wholesale and retail trade	-0.5	-3.8	1.2	-0.4	1.3	-1.3	**-0.4**
Hotel and restaurant services	-7.0	-3.9	-1.7	-3.4	-3.3	-4.2	**-3.8**
Transport, storage and communication	3.4	2.9	3.5	4.6	2.8	3.0	**3.4**
Financial intermediation, real estate, renting and business activities	-0.7	-1.6	2.8	-4.3	2.2	-0.4	**-0.3**
Public administration and defence; compulsory social security	0.1	-2.0	-1.0	-1.6	0.0	-1.4	**-1.0**
Education	-1.7	-2.0	-0.6	-2.1	-3.1	-4.3	**-2.2**
Health and social work	-1.5	-0.5	-0.4	-2.5	-2.1	-2.8	**-1.6**
Other community, social and personal services	9.1	-0.1	2.0	-2.5	-0.6	-1.3	**1.0**
Aggregate TFP growth	**1.6**	**-0.8**	**2.2**	**0.4**	**1.7**	**-0.8**	**0.8**

[55] See in this respect, van Ark *et al*. (1999).

The evidence found shows additionally a clear coincidence between phases of economic expansion and periods of higher TFP growth, and vice-versa, which confirms the pro-cyclical character of the TFP series. Indeed, most industries experience an increase in TFP growth rates between 1986-90 and 1986-2000, and a decline in these rates during the 1982-85 and 2001-03 periods.[56]

Analysing the relative importance of the contributions from labour, capital and TFP growth to average annual growth (cf. Figure 9), it can be seen furthermore that over this period the major contributor to growth was capital deepening (about 66%).[57] TFP contributed in about 33%, and labour made an overall insignificant contribution (about 1%).[58]

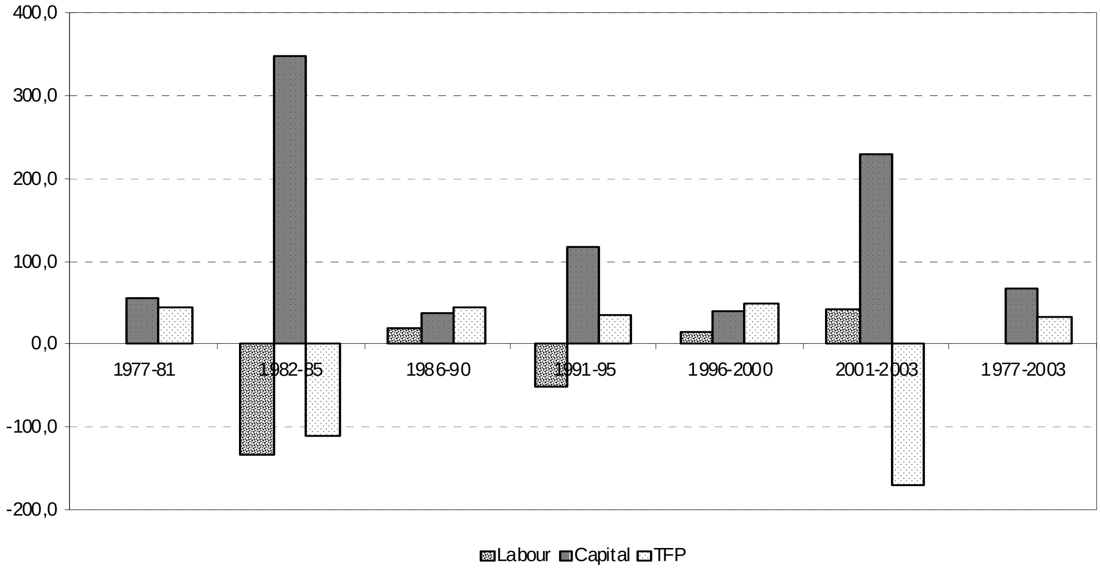


Figure 9: Labour productivity, capital intensity and TFP growth

Portuguese Economy: 1977-2003 (1977 = 100).

Note: Author's computations

56 Several studies report this pro-cyclical feature (e.g., Timmer, 1999; OECD, 2001a), which seems to be partially related with measurement problems. Although statistical data capture output volume changes relatively well, the same does not occur with regard to changes in the rate of utilisation of inputs. As a consequence, output changes tend to be followed by generally more stable input measures, which lead to the observed pro-cyclical nature of productivity growth estimates.

57 The contribution of labour, capital and TFP to average annual aggregate growth by sector can be consulted in Annex 9.

58 It is worth noting, however, that the non-adjustment of labour input to quality changes has probably underestimated the contribution from labour to production.

These results are to a large extent in agreement with previous findings for the Portuguese economy summarised in Table 12. In all the studies, capital deepening is identified as the main source of output growth, although its importance varies over time, and the contribution from labour to output growth is very small. In Afonso (1999), for example, the contribution of the growth of capital stock to output growth is about 64% between 1974 and 1985, and approximately 50% for the 1986-1993 period. Lains (2003), in his turn, finds that capital contributes in about 44% to overall output growth during 1973-1990.

Section 6. Impact of structural change on total factor productivity growth

6.1. Introductory considerations

Having calculated TFP sectoral growth rates in the previous section, we can now investigate whether overall TFP growth has (or not) been significantly influenced by the shift of resources among sectors during the period analysed. As noted in Part I, there are reasons to expect the course of economic development to be accompanied by labour and capital shifts from less productive to more productive branches. We can therefore anticipate aggregate productivity growth to be triggered by such a beneficial transfer of resources, along with any intra-branch productivity gains.

As indicated earlier, we are particularly interested in the relationship between structural change, technology and economic growth. In this context, an important step consists in grouping the selected industrial branches in terms of their technological and innovative potential. In order to do so, the following section presents a critical assessment of the main taxonomical classifications of industries regarding technology and innovation, and from this exercise the sectoral taxonomy that best fits our purposes is identified.

The analysis of the impact of changes in the composition of the economy on overall productivity growth must also take into account the different phases of growth within the time period under scrutiny. In the present study, such a temporal decomposition is based on the results of Bai and Perron's tests of multiple structural change (Bai and Perron, 2003), and on the recent historical record of the Portuguese economy.

After grouping industries according to their technological content, and selecting the temporal sub-periods under comparison, we apply the modified shift-share analysis developed by Timmer and Szirmai (2000). As mentioned previously (Section 4.2.), this methodology allows us to test the relevance of changes in the composition of economic activity, taking explicitly into account productivity gains associated with Verdoorn effects. This in turn provides more accurate results than conventional shift-share analysis. Section 6.4 also provides a broad interpretation of the results taking into consideration the recent history of the Portuguese economy.

6.2. A critical assessment of the main taxonomical classifications

There have been several attempts in the literature to create a classification scheme of industries according to the degree of technological sophistication and innovativeness, to serve as a reliable tool for the analysis and explanation of sectoral differences. The several taxonomies developed, among which we mention only a few, differ on several grounds, such as the main purpose, the chosen unit of analysis, the methodology used, and the degree of inter-relatedness with theory. In this section, we organise the literature in the field, distinguishing in the first place taxonomies based on descriptive procedures (whether or not closely linked with theoretical insights), from the ones relying on previous modelling of innovative behaviour. The former and by far most prolific group is further subdivided, considering independently taxonomies based on factor intensities, and taxonomies based on technological characteristics. In the end, a summary table is presented, in which a comparison of the most relevant aspects of the surveyed classification schemes is carried out, and an identification of the taxonomies that best fit our purposes is undertaken.

6.2.1. Descriptive taxonomies

Taxonomies based on relative factor intensities

A first group of taxonomies is built upon the relative intensity of factor use. Among these taxonomies, the most popular one, mainly because of its inherent simplicity, is the OECD classification. This classification is based on the collection of R&D statistics compiled in the *Frascati Manual*,[59] first published in 1963, and whose latest version (the seventh edition) dates from 2002 (OECD, 2002). The OECD taxonomy separates industries according to their R&D intensity, which is calculated as the ratio of business expenditure on R&D to total production or value added.[60] R&D is seen as comprising both the production of new knowledge and new practical applications of knowledge, stemming from basic and applied research, and from experimental development. The current OECD classification scheme comprises four major categories – low-tech,

[59] This is the most widely-used designation, which derives from the fact that the first edition of the document resulted from an OECD meeting of national experts on R&D held in Frascati, Italy.

[60] Recently, along with the direct calculus of R&D intensity in production (or value added), the OECD also takes into account indirect sources of R&D, considering R&D embodied in capital and intermediate goods used by industries, which is computed using input-output tables. See in this respect Hatzichronoglou (1997).

medium low-tech, medium high-tech and high-tech industries – which correspond to given intervals of R&D intensity (see Table 15).

This categorisation leads generally to the inclusion of industries such as aircraft, pharmaceuticals and computing machinery in the high-tech category, whereas traditional industries such as textiles and food processing lie at the bottom of the classification.[61]

Table 14: OECD taxonomical categories

Categories	R&D intensity
Low-tech industries	0 to 0.9%
Medium low-tech industries	0.9% to 3%
Medium high-tech industries	3% to 5%
High-tech industries	More than 5%

Source: Smith (2005)

The OECD classification has been widely used both in academic and political circles, giving rise to several studies on the impact of R&D on productivity at the country, sector and firm levels. The use of R&D intensity as the main criterion for the classification of industries has the advantages of being available for a long time-period (since the 1950s), and of providing relatively harmonised data for a significant number of countries. However, it also has fundamental weaknesses (see, for example, Kleinknecht *et al.*, 2002; Smith, 2005; Tunzelmann and Acha, 2005). The most common source of criticism concerns the fact that R&D is a source of innovation, not allowing for the measurement of innovation *de per se*. In this respect, Kleinknecht *et al.* (2002) rightly point out that the ways in which R&D expenditures are used can vary greatly in efficiency terms, leading to quite different outcomes in product and/or process innovation. At the same time, R&D is only one of the innovation inputs, and it may be difficult to distinguish what should be included and what should be excluded from its definition (Kleinknecht *et al.*, 2002; Smith, 2005). There are indeed several other sources of innovation which are generally not included in its measurement, such as design activities, learning by doing, education and training of personnel and market research, which are also relevant for the assessment of the industries' technological sophistication and innovativeness. This problem seems to be particularly relevant at the

[61] See Table 15 below. See also in Annex 10 the latest OECD classification of manufacturing industries according to technological intensity, considering the ISIC Rev. 3 breakdown of economic activity.

level of small firms, in which most of innovation expenditure is informal in nature (Kleinknecht *et al.*, 2002; de Jong and Marsili, 2006). Furthermore, it is important to bear in mind that technological performance can vary across firms within the same industry, where firms with high R&D intensities can be included in low R&D intensity sectors, and vice-versa.[62]

Another taxonomy that also relies on factor intensities, but which extends the analysis beyond the consideration of R&D expenditures, has been proposed by Peneder (2002). In this case, the selected variables include relative endowments of capital and labour, and investment in intangible assets comprising advertising and R&D activities. In contrast with the OECD procedure, which exogenously derives the categories by fixing cut-off points, Peneder's taxonomy is endogenously constructed with recourse to cluster analysis. From the use of this technique, the author derives a classification scheme that includes four categories which are differentiated according to the more pronounced reliance on one of the chosen four input dimensions: *technology-driven industries*, *capital-intensive industries*, *marketing-driven industries* and *labour-intensive industries*. Along with these four categories, a residual category is considered for the industries that are not particularly intensive in any of the factor inputs, and which is labelled *mainstream manufacturing*.[63]

In the same work, Peneder proposes a second taxonomy, which takes into account the relevance of human resources. For this purpose he uses occupational data at the 2-digit level of disaggregation (ISIC Rev. 2), which discriminates four broad types of occupations: white-collar high-skill, white-collar low-skill, blue-collar high-skill and blue-collar low-skill. Considering the shares in total employment in each of these categories and applying, as in the first taxonomy, cluster analysis, Peneder (2002) constructs a classification scheme that reflects relative differences in the industries' skill requirements: *high-skilled industries*, *medium-skilled white-collar industries*, *medium-skilled blue-collar industries* and *low-skilled industries*.[64] Peneder finds some complementarity between both taxonomies, with higher shares of high-skilled white-

[62] Additional weaknesses in this classification scheme are related with the aggregation of data in small countries/regions due to the need for secrecy, and to the difficulties arising from the measurement of the effective use of R&D in affiliates of multinational and conglomerate industries (see Kleinknecht *et al.*, 2002: 111-112).

[63] See Table 15 above. See also Peneder (2002) for a more detailed description of the method used in the derivation of the taxonomy.

[64] A list of the NACE 3-digit manufacturing industries classified according to both taxonomies developed by Peneder (2002) can be found in Annex 11.

collar labour being more easily found in technology-driven industries, and higher intangible investments in R&D being more probably related to high-skilled industries or white-collar medium-skilled industries. However, there are also some cases in which high skills are present in other industry types, such as labour-intensive industries (e.g., machine tools, ships and boats) and mainstream manufacturing (e.g., agriculture machinery, weapons and ammunition), which shows the heterogeneity found when attempting to analyse and systematise differences between industries.

A major limitation of Peneder's work is that it covers only manufacturing industries.[65] An extension of this work covering service sectors has, however, been provided by O'Mahony and Vecchi (2002) for both taxonomical classifications. With regard to the first taxonomy, O'Mahony and Vecchi consider 24 additional non-manufacturing sectors, relying on data from the US Bureau of Labor Statistics. The high aggregation of the data does not, however, permit statistical clustering techniques to be performed, which means that the classification of sectors is accomplished by resorting to simple cut-off procedures. In contrast, the second taxonomy (regarding the qualification of the workforce) is derived from the application of the k-means clustering technique to a vast amount of data from the 1998 UK labour survey regarding 139 separate industries. These are divided into three major groups – high-skilled, intermediate-skilled and low-skilled labour –, in a way that is comparable to Peneder's original classification.

Taxonomies based on technological characteristics

Rather than classifying industrial sectors according to factor intensities, some taxonomies arrange them according to technological characteristics. Most of these taxonomies are closely linked with evolutionary strands of economic thought, and in particular with the concept of 'technological regime', originally developed by Nelson and Winter (1977, 1982). This concept provides the basic framework to describe the technological environment of an industrial sector (including its characterisation in terms of the main features of the learning processes, sources of knowledge and nature of knowledge bases), which can ease or hinder the entry of new firms. Generally, two types of technological regimes are distinguished – 'entrepreneurial' vs. 'routinised' regimes – with the former being characterised as facilitating innovative entry, whereas

[65] Another criticism of Peneder's work is related to the consideration of a relatively small number of elements (sectors) when using principal component analysis. This might influence the discriminatory power of the method and, consequently, the robustness of results.

the opposite occurs under routinised regimes (Nelson and Winter, 1982; Winter, 1984). A taxonomy that emerges directly from this characterisation has been developed by Malerba and Orsenigo (1996), who empirically analyse the relevance of the classification of 'Schumpeter Mark I' vs. 'Schumpeter Mark II' industries,[66] associated, respectively, with entrepreneurial and routinised regimes.[67,] Using patent data for 49 sectors in six countries (USA, Japan, Germany, France, United Kingdom and Italy), and applying correlation and principal components analyses, the authors show that the patterns of innovation related to the two Schumpeterian models differ significantly across industries. Furthermore, the categorisation of an industry as Schumpeter Mark I or Schumpeter Mark II is quite similar in all countries under study. Traditional sectors and mechanical technologies are typically found within the Schumpeter Mark I group, whereas chemical and electronic sectors are included in the Schumpeter Mark II classification.[68]

The most representative example of an empirical classification of sectors according to technological trajectories has been, however, provided by Pavitt (1984). Unsatisfied with contemporaneous conceptualisations of technical change, which considered that most technology was publicly available or associated it with capital investment (as in 'vintage' models of technical change), Pavitt attempts to provide both a taxonomy and a *theory* to explain sectoral patterns of technical change. In so doing, he closely follows the arguments developed by the more heterodox perspective of technical change discussed in Part I, related with authors such as Rosenberg, Freeman, Dosi, Nelson and Winter. Like these authors, Pavitt emphasises the cumulative and path-dependent nature of technical change, which relies heavily on the knowledge and the technological paths already pursued by existing firms. He also strongly opposes the idea according to which

[66] The 'Schumpeter Mark I' and 'Schumpeter Mark II' designations were suggested by Nelson and Winter (1982) and Kamien and Schwartz (1982), representing Schumpeter's different views of entrepreneurship during his lifetime, and which are particularly evident in the comparison of his 1934 and 1942 books (*The Theory of Economic Development*, and *Capitalism, Socialism and Democracy*, respectively).

[67] In the first case, innovation is related with the entrepreneurial activity of small and new firms, whereas in 'Schumpeter Mark II' industries, innovation originates in the formal R&D activity of large and established firms.

[68] The Schumpeter Mark I and Mark II distinction has also been applied within the context of industry life cycle models (Utterback and Abernathy, 1975; Klepper, 1992). According to the views expressed in these works, the initial stage of an industry is marked by the existence of several innovator firms, given the low entry barriers and the high uncertainty of the technological paths to be followed. In the stage of industry maturity, however, the technology follows a well-defined trajectory, and economies of scale, learning curves, barriers to entry and financial resources become important in the competitive process. Consequently, in this stage, large firms with monopolistic power come to the forefront of the innovation process.

most of the technology is general purpose and easily diffused, emphasising instead its 'local' character and specific locus of application by firms. At the same time, Pavitt acknowledges the considerable sectoral diversity in innovation patterns, explicitly taking into account differences in terms of the relative importance of product/process innovations, main sources of knowledge inputs, and of the degree of technological diversification across sectors. Nevertheless, he manages to find important regularities which allow him to construct a taxonomical classification that sheds light on the different technological trajectories pursued, taking the *firm* as the basic unit of analysis. According to this exercise, the taxonomical categories represent major 'technological families' to which firms belong, which are determined by the firms' main activities.[69] Firms are thus grouped into four major categories – *supplier-dominated*, *scale-intensive*, *specialised suppliers* and *science-based* – which are determined according to three main criteria: technology sources, nature of the users' requirements, and possibilities of successful appropriation of innovation rents. These categories establish a gradual scale of technological opportunities (identified with the number of significant innovations achieved): they are lowest in supplier-dominated firms, in which most of the technological advances come from suppliers of equipment and other inputs; they are relatively higher in scale-intensive firms, which develop investment and production activities in large-scale production systems and major sources of innovation come from production engineering departments and suppliers of specialised inputs; and finally, they are highest in science-based and in specialised supplier firms, the former being characterised by high levels of in-house R&D and strong links with science, and the latter facing continuous pressures to improve efficiency on the part of their users.[70]

Pavitt's pioneering work, based on the classification of industries according to technology characteristics, rather than product range (such as the OECD taxonomy), provided important policy implications. By demonstrating empirically that firms and sectors differ greatly in terms of innovative activity, Pavitt called into question the use of single-purpose technology policies, usually oriented towards the increase in R&D ratios, showing the relevance of multidimensional innovation policies targeted at the distinct needs of firms and industries. The specific survey method used in this work,

[69] Given the cumulative nature of patterns of innovation, it is assumed that what firms did in the past (their main activities) will determine their technological trajectories.
[70] The nature of technological opportunities and the extent to which they can be successfully exploited also depends on the firms' size. See Pavitt (1984) and Pavitt *et al*. (1989) for a more detailed analysis of this matter and also for a more comprehensive description of the taxonomy.

based on the identification of innovations by sectoral experts,[71] allowed him furthermore to get an assessment of innovations independent of personal judgement, although it might also have probably implied a bias towards more relevant innovations, neglecting the role of minor, incremental-type innovations (Smith, 2005).

Pavitt did not take the proposed taxonomy as definitive, considering that it should be incremented and extended (Pavitt, 1984: 370). Apparently, his advice has been taken very seriously, given the proliferation of refined versions of the original taxonomy that have ever since emerged in the literature (e.g., Pavitt, 1990; Fagerberg *et al.*, 1999; Evangelista, 2000; Marsili, 2001; de Jong and Marsili, 2006; Castellaci, 2008).

Pavitt himself proposed a modified version of his original work (Pavitt *et al.*, 1989; Pavitt, 1990), which took into account the transformations taking place under the new technological revolution, associated with information and communication technologies. This new technological paradigm has had a particularly strong impact on many of the services sectors, given their information-based characteristics (Miles, 1996, 2005; OECD, 1997), sectors which were uniformly included in the supplier-dominated category under Pavitt's original taxonomy.[72] In the revised version, Pavitt adds a new category – information-intensive firms –, which accounts precisely for the firms that benefit most in technological terms from the new technological breakthrough, such as financial and retailing services. However, the inclusion of this additional category is accompanied by the removal of supplier-dominated firms which, according to the authors (Pavitt *et al.*, 1989), would be characterised as non-innovative, unless they manage to adapt so as to become information-intensive or scale-intensive firms. This point is strongly criticised by Archibugi (2001), who highlights the relevance of the relationship with suppliers as a source of innovation, especially in countries whose productive structures rely heavily on 'traditional' industries.[73]

Additionally, and despite considering some diversity in the services sector, the revised version proposed by Pavitt *et al*. (1990) does not seem to provide a totally satisfactory

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[71] The methodology used in the survey consisted in two major steps. First, a number of experts in several sectors were asked to identify significant technical innovations that had been successfully commercialised in the UK since 1945, and to name the firm responsible. Then questionnaires were sent to the innovative firms, who were asked to answer several questions regarding innovation features and procedures.

[72] The uniform treatment paid to the services sector was precisely one of the more severely criticised aspects of Pavitt's original work (see, for example, Archibugi, 2001).

[73] In a later work in co-authorship with Tidd and Bessant (Tidd *et al*., 2001), the supplier-dominated firms category is once again included, along with the other four categories (scale-intensive, science-based, information-intensive and specialised suppliers).

account of this sector. Indeed, its heterogeneity and peculiar features require some adjustments in the definition of the concept and measurement of innovation, which could not be undertaken within the original source of analysis (the SPRU database).[74] Some of these peculiarities have recently been accommodated in the Community Innovation Surveys (CIS), developed under the guidelines of the OECD Oslo manual, whose latest edition dates from 2005 (OECD-EUROSTAT, 2005). Although adopting a unified framework for both manufacturing and service sectors, the Oslo manual considers a very broad concept of innovation activities and of technological product and process innovation, which thus enabling the inclusion of innovation stemming from services sectors, that otherwise would not be taken into account.[75]

A taxonomical exercise relying on data of this nature (more precisely the 1997 CIS Italian innovation survey in services), and which focus exclusively on the services sectors has been developed by Evangelista (2000). The author identifies four major groups of sectors - *technology-users, science and technology-based, interactive and IT-based* and *technical consultancy* – using principal components and cluster analyses. The first technique allows him to reduce the extraordinary amount of information available in the database to a manageable dimension, extracting three major factors of influence. Two of these factors, related with innovation intensity, sources of innovation and the interactive patterns through which firms innovate, are then used to perform cluster analysis at the sectoral level, which lays the foundations for the proposed sectoral taxonomy. Despite focusing exclusively on services firms and being derived from a different methodology, this taxonomy shares a close resemblance with Pavitt's (1984) classification scheme. Indeed, technology-users and science and technology-based trajectories are very similar to the supplier-dominated and the science-based categories identified by Pavitt. In each classification scheme, the two categories lie at the extreme ends in terms of innovativeness intensity, and the identification of the main sources of innovation and of interactive patterns is similar in both situations. At the same time, the interactive and IT-based category shows some resemblance with specialised suppliers, since in both cases the main source of innovation stems from close interaction with

[74] See in this respect Evangelista (2000).
[75] The definition of innovation has been progressively broadened following subsequent revisions of the Oslo Manual. The latest version (OECD-EUROSTAT, 2005), for example, explicitly takes into account organisational innovation and marketing innovation, which were not included in the previous editions. The consideration of these additional sources of innovation is particularly relevant for the measurement of innovation in less R&D-intensive industries, such as services and low-technology manufacturing.

customers. Only the technical consultancy category presents some aspects of novelty, lying somewhere in between the science and technology-based and interactive and IT-based sectors.[76]

Along with the taxonomical exercise, Evangelista compares innovation features in both manufacturing and services sectors using results from the CIS surveys, concluding that despite the peculiarities of the services sector, there are 'more similarities than differences with respect to the basic dimensions of innovation processes' (Evangelista, 2000: 214), at least with respect to the Italian case. This finding, together with the observation that the boundaries between manufacturing and services within organisations have become progressively more difficult to establish (Miles, 1993, 2005), provides some support for the joint development of a taxonomy for manufacturing and services, as suggested by Archibugi (2001).

An additional refinement of Pavitt's (1984) work has been proposed by Marsili (2001), who extends the original taxonomy by taking into account the technological environment, i.e., the underlying 'technological regime', in which firms operate. The consideration of this concept allows Marsili to identify the technological conditions under which an 'entrepreneurial' or 'routinised' pattern of innovation is more likely to emerge, that is, the conditions which create or hinder opportunities for entrepreneurial behaviour under different technological environments. The proposed taxonomy, focusing exclusively on manufacturing industries, distinguishes among five different categories: *science-based*, *fundamental-process*, *complex-system*, *product-engineering* and *continuous-process* regimes. The different regimes are typified according to a variety of criteria: level of technological opportunity (defined in terms of the general level or potential for innovation); level of technological entry barriers; degree of cumulativeness (persistence) of innovation; contribution of external sources of knowledge, and in particular, of academic research; differentiation of the knowledge base; degree of inter-firm diversity in the exploitation of technological opportunities; and the different nature of product and process innovation. Like in Pavitt's (1984) work, this categorisation establishes a gradual scale of technological opportunity, which is lowest in the continuous-process regime and highest in the science-based one. The consideration of additional criteria permits, however, a more detailed technological characterisation of firms (and sectors), with a special focus on technological entry

[76] See Evangelista (2000) for a more detailed description of the proposed taxonomy.

barriers, a concept that is related to the nature of technological knowledge underlying innovative processes. According to this criterion, the top and bottom technological regimes are, once again, and respectively, science-based and continuous-process regimes. [77]

Another version of Pavitt's taxonomy has been proposed by Fagerberg, Guerrieri and Verspagen (1999) to analyse changes in world export shares. Rather than applying the taxonomy at the firm level, the authors consider it at the product level, which is a major transformation of the procedure, although the taxonomical categories remain practically unaltered.[78] This exercise thus removes one of the criticisms of Pavitt's (1984) work, that related to the difficulty of classifying firms which produce multiple products and make use of multiple technologies (Archibugi, 2001).[79].

More recently, de Jong and Marsili (2006) provide a new refinement of Pavitt's (1984) taxonomy, focusing on small-sized firms, which were under-represented in Pavitt's original work.[80] The unit level of analysis is the same as Pavitt's (the firm), but unlike Pavitt, whose empirical validation of the proposed taxonomy relied on industry data, de Jong and Marsili develop the taxonomy directly at the firm level and the industry composition of firms is only seen after the clustering of firms has been made.[81] They also differ from Pavitt in that they develop the taxonomy jointly for the manufacturing and services sectors. At the same time, and because traditional innovation indicators, such as R&D and patents, do not account for the more informal innovative activities typical of small and micro firms, they expand the set of relevant factors considered, including variables related to the firm's strategy – such as managerial attitude towards innovation and the existence of documented innovation plans – in the construction of the classification scheme.

Relying on data collected in a survey of small firms in the Netherlands in 2003, and applying principal component analysis and cluster analysis, the authors obtain a taxonomy similar to Pavitt's original work, despite the differences in the methodologies

[77] Annex 12 presents a list of manufacturing industries classified according to Marsili's (2001) taxonomy.
[78] The only modification consists in splitting up the supplier-dominated classification into the categories 'agricultural products and raw materials' and 'traditional industries' (see Table 15 below).
[79] Archibugi (2001) considers, however, that the interaction between the application of the same taxonomy at the product level and at the firm level deserves further discussion.
[80] Small firms were considered only in two of Pavitt's categories: supplier-dominated and specialised suppliers.
[81] In so doing, de Jong and Marsili remove a major criticism of Pavitt's (1984) work. See Archibugi (2001) for a more comprehensive discussion on the matter.

used. Indeed, with the exception of the 'resource-intensive' category which replaces 'scale-intensive' firms, the other categories maintain the original designations (science-based, specialised suppliers and supplier-dominated) and share their main characteristics. The 'resource-intensive' firm differentiates from the 'scale-intensive' one, because in the de Jong and Marsili category no consideration is made of the firm's size. The application of a broader classification range to small-sized firms shows that Pavitt's original taxonomy probably understated their impact on overall innovation activities. The results reveal furthermore that although there is a clear difference amongst sectors, intra-industry diversity is always present.[82]

Another sectoral taxonomy that builds on Pavitt's original work and which applies to both manufacturing and services has been recently proposed by Castellaci (2008). The author extends Pavitt's classification scheme by combining sectoral features regarding the technological content of industries with the sectors' function in the economic system as providers or users of goods and services. The cross-classification according to the two criteria leads to the conceptual distinction of four groups of industries: advanced knowledge providers, mass production goods, supporting infrastructure services and personal goods and services. These categories do not differ much from Pavitt's original classification: 'advanced knowledge providers' stands for Pavitt's 'specialised suppliers', 'mass production goods' for 'scale-intensive' sectors, and 'personal goods and services' for 'supplier-dominated' sectors. The major differences arise with respect to the consideration of an additional category – supporting infrastructure services –, and with the inclusion of science-based manufacturing within the 'mass production goods' group. This latter feature constitutes indeed the most profound break with Pavitt's original classification and its earlier refinements. Mass-production sectors differ considerably from science-based sectors in terms of technological content and the extent of technological opportunities, but the joint classification of both sectors is explained by Castellaci (2008), on the grounds of their similarity in terms of the functions performed in the economic system. In our perspective, however, the taxonomical distinction of the two groups of branches is not only important, but is also desirable. As we see it, the substantial differences in terms of technological opportunities for the two groups of industries do indeed require a separate classification. Only in this way is it possible to obtain a deeper understanding of how the specialisation pattern fosters the overall

[82] For example, about 8% of the firms in each industry are supplier-dominated.

development of the economy, and of the role that high-opportunity manufacturing and service industries have in the process.

6.2.2. Taxonomies based on the definition of a model of a firm's innovation decisions

A new approach to the development of (innovation) taxonomical classifications has recently been proposed by Raymond *et al*. (2004). The authors determine an industry classification for Dutch manufacturing, by estimating a model of the determinants of innovation, and on the basis of that model, testing for homogeneity across industries. This is done with data from the Community Innovation Surveys (CIS), and production and finance surveys conducted in the Netherlands in the late 1990s.

The basic procedure consists in estimating a two-limit tobit model with a sample selection for each industry considered, which expresses simultaneously the incidence and the magnitude of innovation, using data regarding firms' R&D activities and firm-level specific characteristics (e.g., size, subsidisation, cooperation with other firms). The authors perform likelihood ratio tests to classify industries into separate categories, according to the similitude of the model's parameters.[83]

Based on this procedure, Raymond *et al*. (2004) propose a new industry classification that distinguishes between high-tech (e.g., chemicals, electrical), low-tech (e.g., food, textiles) and wood industries. This classification shows some differences with existing taxonomies, such as the separate consideration of the wood sector, included in the low-tech category under the OECD classification and in the supplier-dominated category in Pavitt's classification. At the same time, this taxonomy provides a relative blend of Pavitt's categories, with the exception of the high-tech category that is similar to the science-based classification. The relatively small number of classification categories may, however, be related with the broad aggregation level of the manufacturing activities considered (only eleven industries).

[83] More precisely, a category of industries is taken as 'homogeneous' if the hypothesis according to which the parameters of the model are the same for all the industries included in that category cannot be rejected.

Table 15: Summary description of the main industrial taxonomies focusing on innovation and technical change

Taxonomies based on relative factor intensities

Author(s)	Main purpose	Data	Unit of analysis	Method	Taxonomical categories	Typical core sectors	Categorisation criteria/ Variables used in the development of the taxonomy
OECD (2002)	Policy analysis	ANBERD and STAN databases	Industry	Definition of critical intervals for chosen indicators by identification of cut-off points	Low-tech industries	• Wood, pulp, paper, paper products, printing and publishing • Food products, beverage and tobacco • Textiles, textile products, leather and footwear	Industrial direct and indirect R&D intensity
					Medium low-tech industries	• Building and repairing of ships • Rubber and plastic products • Coke, refined petroleum products and nuclear fuel	
					Medium high-tech industries	• Electrical and non-electric machinery • Chemicals (exc. Pharmaceuticals) • Transport equipment	
					High-tech industries	• Aircraft and spacecraft • Pharmaceuticals • Office and computing machinery	
Peneder (2002) *Taxonomy I*	Create taxonomies that take into account the role played by intangible factors of production	Data from US manufacturing industries (NACE 3-digits, 1994/1995)	Manufacturing industry	Statistical cluster analysis	• Mainstream manufacturing	• Machinery • Articles of paper • Electronic equipment • Motorcycles	More pronounced reliance on one of the four input dimensions • Labour input • Capital investment • Advertising • R&D
					• Labour-intensive	• Textiles and clothing • Wood processing • Construction material • Metal processing	
					• Capital-intensive	• Pulp and paper • Refined petroleum • Basic chemicals • Iron and steel	
					• Marketing-driven	• Food • Leisure and entertainment industries	
					• Technology-driven	• Chemicals and biotechnology • Information and communication technologies • Vehicles for transport	

Peneder (2002) *Taxonomy II*		Occupational data from OECD (1998) for the 1990-1994 period			• High-skilled industries	• Pharmaceuticals • Aircraft • Non-electrical machinery	Based upon the average shares of occupations, distinguishing between blue- and white-collar and high- and low-skilled labour
					• Medium-skilled white-collar industries	• Electronics • Instruments • Electrical equipment	
					• Medium-skilled blue-collar industries	• Motor vehicles • Wood products	
					• Low-skilled industries	• Food • Textiles	
O'Mahony and Vecchi (2002) (I)	Extend Peneder's (2002) taxonomies in order to analyse the effect of knowledge-based activities on companies' productivity performance	US Bureau of Labour Statistics	Industry (manufacturing and non-manufacturing)	Cut-off procedures	• Mainstream industries	• Construction • Eating and drinking places	*Similar to Peneder's Taxonomy I*
					• Labour-intensive	• Textile • Construction and related machinery	
					• Capital-intensive	• Metal mining • Chemicals and allied products	
					• Marketing-driven	• Printing and publishing • Retail trade • Entertainment	
					• Technology-driven	• Computing Services • Accounting, editing	
O'Mahony and Vecchi (2002) (II)		1998 UK Labour Force Statistics		Statistical cluster analysis	• High-skilled industries	• Communication • Computer and data processing services	Based on the qualifications of the workforce, which were initially divided into higher, higher intermediate, lower intermediate and no-vocational qualifications.
					• Intermediate-skilled industries	• Tobacco manufactures • Auto repair services	
					• Low-skilled industries	• Retail trade • Trucking and warehousing	
Malerba and Orsenigo (1996)	Analyse the empirical relevance of Schumpeter Mark I and Schumpeter Mark II characterisations of technical change	Patent data from the European Patent Office for the period 1978-1991[5]	Technological class[6]	Correlation analysis and principal component analysis	Schumpeter Mark I	• Mechanical technologies • Traditional sectors	• Concentration of innovative activities among firms • Size of innovating firms • Stability in hierarchy of innovators • Relevance of entry of new innovators;
					Schumpeter Mark II	• Chemicals • Electronics	

Taxonomies based on technological characteristics	Pavitt (1984)	Describe and *explain* sectoral patterns of technical change	SPRU Innovation Survey[1]	Innovative firm	Qualitative and quantitative analysis (statistical analysis plus inductive methods of organisation)	Supplier-dominated	• Agriculture • Housing • Private services • Traditional manufacture	
						Scale-intensive	• Basic materials (steel, glass) • Assembly (consumer durables and autos)	
						Specialised suppliers	• Machinery • Instruments	
						Science-based	• Electronics • Chemicals	
	Pavitt (1990)					Scale-intensive	• Basic materials • Durable consumer goods	Relies on technological trajectories of firms, which are determined by sectoral differences in three main characteristics: • Sources of technology • Requirements of users • Capability of appropriating innovation rents
						Specialised suppliers	• Machinery • Instruments • Specialty chemicals • Software	
						Information-intensive	• Financial services • Retailing	
						Science-based	• Electronics • Chemicals	
	Evangelista (2000)	Identify the main patterns of innovation in services	1997 Italian innovation survey (CIS) in services, comprising information for the 1993-1995 period [2]	Service firm	Principal component analysis and cluster analysis	Technology-users	• Waste, land and sea transportation • Security, cleaning and other businesses • Legal services, other financial services • Travel and retail services	• Innovation intensity • Nature of activities carried out • Relevance of different knowledge bases underlying innovation • Different patterns of interaction (user/producer, universities and research institutes…)
						Science and technology-based	• R&D services • Engineering and computing services	
						Interactive and IT-based	• Advertising • Banks and insurance • Hotels • Trade/repair of motor vehicles	
						Technical consultancy	• Technical consultancy	
	Marsili (2001)	Extend Pavitt's (1984) taxonomy taking into account the	Combination of data sources (patents, R&D statistics,	Manufacturing firm	Qualitative and quantitative analysis (statistical	Science-based regimes	• Pharmaceutics • Electrical and electronic industries	• Level of technological opportunities • Level of technological entry barriers

		technological environment in which firms operate	scientific inputs, innovation surveys) compiled at SPRU		analysis plus inductive methods of organisation)	Fundamental-process regimes	• Chemical industry • Petroleum industry	• Cumulativeness of innovation • Inter-firm diversity in the rate and directions of innovation • Diversification of the knowledge base • Relevance of external sources of knowledge (in particular, academic research) • Nature of innovation (product/process)
						Complex-systems regimes	• Aircraft • Motor vehicle industries	
						Product-engineering regimes	• Non-electrical machinery • Instruments	
						Continuous-process regimes	• Textiles • Paper • Food and tobacco • Metals and building materials	
Taxonomies based on technological characteristics	Fagerberg et al. (1999)	Refine Pavitt's (1984) taxonomy in order to analyse changes in the sectoral composition of world trade	UN and OECD data from SIE-World Trade Database covering the 1970-1995 period	Product		Agricultural products and raw materials	• Agricultural and raw material products • Petroleum and refineries • Non-ferrous metal basic industries • Pulp and paper	Nature and sources of technological knowledge, with each type of industry representing a different style of technological learning
						Traditional industries	• Textiles and clothing • Furniture • Leather and shoes • Ceramics	
						Scale-intensive	• Automobiles • Consumer electronics • Consumer durables • Rubber and steel	
						Specialised suppliers	• Mechanical engineering • Instruments	
						Science-based	• Fine chemicals • Electronic components and computers • Telecommunications	
	De Jong and Marsili (2006)	Provide an empirical taxonomy for small-sized firms	EIM Business & Policy Research Survey[3]	Firm	Principal component analysis and cluster analysis	Science-based	• Chemicals[4] • Machinery • Office and electrical equipment • Economic services • Engineering and architectural services	• Innovativeness of the firm (at the input and output levels) • Nature of innovation (product/process) • Sources of innovation (including the relative

						Specialised suppliers	• Wholesale • Computer and related services	importance of suppliers, customers and scientific developments, along with information regarding the innovative strategy of the firm);
						Supplier-dominated	• Metals • Transport • Construction	
						Resource-intensive	• Hotels and restaurants • Personal services	
	Castellaci (2008)	Develop a taxonomy that applies both for manufacturing and services, taking into account, along with technological characteristics, the functions played by industrial branches in the economic system	CIS4 (2002-2004) and STAN database (1970-2003)[7]	Industry	Conceptual analysis	Advance knowledge providers	• Software • R&D • Engineering • Machinery • Instruments	Cross-classification according to the position assumed by the industry in the vertical chain (provider or user of goods and services), and to the technological content of the industry
						Mass production goods	• Electronics • Motor vehicles	
						Supporting infrastructure services	• Telecommunications • Finance • Transport • Wholesale trade	
						Personal goods and services	• Textiles and wearing • Hotels and restaurants	
Taxonomies based on the definition of an innovation model	Raymond et al. (2004)	Provide an empirically-based taxonomy to be used for Dutch innovation policy	Data comprising the 3 waves of the Dutch Innovation Survey (CIS 2, 2.5 and 3), and data from production (PS) and finance (SFO) surveys	Manufacturing firm	Econometric modelling	High-tech	• Chemicals • Electrical • Machinery and equipment • Plastic • Vehicle	**Dependent variables**: incidence and magnitude of innovation **Independent variables**: Size and relative size of firms, relevance of demand pull and technology-push, subsidisation, cooperation between firms, R&D enterprise activities
						Low-tech	• Food • Metals • Non-metallic products • Textiles • Products not elsewhere classified	
						Wood industry	• Wood	

Notes: (1) Pavitt's 1984 work was based on the 1981 version of the database, collected by Townsend *et al.* (1981), which covered the characteristics of about 2000 significant innovations and of innovating firms in Britain from 1945 to 1979. The 1990 work was based on an update of this survey to 1984 (Robson and Townsend, 1984), covering the entire 1945-1984 period. (2) The database consisted of 6005 firms from a universe of 19300 market service companies with more than 20 employees. (3) The survey was implemented in 2003, being directed at managers of small innovative firms (defined as having implemented at least one innovation in the previous 3 years). (4) In de Jong and Marsili's (2006) study, the taxonomy of innovation is developed at the firm level, and the industry composition of clusters it only analysed after the clustering process is made. (5) The patent data include 49 technological classes in 6 countries over the 1978-1991 period. (6) 'Technological classes' were created starting from the various subclasses of the International Patent Classification and grouping them according to specific applications. (7) The taxonomy is developed on pure conceptual terms and only then illustrated by descriptive evidence stemming from these data sources.

After reviewing the characteristics and procedures of the main innovation taxonomies developed in the literature, we are now able to select the industrial classification that is more suited to our research aims.

As indicated earlier, the most popular taxonomy, the one developed by OECD, presents a relatively restricted approach, and although having some advantages, it does not seem appropriate in the context of the present work. Indeed, the reliance on just one innovation input (no matter how important it may be), neglects other facets of the innovation process, which seem to be particularly important in small and micro-sized firms, which represent the majority of the Portuguese entrepreneurial structure. The cut-off procedure used in the derivation of this taxonomy does not seem to provide, furthermore, an analytically satisfactory solution for our purposes.

Other taxonomies, although relying on relatively sophisticated techniques, such as factor analysis, statistical clustering techniques and econometric modelling, also do not seem to provide an adequate response to our needs, given their specific focus on very particular cases, which cannot be generalised to the Portuguese reality (e.g., Raymond *et al*., 2004; de Jong and Marsili, 2006).

From our perspective, Peneder's (2002) taxonomies provide a good working basis, since they combine both technology and product dimensions. As indicated earlier, these taxonomies cover only the manufacturing sector, but an extension to 24 non-manufacturing sectors (including mining and service activities) has been developed by O'Mahony and Vecchi (2002). Ideally we would like to use both taxonomies, but unfortunately the level of aggregation of our data does not permit that Taxonomy I be considered. We therefore apply only Peneder's classification regarding relative differences in the industries' skills requirements (Taxonomy II) to our data. Moreover, because O'Mahony and Vecchi consider a more coarse classification scheme, comprising three categories instead of the original four categories used by Peneder (see Table 15 above), and because of the aggregation level of our data, we distinguish only between low-skill, low/medium-skill, medium-skill and medium/high-skill groups of industries.

Additionally, and because Pavitt-based taxonomies provide a more comprehensive treatment of technology features (which have a strong interconnection with structural change), we also consider a taxonomy of this kind. More precisely, the classification scheme presented in Tidd *et al*. (2001) is taken into account, an option which best fits the sectoral desegregation of our data, and which extends Pavitt's original work (Pavitt, 1984), to cover the impact of the ICT revolution on the technological trajectories of industries. Table 16 shows the application of both taxonomies to our data.

Table 16: Classification of sectors according to the Peneder (2002)/O'Mahony and Vecchi (2002) and Tidd, Bessant and Pavitt (2001) taxonomies

ISIC rev.3	Industries	Peneder (2002)/ O'Mahony and Vecchi (2002)	Tidd, Bessant and Pavitt (2001)
01 to 05	Agriculture, forestry and fishing	Low-skill	Supplier-dominated
10 to 14	Mining and quarrying	Low-skill	Scale-intensive
15-16	Food, beverages and tobacco	Low-skill	Supplier-dominated
17-18	Textiles and clothing	Low-skill	Supplier-dominated
19	Leather and footwear	Low-skill	Supplier-dominated
20	Wood and wood products	Medium-skill	Supplier-dominated
21-22	Pulp, paper and paper products, printing and publishing	Medium-skill	Supplier-dominated
23	Coke, refined petroleum products and nuclear fuel	Medium-skill	Scale-intensive
24	Chemicals and chemical products	Medium-skill/High-skill	Science-based
25	Rubber and plastics	Low-skill	Specialised supplier
26	Non-metallic mineral products	Low-skill	Supplier-dominated
27-28	Basic metals and fabricated metal products	Low-skill/Medium-skill	Specialised supplier
29	Machinery and equipment n.e.c	Medium-skill/High-skill	Specialised supplier
30-33	Electrical and optical equipment.	Medium-skill/High-skill	Science-based
34-35	Transport equipment	Medium-skill/High-skill	Scale-intensive
36-37	Manufacture n.e.c.	Low-skill/Medium-skill	Supplier-dominated
40-41	Electricity, gas and water supply	Medium-skill	Scale-intensive
45	Construction	Low-skill	Supplier-dominated
50-52	Wholesale and retail trade	Low-skill	Information-intensive
55	Hotel and restaurant services	Low-skill	Supplier-dominated
60-64	Transport, storage and communication	Medium-skill/High-skill	Information-intensive
65-74	Financial intermediation, real estate, renting and business activities	Medium-skill/High-skill	Information-intensive
75	Public administration and defence; compulsory social security	Medium-skill	Non-market services
80	Education	High-skill	Non-market services
85	Health and social work	Medium-skill	Non-market services
90-95	Other community, social and personal services	Medium-skill	Supplier-dominated

Some industries were not classified by the authors and therefore we had to include a classification of our own. This was the of case of ‘Agriculture, forestry and fishing’ and ‘Electricity, gas and water supply’ under Peneder’s taxonomy, and of ‘Rubber and plastic’, ‘Non-metallic mineral products’, ‘Manufacture n.e.c.’, ‘Electricity, gas and water supply’, and ‘Construction’ under Tidd *et al*.’s (2001) taxonomy. The choice of the adequate categories was based on the analysis of the main characteristics of the aforementioned sectors in the Portuguese case.

With regard to qualification levels, the low average qualification scores of the Portuguese workforce are well-known, and most particularly of the agricultural workforce (cf. INE, 2007). Average qualification levels tend to be relatively higher, however, in the utilities sector (e.g., Teixeira, 2002), and therefore, we classify this industry as medium-skilled.

With respect to the Tidd *et al*. classification scheme, we considered ‘Manufacture n.e.c.’ as supplier-dominated, given the prevalence of the furniture industry, which fits rather well within the ‘traditional industry’ category, in which there are relatively few technological opportunities that come mostly from supplier chains. The same classification was given to ‘Non-metallic mineral products’ and to ‘Construction’ for similar reasons.[84] ‘Rubber and plastics’, on the other hand, was classified as specialised supplier, given the relatively small size of most firms in this industry and the strong pressures they face to improve efficiency on the part of their users.[85] Regarding the utilities sector (Electricity, gas and water supply) we opted for the scale-intensive classification, since very important productivity gains arise with the increase of scale of operation in this sector.

Finally, and following van Ark and Bartelsman (2004), we decided to include a separate category – non-market services – for the activities included in the 75, 80 and 85 ISIC rev.3 codes (public administration, education and health services). Generally, non-profit activities obey a distinct logic in terms of the relationship between innovation and productivity growth (Lumpkin and Dess, 1996; McDonald, 2007), and therefore it seemed reasonable to include them in a separate category.

[84] See IAPMEI (2007) for a description of the non-metallic mineral products sector in the Portuguese economy. Despite having a few large firms within the cements subsector, this sector is mostly characterised by small firms (the average number of workers in 2006 was 14), whose innovation trajectories are mainly dependent on the relationships established with suppliers.

[85] See Beira and Menezes (2001) and Beira *et al*. (2003) for an analysis of the Portuguese plastics industry and its innovation patterns during the period under scrutiny.

6.3. Decomposition of the time series

Before proceeding with the shift-share calculus, the appropriate breakpoints for dating the different phases of Portuguese TFP growth must be identified.

Afonso (1999), in an earlier work focusing on the relationship between foreign trade and economic growth, adopts a temporal decomposition inspired by Lopes (1996), distinguishing three intervals (1974-1985, 1986-1990 and 1991-1993) for the 1974-1993 period. Lains (2003), in his study of the Portuguese economy's catching-up process to the European core during 1910-1990, considers Maddison's phases of development, taking the 1973-1990 period as a whole. However, in a more recent paper in which a version of the shift-share methodology is applied (Lains, 2008), the author distinguishes between the 1979-85, 1986-93 and 1994-2002 periods. Aguiar and Martins (2004), for their part, establish different temporal intervals based on the comparison of observed productivity growth with the corresponding trend growth rate. This procedure leads to the consideration of a unique breakpoint during the 1974-2000 period in 1984/85.

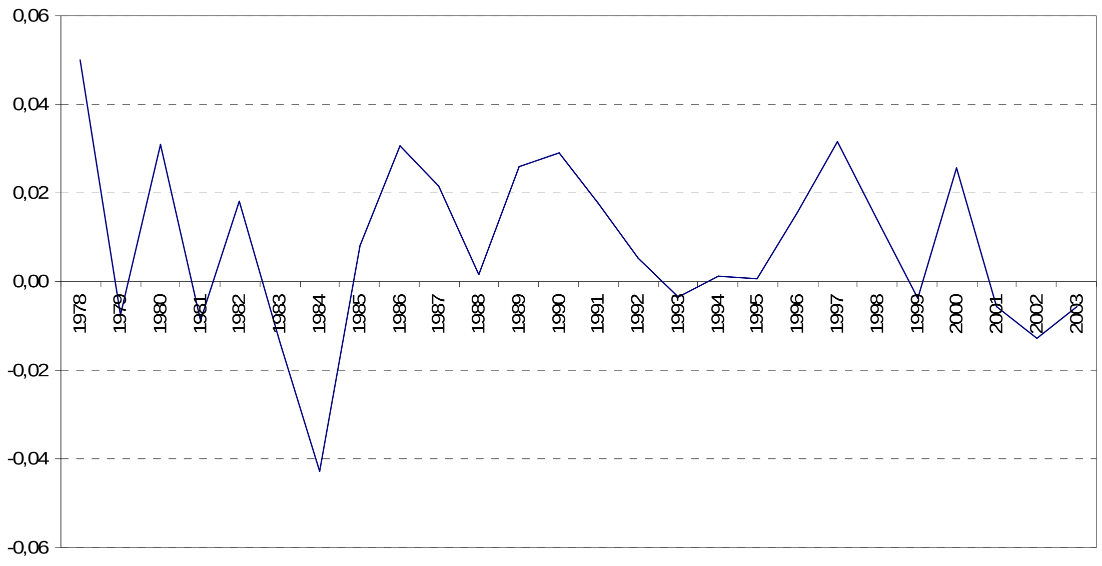

Figure 10: Total factor productivity growth (annual growth rates), 1978-2003

Note: Author's computations

From the examination of the TFP growth series depicted in Figure 10, it seems clear that there is at least one breakpoint, located in the mid-1980s. As seen previously, this is a traditional break considered in the study of Portuguese productivity trends. Another candidate for a temporal break in the series is 2000 (although to be precise, we should have information subsequent to 2003).

In order to help identify temporal breaks in the series, we use Bai and Perron's (1998, 2003a, 2003b) test of multiple structural change. This test is based on the comparison of the sum of squared residuals associated with each time partition, using an efficient algorithm that allows for the identification of the partition that minimises the overall sum of squared residuals.

To this end, we employ a simple model where TFP growth equals a constant that is allowed to change during the time period under analysis, and apply the WINRATS program developed by Tom Doan for Estima (available on-line at http://www.estima.com/Stability.shtml). Assuming a minimum time span of three years and setting five as the maximum number of breaks, this procedure identifies three significant breakpoints located in 1980, 1984 and 2000. The 1984 and 2000 breaks are in agreement with the data check and, most importantly, with the common understanding of the recent history of the Portuguese economy (cf., Lopes, 1996; Barros, 2002; Färe *et al*., 2006; Blanchard, 2006). The mid-1980s marks the transition between a period of tremendous economic and political instability, to a new context where joining the EU and the consequent stimulus to productivity and economic growth through political stability, infrastructure funding, and economic deregulation take place.[86] The year 2000, in turn, represents Portugal's entry into the European single currency, and is usually taken as an important breakpoint in its recent economic history. Indeed, the early 2000s represent a move from low to inexistent (or even negative) productivity growth [see, in this respect, Blanchard (2006)]. Portugal has been facing a particularly difficult macroeconomic setting since that time, characterised by low growth, high unemployment, and large fiscal and current account deficits, taking place within the context of strong rigidity in the labour market (Cardoso and Portugal, 2005), and in which a devaluation policy is not possible.

The choice of 1980, on the other hand, seems to reflect the scarcity of information prior to 1984. Generally, the post-revolutionary years spanning from the second half of the 1970s to the mid-1980s are taken as a whole, given the relative homogeneity of the period in terms of major political and economic features, and therefore, we do not take this break into account. Furthermore, because we want to identify the impact of economic cycles on the decomposition of TFP growth into intra-branch and structural change components, along with the full 1985-2000 time span, the 1985-1990, 1991-

[86] In a recent study, Baer and Leite (2003) argue that Portugal has greatly benefited in productivity terms from joining the EU, although it has also suffered from an increase in income asymmetries.

1995 and 1996-2000 sub-periods are also considered in the analysis of the whole set of sectors (but not for the sectors grouped within taxonomical categories).

6.4. Application of modified shift-share analysis

6.4.1. Methodology

The Timmer and Szirmai (2000) method consists, in basic terms, in comparing two different procedures to obtain aggregate output growth, the first corresponding to its direct calculus from aggregate variables, and the second consisting in the summation over all the sectors composing total output.

Neglecting, for now, the impact of Verdoorn effects, and considering, as in Timmer and Szirmai, a Cobb-Douglas production function with constant returns to scale and disembodied Hicks-neutral technical change, the two formulations of aggregate output growth are written as:

$$\hat{Y} = \alpha\hat{L} + (1-\alpha)\hat{K} + \hat{A} \quad \ldots\ldots (10)$$

$$\hat{Y} = \sum_i \rho_i \hat{Y} = \sum_i \rho_i \alpha_i \hat{L}_i + \sum_i \rho_i (1-\alpha_i)\hat{K}_i + \sum_i \rho_i \hat{A}_i \quad \ldots\ldots (11)$$

Equation (10) represents aggregate growth computed with aggregate variables. $Y = \sum_i Y_i$, $L = \sum_i L_i$, $K = \sum_i K_i$, $\alpha = \overline{\alpha}_i$, where subscript i denotes industrial branches, L and K represent labour and capital inputs, respectively, $\alpha_{it} = 1/2(v_{it} + v_{i,t-1})$ (v_t is the share of labour in value added), and $\hat{A}$ stands for TFP growth obtained directly at the aggregate level.

Equation (11) identifies aggregate growth with a weighted average of sectoral output growth rates, in which $\rho_i = Y_i / \sum_i Y_i$ are the sectoral weights, and A_i denotes the level of total factor productivity in sector i.

The difference between aggregate TFP growth and output-weighted sectoral TFP growth, referred to by Timmer and Szirmai as the 'total reallocation effect' (TRE), provides the basis for identifying the impact of the transfer of resources among sectors on overall productivity growth and corresponds to the following expression:

$$TRE = \hat{A} - \sum_i \rho_i \hat{A}_i = \sum_i \rho_i v_i \hat{\lambda}_i + \sum_i \rho_i (1-v_i)\hat{k}_i \quad \ldots\ldots (12)$$

where $\lambda_i = L_i / L$ and $k_i = K_i / K$ represent sector i's share in aggregate labour and aggregate capital, respectively.

The first term on the right-hand side indicates the impact of reallocation of labour on aggregate total factor productivity growth, whereas the second term gives the corresponding effect associated with the reallocation of capital.

In order to incorporate Verdoorn effects, Timmer and Szirmai (2000) propose the following modification in Equation (11):

$$T\tilde{R}E = \hat{A} - \sum_i \rho_i \left[\hat{A}_i - \varepsilon_i (\hat{Y}_i - \hat{Y})\right]_i \quad (12)$$

In this expression, the measurement of the impact of the reallocation of labour and capital inputs in TFP growth takes into account, along with the conventional gains stemming from shifts towards industries with higher-level or higher-growth productivity rates, the benefits arising from shifts towards industries with higher Verdoorn elasticities (ε).[87]

In order to calculate $T\tilde{R}E_i$ we have thus to start by computing Verdoorn elasticities across sectors, which, following Timmer and Szirmai (2000), is done with recourse to the estimation of the following equation:

$$T\hat{F}I = \alpha_0' + \beta_0'\hat{Q} + \beta_1' d_1 \hat{Q} + ... + \beta_{25}' d_{25} \hat{Q} + u \quad (13)$$

In this expression, $T\hat{F}I$ is total factor input growth [$T\hat{F}I = v\hat{L} + (1-v)\hat{K}$], and the Verdoorn elasticity for branch i is given by $(1-(\beta_0' + \beta_1'))$, where β_0' is the slope coefficient for the excluded branch in the definition of sectoral dummy variables ($d_1, \ldots, d_{25}$), and β_1' is the slope dummy coefficient for branch i. u is a normal distributed error term.[88]

6.4.2. Shift-share results

In order to account for the impact of structural change on total TFP growth, we consider first the shift-share procedure without taking into account Verdoorn effects. The results are described in Table 17.

[87] The Verdoorn elasticity of industry i is defined as the elasticity of TFP growth in output growth.
[88] See Timmer and Szirmai (2000) for a more detailed description of the method.

Table 17: Decomposition of total factor productivity growth into intra-sectoral and structural change effects

Period	TFP growth	TFP growth due to		Reallocation effect due to	
	(av. annual growth rate)	Intra-sectoral effect	Total reallocation effect	Labour	Capital
1978-1984	0,3	-1,2	1,5	0,9	0,5
1985-2000	1,4	0,6	0,8	0,4	0,3
1985-1990	1,9	1,1	0,8	0,5	0,2
1991-1995	0,4	-0,6	1,0	0,6	0,3
1996-2000	1,7	1,1	0,5	0,0	0,3
2001-2003	-0,8	-1,1	0,3	0,0	0,1
1978-2003	**0,8**	**-0,1**	**0,9**	**0,5**	**0,3**

Note: Figures may not add up due to rounding.

According to our results, the shift of labour and capital towards sectors with higher productivity levels or higher productivity growth has played a very significant role on TFP growth of the Portuguese economy during the last thirty years. In this period, structural change did indeed constitute the major source of TFP growth, whereas the intra-branch effect had a negative, although very small, impact on growth.

The total reallocation effect is always positive and in many cases higher than the intra-branch effect, although it seems have lost ground in the more recent years. Looking specifically at the 1985-2000 period, it seems that the structural change effect is particularly important in periods of economic recession, such as between 1991 and 1995, when it partly overcomes the negative impact of intra-sectoral productivity gains.

These results contrast with the evidence found with respect to other (more developed) countries, in which the intra-sectoral component is strongly dominant, but not so much with previous findings regarding the Portuguese economy. As indicated earlier (cf. Section 4.2), some studies (e.g., Aguiar and Martins, 2004; Lains, 2008) have already pointed out a significant impact of structural change on Portuguese productivity growth, although not as important as our results suggest. The more pronounced role of structural change found in the present study is probably due to the inclusion, along with labour, of the impact of capital shifts across sectors, which provides a more comprehensive picture of the impact of structural change on global productivity growth. Indeed, when analysing the last column of Table 17, it is clear that capital shifts accounted for about 40% of the total reallocation effect during the whole period under study.

It is worth noting, furthermore, that whereas the intra-branch component reveals a marked pro-cyclical behaviour, reaching the highest values in the two expansionary subperiods (1985-1990 and 1996-2000), and presenting negative values in periods of economic recession, the structural change component is relatively stable (although declining in the more recent period), contributing positively to total TFP growth during the whole period under study.

The effect of structural change on global TFP growth is also assessed considering the breakdown of economic activity according to the Peneder (2002) and Tidd *et al.* (2001) taxonomies (cf. Section 6.2). The computation of TFP growth for each group of industries (low, low-medium, medium and medium-high skill industries, and information intensive, non-market services, science-based, scale-intensive and specialised suppliers industries), was made calculating separately for each group the growth rates of VAB, labour and capital services. This task was particularly time-consuming with respect to capital services, since all the procedures outlined in Sections 5.3.2.-5.3.4. had to be performed once more, this time considering the aforementioned industry groups. After determining service lives of assets for each group of industries, considering a weighted average of the corresponding values for the sectors included in each category, capital services by industry group and asset type were computed, considering the age-efficiency and retirement profiles described earlier. Then capital stocks were aggregated to obtain overall measures of capital services for different types of activities, considering user costs of capital as the appropriate weights.

The results are reported in Tables 18 and 19.

Table 18: Decomposition of total factor productivity growth into intra-sectoral and structural change effects (industries grouped according to the Peneder (2002)/O'Mahony and Vecchi (2002) taxonomy; 1978-2003)

	TFP growth	**TFP growth due to**	
Period	**(av. annual growth rate)**	**Intra-sectoral effect**	**Total reallocation effect**
1978-1984	0.3	-0.4	0.7
1985-2000	1.4	1.1	0.3
1985-1990	1.9	1.7	0.3
1991-1995	0.4	0.0	0.4
1996-2000	1.7	1.5	0.2
2001-2003	-0.8	-0.8	0.0
1978-2003	**0.8**	**0.5**	**0.4**

Note: Figures may not add up due to rounding.

Table 19: Decomposition of total factor productivity growth into intra-sectoral and structural change effects (industries grouped according to the Tidd, Bessant and Pavitt (2001) taxonomy; 1978-2003)

Period	TFP growth (%)	TFP growth due to	
	(av. annual growth rate)	Intra-sectoral effect (%)	Total reallocation effect (%)
1978-1984	0.3	-0.3	0.6
1985-2000	1.4	1.0	0.3
1985-1990	1.9	1.6	0.3
1991-1995	0.4	0.0	0.4
1996-2000	1.7	1.4	0.2
2001-2003	-0.8	-0.9	0.1
1978-2003	**0.8**	**0.5**	**0.4**

Note: Figures may not add up due to rounding.

From the inspection of Tables 18 and 19 it can be seen that the results are quite similar when the two partitions of economic activity based on the selected taxonomies are taken into account. In both cases there is a significant decline of the contribution of the structural change component on TFP growth relative to the situation in which the 26 sectors are taken separately. The structural change component ceases to be the dominant effect and reduces its impact in all subperiods under study, particularly in periods of economic expansion, despite maintaining an overall significant impact over the entire period (1978-2003). In agreement with the previous results, there is also a gradual decline in the structural change effect, which is practically non-existent in the more recent years.

The substantial decline in the importance of the structural change component on total factor productivity growth when the Peneder and Tidd *et al.* industry groups are considered seems to indicate that the major part of structural change gains reported in Table 17 occurred *within* those groups. As a matter of fact, their relative employment and VAB shares changed very little during the period under study (cf. Table 20). Supplier-dominated and information-intensive industries, for example, industry groups which account for the overwhelming part of Portuguese output and labour between 1977 and 2003, show only modest changes. The same happens with regard to groups of industries organised in terms of the qualification of the workforce, despite the overall positive movement towards a relative decline of low-skill industries and the correspondent rise of higher-skill industries.

Table 20: Relevance of sectoral output and labour in industry groups (1978-2003; proportion)

	VAB[1]				Labour			
Taxonomy: Peneder (2002)								
	1977	**1984**	**1994**	**2003**	**1977**	**1984**	**1994**	**2003**
Low-skill	0.39	0.37	0.33	0.31	0.56	0.50	0.45	0.42
Low/Medium-skill	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03
Medium-skill	0.30	0.31	0.31	0.29	0.27	0.30	0.31	0.33
Medium/High-skill	0.30	0.30	0.34	0.38	0.14	0.16	0.21	0.22
Taxonomy: Tidd, Bessant and Pavitt (2001)								
	1977	**1984**	**1994**	**2003**	**1977**	**1984**	**1994**	**2003**
Supplier-dominated	0.34	0.34	0.31	0.28	0.61	0.56	0.48	0.46
Scale-intensive	0.04	0.04	0.05	0.06	0.02	0.02	0.02	0.02
Specialised supplier	0.04	0.03	0.02	0.02	0.03	0.03	0.03	0.02
Science-based	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02
Information-intensive	0.36	0,35	0.39	0.42	0.21	0.22	0.27	0.28
Non-market services	0.19	0.21	0.20	0.19	0.11	0.15	0.19	0.20

Notes: 1) Sectoral proportions are calculated with reference to total value added measured at 1995 constant prices.

6.4.2. Shift-share results accounting for the Verdoorn effect

Up to this point we have not taken into account possible structural change gains related with the so-called ‘Verdoorn effect’. We now consider these effects, together with gains arising from labour and capital shifts to branches with higher levels or higher growth rates of productivity. To this end, we estimate Equation (13) by ordinary least squares, taking 9-year averages of data on value added and total factor input growth. The results are reported in Table 21.

Table 21: Estimation of the Verdoorn elasticity (26 manufacturing branches; 1978-2003)

	Variable	Coefficient	t-value	Verdoorn elasticity
Intercept		0,014	4,849***	
Rubber and plastics	*Q*	0,394	1,829*	0,606
Agriculture, forestry and fishing	$Q.d_1$	-0,876	-1,934*	1,27
Mining and quarrying	$Q.d_2$	-0,171	-0,585	0,565
Food, beverages and tobacco	$Q.d_3$	-0,337	-0,519	0,731
Textiles and clothing	$Q.d_4$	0,170	0.417	0,224
Leather and footwear	$Q.d_5$	0,470	1,779*	-0,076
Wood and wood products	$Q.d_6$	-0,511	-1,355	0,905
Pulp, paper and paper products, printing and publishing	$Q.d_7$	0,336	0,707	0,058
Coke, refined petroleum products and nuclear fuel	$Q.d_8$	-0,682	-2,208**	1,076
Chemicals and chemical products	$Q.d_9$	1,042	1,368	-0,648
Non-metallic mineral products	$Q.d_{10}$	-0,466	-1,119	0,86
Basic metals and fabricated metal products	$Q.d_{11}$	-0,717	-1,329	1,111
Machinery and equipment n.e.c	$Q.d_{12}$	-0,613	-1,995*	1,007
Electrical and optical equipment.	$Q.d_{13}$	0,047	0,18	0,347
Transport equipment	$Q.d_{14}$	-0,370	-1,33	0,764
Manufacture n.e.c.	$Q.d_{15}$	-0,142	-0,46	0,536
Electricity, gas and water supply	$Q.d_{16}$	-0,709	-2,086**	1,103
Construction	$Q.d_{17}$	-0,429	-0,797	0,823
Wholesale and retail trade	$Q.d_{18}$	0,055	0,117	0,339
Hotel and restaurant services	$Q.d_{19}$	1,221	1,701*	-0,827
Transport, storage and communication	$Q.d_{20}$	-0,516	-1,712*	0,91
Financial intermediation, real estate, renting and business activities	$Q.d_{21}$	0,298	0,923	0,096
Public administration and defence; compulsory social security	$Q.d_{22}$	0,332	0,643	0,062
Education	$Q.d_{23}$	0,729	2,137**	-0,335
Health and social work	$Q.d_{24}$	0,628	1,669	-0,234
Other community, social and personal services	$Q.d_{25}$	0,076	0,277	0,318
Number of observations	**78**			
R^2 (Adj R²)	**0,66**	**(0,50)**		

Notes: Estimation by OLS. Dependent variable is the growth of total factor inputs. The Verdoorn elasticity for branch *i* is derived as $(1-\beta'_0-\beta'_i)$, where β'_0 is the slope coefficient for the rubber and plastics branch and β'_i is the slope dummy coefficient for branch *i*. *, ** and *** denote significance at the 10, 5 and 1% level, respectively, in a two-tailed test. R^2 in brackets is adjusted for degrees of freedom.

The explanatory power of Table 21 is quite respectable, and the intercept, representative of exogenous technical progress, is both positive and significant. In terms of the Verdoorn effect, the value of the Verdoorn coefficient, corresponding to the estimate associated with the rubber and plastics industry $(1-\beta'_0)$,[89] is found to be approximately 0.60, a value which is close, although somewhat higher than the 0.53 estimate found by Timmer and Szirmai (2000).

[89] Rubber and plastics is taken as the base industry as it shows the highest (statistically significant) coefficient of all branches.

As is apparent from Equation (12), the results from the modified shift-share only differ from the traditional procedure if Verdoorn elasticities differ significantly across branches. This does not seem to be the case, since only in eight industries (in a total of 26) do we find significant dummy coefficients. Even so, and following Timmer and Szirmai (2000), we estimate the potential impact of the Verdoorn effect, by applying the modified shift-share formula, described in Equation (12), considering the branch estimates of the Verdoorn elasticities. The results are reported in Table 22.

Table 22: Decomposition of total factor productivity growth into intra-sectoral and structural change effects including Verdoorn effect

	TFP growth (%)	TFP growth due to	
Period	**(av. annual growth rate)**	**Intra-sectoral effect (%)**	**Total reallocation effect (%)**
1978-1984	0.3	-1.1	1.5
1985-2000	1.4	0.6	0.7
1985-1990	1.9	1.3	0.6
1991-1995	0.4	-0.6	1.0
1996-2000	1.7	1.1	0.6
2001-2003	-0.8	-1.1	0.3
1978-2003	**0.8**	**0.0**	**0.9**

Notes: Figures may not add up due to rounding.

As can be seen in Table 22, the results are not very different from the ones derived under the traditional shift-share procedure. The structural change effect is still dominant and always positive during the whole period under study. The new estimates of the reallocation effect are slightly lower than the previous outcome, with the exception of the value regarding the 1996-2000 period, in which the structural change effect is slightly amplified.

Summarising, we can say that the adoption of a more complete approach in the measurement of the impact of structural change on Portuguese economic growth, by considering simultaneously the effects from shifts of labour and capital, has led to a entirely new perspective regarding the sources of Portuguese productivity growth over the last three decades. Indeed, the explicit consideration of capital movements across sectors, together with the use of a relatively high sectoral desegregation level, leads to the conclusion that structural change was the major source of productivity growth, well above intra-productivity gains, during the period under analysis. However, most of the gains arising from structural change have taken place within the broad industrial categories taken into account. This means that the Portuguese economic structure, while retaining some of its traditional characteristics, namely the strong bias towards traditional and low-skilled activities, has been able to reap some gains from the movement of capital and low-skilled work towards industries with a higher level, or growth rate, of productivity. Indeed, the relatively strong inertia regarding the achievement of higher qualification levels (Teixeira, 2006), which has probably had an influence on the maintenance of the global characteristics of the Portuguese economic structure (particularly, its incapacity to move towards a specialisation more centred on the technologically expanding industries), and on the low intra-productivity gains achieved, has been somewhat compensated by movements of labour and capital towards relatively more dynamic industries with similar technological and skill characteristics.

The analysis conducted so far does not take into account, however, the possible impact of spillover effects across industries, and does not, furthermore, allow us to explore the existence of causality chains between the meso and macro levels of the economy. We therefore continue our analysis of the relationship between structural change and productivity growth in Part III, by applying econometric estimation methods.

Part III. Structural change and economic growth: an econometric approach

Section 7. Economic growth and structural change in a panel cross-country set

7.1. Introductory considerations

The analysis of Portuguese economic growth and structural change over the last three decades conducted in Part II led to a number of important results. First of all, the inclusion of capital in the measurement of productivity growth has shown that the performance of the Portuguese economy was globally mediocre in the period under scrutiny, which was characterised by very slow rates of TFP growth. The results showed furthermore that most of the (low) productivity gains came from the shift of labour and capital resources across sectors, rather than from intra-productivity gains. Structural change gains arose, however, in a context of relatively slow change in the broad Portuguese economic structure, which maintained a strong bias towards traditional and low-skilled activities.

The analysis developed so far does not permit, however, to establish a causal relationship between structural change and economic growth, since it is based on a pure accounting procedure. Furthermore, the shift-share technique only takes into account the direct contributions from structural shifts at the industry level to aggregate growth, ignoring indirect effects stemming from spillovers between different industries.

In the following sections we complement the earlier analysis by adopting a wider perspective, using econometric methods and analysing the Portuguese case with reference to a number of other countries. We are particularly interested in examining whether the disappointing performance of Portuguese growth was, to some extent, related to the country's relative incapacity to boost major changes in the composition of economic activity and to benefit from the more technologically dynamic industries. As indicated earlier, there are reasons to expect leading technological industries, and particularly those more closely related to new technological paradigms, to have a major influence on growth.[1] We therefore anticipate that countries more capable of changing their economic structures in favour of high-skill and high-tech branches to present better performances in economic and productivity growth.

The countries included in the analysis are those which were experiencing similar structural backwardness at the beginning of the period under study (the late 1970s). The

[1] See our discussion on the neo-Schumpeterian stream of research in Part I.

restricted range of countries to be considered in this particular subset resulted from two fundamental aspects. First, the purpose of this work is not so much to assess globally the impact of technology-led sectors on economic growth, but to investigate their specific importance with respect to relatively less developed countries, as was the case of Portugal and a number of other countries in the late 1970s. The period under analysis was characterised by the emergence of a new technological paradigm, strongly based on the application of information and communication technologies (Freeman and Soete, 1997), which replaced the previous paradigm based on low-cost oil and mass-production technologies. According to some views expressed within the new Schumpeterian approach (e.g., Perez, 1985), it is precisely in periods of transition and emergence of new techno-economic paradigms that the relatively less developed countries have higher opportunities to catch-up. In these circumstances, it seems pertinent to compare the Portuguese case with other economies that faced similar growth problems in the late 1970s and which have experienced widely different growth trajectories since then, and relate those experiences with changes occurring at the meso-level of the economy. Secondly, given the strong empirical rejection of the hypothesis of a common growth model for all countries in favour of the hypothesis of different convergence clubs (e.g., Durlauf and Jonhson, 1995; Färe et al., 2006), it does indeed seem more reasonable to compare the Portuguese case with a group of economies that shared similar structural characteristics at the beginning of the period considered.

To our knowledge, this issue has not yet been addressed in the literature. Several studies analyse empirically the impact of technology-led sectors on overall economic performance (e.g., Fagerberg, 2000; Amable, 2000; Carree, 2002; Peneder, 2003), but the specific role of these branches in intermediate, developing countries' growth trajectories has not yet been assessed.

In the following sections an attempt is made to fill this gap, by considering a number of countries with similar structural characteristics in the late 1970s and by analysing their relative performances between 1979 and 2003. We first identify the list of countries to be compared by applying hierarchical cluster analysis (Section 7.2.). Subsequently, a descriptive characterisation of the growth and structural change processes of the selected countries during the period under study is undertaken (Section 7.3.). It is shown that a striking increase in the countries' dissimilarities came into play during this period, and an association between changes in economic performance and changes in economic structure is hypothesised. In Section 7.4., this hypothesis is examined through the estimation of a panel data regression, considering fixed effects methods. The results reveal a robust relationship between structure and (labour) productivity growth.

7.2. The countries' structural similarity at the beginning (1979) and at the end (2003) of the period: a cluster analysis

7.2.1. Some considerations on the data

As indicated earlier, we aim to identify a list of countries which had similar economic structures to the Portuguese case at the beginning of the period under study (1979), and that ultimately experienced diverse processes of growth and structural change during the last thirty years (1979-2003). In order to do so, a comparison of 21 countries (20 OECD members plus Taiwan) is undertaken, based on their per capita income and on the relative importance of the industry groups defined in the taxonomies described in Section 6.2..[2] More precisely, we compare the relative shares of low, medium and high-skill industries, as well as the relative shares of supplier-dominated, scale-intensive, specialised supplier, information-intensive and science-based industries in total VAB and employment figures. Along with these variables, we also consider a measure of the aggregate stock of human capital, expressed by the average number of years of formal education of the working age population (25 to 64 years). The choice of this variable reflects the crucial role of education in determining the capacity to assimilate advanced technologies from more developed countries, and to foster rapid structural change and economic growth.[3]

With regard to per capita income, we use data from the *World Economic Outlook Database* (April 2008) of the International Monetary Fund. This database provides full information regarding per capita GDP based on purchasing-power-parity (PPP) in current international dollars for a vast number of countries for the 1980-2007 period.

Data on sectoral VAB and employment (in hours) is taken from the 60-Industry Database of the Groningen Growth and Development Centre, which is available on-line at http://www.ggdc.net. This database covers 26 countries for 56 industries classified according to the International Standard Industrial Classification (ISIC) revision 3. Table 23 presents our classification of the 56 industries according to the selected taxonomies.

[2] The complete list of the countries considered can be found in Table 23.
[3] See our discussion in Part I regarding the 'technology-gap' literature and the specific concept of 'social capability'.

Table 23: Classification of sectors according to Peneder (2002)/O'Mahony and Vecchi (2002) and Tidd, Bessant and Pavitt's (2001) taxonomies

ISIC rev.3	Industries	Peneder (2002)/ O'Mahony and Vecchi (2002)	Tidd, Bessant and Pavitt (2001)
01	Agriculture	Low-skill	Supplier-dominated
02	Forestry	Low-skill	Supplier-dominated
05	Fishing	Low-skill	Supplier-dominated
10-14	Mining and quarrying	Low-skill	Scale-intensive
15-16	Food, drink & tobacco	Low-skill	Scale-intensive
17	Textiles	Low-skill	Supplier-dominated
18	Clothing	Low-skill	Supplier-dominated
19	Leather and footwear	Low-skill	Supplier-dominated
20	Wood & products of wood and cork	Medium-skill	Supplier-dominated
21	Pulp, paper & paper products	Medium-skill	Supplier-dominated
22	Printing & publishing	Medium-skill	Supplier-dominated
23	Mineral oil refining, coke & nuclear fuel	Medium-skill	Scale-intensive
24	Chemicals	High-skill	Science-based
25	Rubber & plastics	Low-skill	Specialised supplier
26	Non-metallic mineral products	Low-skill	Scale-intensive
27	Basic metals	Low-skill	Scale-intensive
28	Fabricated metal products	Medium-skill	Scale-intensive
29	Mechanical engineering	High-skill	Specialised supplier
30	Office machinery	High-skill	Specialised supplier
313	Insulated wire	Medium-skill	Specialised supplier
31-313	Other electrical machinery and apparatus nec	Medium-skill	Science-based
321	Electronic valves and tubes	Medium-skill	Specialised supplier
322	Telecommunication equipment	Medium-skill	Specialised supplier
323	Radio and television receivers	Medium-skill	Science-based
331	Scientific instruments	Medium-skill	Specialised supplier
33-331	Other instruments	Medium-skill	Specialised supplier
34	Motor vehicles	Medium-skill	Scale-intensive
351	Building and repairing of ships and boats	High-skill	Scale-intensive
353	Aircraft and spacecraft	High-skill	Scale-intensive
352+359	Railroad equipment and transport equipment nec	Medium-skill	Scale-intensive
36-37	Furniture, miscellaneous manufacturing; recycling	Low-skill	Supplier-dominated

40-41	Electricity, gas and water supply	Medium-skill	Scale-intensive
45	Construction	Low-skill	Supplier-dominated
50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	Low-skill	Information-intensive
51	Wholesale trade and commission trade, except of motor vehicles and motorcycles	Medium-skill	Information-intensive
52	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	Low-skill	Information-intensive
55	Hotels & catering	Low-skill	Supplier-dominated
60	Inland transport	Low-skill	Information-intensive
61	Water transport	Medium-skill	Information-intensive
62	Air transport	High-skill	Information-intensive
63	Supporting and auxiliary transport activities; activities of travel agencies	Medium-skill	Supplier-dominated
64	Communications	High-skill	Information-intensive
65	Financial intermediation, except insurance and pension funding	High-skill	Information-intensive
66	Insurance and pension funding, except compulsory social security	Medium-skill	Information-intensive
67	Activities auxiliary to financial intermediation	Medium-skill	Information-intensive
70	Real estate activities	High-skill	Information-intensive
71	Renting of machinery and equipment	Low-skill	Information-intensive
72	Computer and related activities	High-skill	Specialised supplier
73	Research and development	High-skill	Specialised supplier
741-3	Legal, technical and advertising	High-skill	Specialised supplier
749	Other business activities, nec	High-skill	Information-intensive
75	Public administration and defence; compulsory social security	Medium-skill	Non-market services
80	Education	High-skill	Non-market services
85	Health and social work	Medium-skill	Non-market services
90-93	Other community, social and personal services	Medium-skill	Supplier-dominated
95	Private households with employed persons	Medium-skill	Supplier-dominated
99	Extra-territorial organizations and bodies	Medium-skill	Non-market services

This classification shows some discrepancies relative to the one considered in Part II of the present work (cf. Table 16), which adopted a more aggregate breakdown of economic activity. More precisely, "Food, beverages and tobacco", "Non-mineral metallic products" and "Fabricated metal products" were previously defined as supplier-dominated industries, and are now included within the scale-intensive group. The difference in classification is attributable to a shift in focus considered in both analyses. In Part II we only took into account the Portuguese case, and therefore adapted Tidd *et* *al.*’s (2001) taxonomy to the specific features of the country’s economic structure. In the present case, however, because an international comparison is undertaken, a standard classification is employed, more in line with previous studies using Pavitt-type taxonomies (e.g., Pavitt *et al.*, 1989; Kristensen, 1999; van Ark and Bartelsman, 2004).

At the same time, branches 24 (“Chemicals”) and 50 (“Sale, maintenance and repair of motor vehicles,…”) are defined as high-skill and low-skill, respectively, although to be precise we should consider them as medium/high-skill and low/medium-skill.[4] This simplified classification was introduced to reduce the number of industry groups to be compared, in order to facilitate the determination of broad structural characteristics across countries.

With regard to our measure of human capital stock, most of the data was taken from Bassanini and Scarpetta (2001). The authors extend de la Fuente and Doménech’s earlier computations (de la Fuente and Doménech, 2000), determining the average number of years of formal education of the working age population on an annual basis over the 1971-1998 period.[5] We consider additionally Barro and Lee’s (2001) estimates for the same variable for Korea and Taiwan, because these countries were not taken into account in Bassanini and Scarpetta’s work. Barro and Lee (2001) show that the estimates of educational attainment based on OECD data are quite similar to their own measures, and therefore the inclusion of a different source of information does not seem to be problematic.[6]

Table 24 presents the list of variables considered for our sample of 21 countries.

[4] See Peneder’s (2002) industrial classification in Annex 11.

[5] Up to the early 1980s Bassanini and Scarpetta (2001) interpolate the five-year estimates provided by de la Fuente and Doménech (2000), whereas from that date onwards they calculate average years of education based on data from the OECD *Education at a Glance* (various issues), and consider the cumulative years of schooling in each educational level described in the OECD (1998: 347).

[6] The major differences arise with respect to Germany and the UK, because of a different classification of educational attainment between the OECD and the UNESCO sources.

Table 24: Industry shares in VAB and employment hours (%), average number of years of formal education of the working age population and per capita income (1979, various countries)

	Low-skill		Medium-skill		High-skill		Sup.-Dominated		Scale-intensive		Spec. supplier		Science-based		Inf.-Intensive		Non-market serv.		Education	PPPpcGDP[1]
	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	YEARS	C. int. $
Australia	40,7	48,1	31,0	34,8	28,3	17,1	25,1	30,6	19,7	13,4	5,6	5,4	1,8	1,5	31,1	33,0	16,7	16,0	11,5	9.809,8
Austria	42,0	56,6	35,7	28,0	22,2	15,5	28,2	42,8	14,8	11,7	6,1	6,5	2,4	1,9	31,9	22,6	16,6	14,6	10,3	10.495,0
Belgium	32,8	40,7	36,3	37,8	30,9	21,6	18,4	24,2	17,1	13,9	11,0	6,5	4,2	3,6	29,4	29,5	19,9	22,3	9,2	9.758,3
Canada	39,1	46,1	33,3	35,1	27,6	18,9	22,8	31,5	18,7	11,1	5,5	6,9	1,9	1,7	32,6	30,2	18,5	18,6	12,0	11.119,8
Denmark	32,3	41,8	38,7	37,4	29,0	20,8	21,2	28,7	9,7	9,2	7,1	7,7	1,7	1,7	37,9	28,5	22,3	24,2	10,5	10.038,2
Finland	37,5	51,8	38,2	33,5	24,4	14,6	33,4	43,2	13,2	8,6	6,3	5,6	2,0	1,4	30,0	23,5	15,1	17,6	9,5	8.763,6
France	33,3	45,1	33,4	34,2	33,4	20,8	23,5	33,7	11,5	11,5	10,7	8,2	2,8	1,8	34,2	25,7	17,2	19,0	9,5	9.985,8
Germany	31,0	41,9	39,1	38,0	30,0	20,0	21,0	28,4	16,6	14,5	11,4	10,1	5,3	4,0	28,7	24,3	16,9	18,6	11,2	9.796,7
Greece	53,4	69,8	21,9	20,0	24,7	10,2	38,9	55,6	9,5	9,8	2,9	3,3	0,9	0,9	34,7	20,6	13,0	9,9	7,9	8.515,3
Ireland	49,7	55,1	24,3	28,2	26,0	16,7	35,8	42,7	13,8	13,0	11,3	5,1	3,1	1,9	24,3	21,2	11,8	16,0	8,4	6.612,4
Italy	42,2	52,0	31,0	31,4	26,7	16,6	29,9	40,4	13,4	11,8	9,3	6,9	3,7	2,7	31,0	22,3	12,7	16,0	7,3	8.999,2
Japan	41,7	57,8	32,1	27,4	26,2	14,8	29,1	45,7	13,4	8,5	6,5	7,0	3,9	2,4	37,7	29,1	9,4	7,3	10,1	8.901,2
Korea	57,2	71,7	26,3	20,7	16,4	7,5	41,7	59,7	12,5	7,8	4,8	4,2	4,3	2,3	27,1	19,6	9,5	6,3	6,8[1]	2.486,8
Netherlands	33,0	39,4	41,0	40,7	25,9	19,8	21,9	31,3	15,0	10,0	6,3	6,1	4,0	3,2	29,3	27,7	23,5	21,7	10,0	10.696,1
Norway	37,8	42,6	36,2	39,1	26,0	18,2	19,6	31,4	21,8	11,1	4,8	5,0	2,0	1,7	34,6	28,2	17,2	22,6	10,6	12.576,6
Portugal	49,3	64,2	30,4	26,0	20,2	9,8	33,4	54,4	11,7	9,6	6,1	2,4	2,2	1,6	33,8	19,9	12,8	12,1	6,9	5.130,1
Spain	46,6	60,9	29,7	26,0	23,7	13,2	32,1	46,3	14,8	11,0	5,3	3,9	2,9	2,0	31,9	23,7	13,0	13,1	6,3	7.287,5
Sweden	27,5	36,8	43,6	42,6	28,9	20,7	23,4	29,2	12,2	10,5	8,1	8,0	2,0	1,8	31,8	24,8	22,4	25,9	10,0	9.953,5
Taiwan	47,0	63,5	31,9	26,7	21,1	9,8	30,3	47,7	18,0	9,4	6,5	8,2	5,0	4,7	29,4	21,5	10,8	8,4	6,4[1]	3.355,7
UK	34,8	43,7	34,4	33,8	30,9	22,5	21,1	27,3	18,8	15,5	9,6	8,8	3,2	2,9	30,4	27,8	16,9	17,7	10,0	8.636,4
US	31,8	37,1	37,5	37,7	30,7	25,2	18,9	25,6	14,4	10,7	9,2	8,5	2,7	1,9	35,9	29,0	19,0	24,3	12,2	12.255,1
Average	**40,0**	**50,8**	**33,6**	**32,3**	**26,3**	**16,9**	**27,1**	**38,1**	**14,8**	**11,1**	**7,3**	**6,4**	**3,0**	**2,3**	**31,8**	**25,4**	**16,0**	**16,8**	**9,4**	**8.817,8**
Std. Dev.	**8,1**	**10,7**	**5,4**	**6,4**	**4,1**	**4,7**	**6,9**	**10,6**	**3,3**	**2,1**	**2,4**	**2,0**	**1,2**	**0,9**	**3,4**	**3,9**	**4,1**	**5,7**	**1,8**	**2.602,3**
Max.	**57,2**	**71,7**	**43,6**	**42,6**	**33,4**	**25,2**	**41,7**	**59,7**	**21,8**	**15,5**	**11,4**	**10,1**	**5,3**	**4,7**	**37,9**	**33,0**	**23,5**	**25,9**	**12,2**	**12.576,6**
Min.	**27,5**	**36,8**	**21,9**	**20,0**	**16,4**	**7,5**	**18,4**	**24,2**	**9,5**	**7,8**	**2,9**	**2,4**	**0,9**	**0,9**	**24,3**	**19,6**	**9,4**	**6,3**	**6,3**	**2.486,8**

Source: Composition of economic activity: GGDC – 60 Industry Database; Education: Bassanini and Scarpetta (2001) and Barro and Lee (2001); Per capita income: IMF - World Economic Outlook Database (April 2008).

Notes: 1) Year of reference 1980.

As we can see from Table 24, countries with larger per capita incomes tend to have higher educational capital stocks and relatively higher shares of high-skill industries. Inversely, countries with relatively low levels of GDP per capita income and human capital have higher shares of low-skill and supplier-dominated industries (the industry group with fewer technological opportunities). The US and Germany, for example, belong to the first group of countries, whereas Portugal, Greece and Korea are good representatives of the second, less developed group of countries.

This impression is confirmed by the computation of Pearson bi-variate correlation coefficients, considering both data on VAB or employment variables (cf. Table 25). The high positive relationship between education and per capita income and, inversely, the strong negative relationship of each of these variables and the relative shares of low-skilled and less innovative industries is clearly apparent. All the correlation coefficients relating education (or per capita GDP) to either the shares of low-skill or supplier-dominated industries are negative and strongly significant.

Table 25: Correlation matrix

VAB shares						
	High-skill	**Science-based**	**Spec. supplier**	**Sup.-dominated**	**Education**	**GDPper capita**
High-skill	1,00	-0,07	0,64***	-0,77***	0,64***	0,71***
Science-based		1,00	0,46**	-0,06	-0,24	-0,37
Specialised supplier			1,00	-0,43**	0,19	0,16
Supplier-dominated				1,00	-0,72***	-0,75***
Education					1,00	0,82***
GDPper capita						1,00

Employment shares						
	High-skill	**Science-based**	**Spec. supplier**	**Sup.-dominated**	**Education**	**GDPper capita**
High-skill	1,00	0,06	0,67***	-0,95***	0,75***	0,7***9
Science-based		1,00	0,52**	-0,18	-0,17	-0,27
Specialised supplier			1,00	-0,67***	0,51**	0,36
Supplier-dominated				1,00	-0,76***	-0,76***
Education					1,00	0,82***
GDPper capita						1,00

Notes: N = 21;***, ** Correlation is significant at the 0.01 and 0.05 levels, respectively (two-tailed test).

7.2.2. Hierarchical cluster analysis

Cluster analysis involves a number of different procedures that allow for the division of a specific dataset into distinct groups, such that the degree of homogeneity is maximal if the observations belong to the same group and minimal otherwise. In the present study, because we have a relatively small dataset, we use the hierarchical clustering approach to classify the individual observations into clusters of maximum homogeneity.

Hierarchical clustering identifies successive clusters by using previously established clusters. It can be either agglomerative or divisive, although the former is the most commonly used.[7] In the present case, we have opted for the agglomerative approach, starting with each case as a separate cluster and successively merging the two closest clusters until a single, all-inclusive cluster remains.

The application of hierarchical agglomerative clustering requires the prior definition of a criterion to determine the distance or similarity between cases. The most straightforward way to compute distances between cases is to use the Euclidean distance, which is simply the geometric distance in the multidimensional space, although other measures, such as the Manhattan or the Chebychev distances, are also available. In terms of similarity measures, possible choices include the computation of the cosine and the calculus of correlations of vectors of variables. We apply the cosine similarity criterion, although there is no clear-cut indication as to this measure's superiority in comparison to the others.[8]

The use of agglomerative clustering also requires the definition of the rules for cluster formation. Once again, various possibilities arise, including single linkage and complete linkage methods, weighted and unweighted pair group averages, and Ward's and centroid methods. In the present case, we use the average linkage between groups method, also known as UPGMA (Unweighted Pair Group Method using Arithmetic averages). This method defines the distance between two clusters as the average distance between all pairs of cases in the two different clusters. The UPGMA method seems to be preferable relative to single and complete linkage rules, since it uses information regarding all pairs of distances, and not just the nearest or the furthest.

[7] See Everitt et al. (2001) and Aldenderfer and Blashfield (1985) for more information on hierarchical cluster analysis and on cluster analysis procedures in general.

[8] Acknowledging the subjective nature of this choice, we have also considered distance measures, as well as the alternative similarity measure (the correlation of vectors). The resulting cluster solution was always the same.

Agglomerative clustering is applied to the standardised scores of the variables, rather than to their real values, because they are measured on different scales (industry share variables in percentage points, human capital in years, and per capita income in PPP current international US dollars).

7.2.3. Clustering results

Figure 11 presents the resulting dendrogram, which is the usual graphical representation of the hierarchical clustering procedure. In the dendrogram, which should be read from left to the right, cases are listed along the left vertical axis, whereas the horizontal axis indicates the distance at which clusters are merged.[9]

The first vertical lines represent the smallest rescaled distance, which in the present case corresponds to the merging of Portugal, Spain and Korea. Subsequent vertical lines represent merges at higher distances, until only one cluster, encompassing all cases, is obtained.

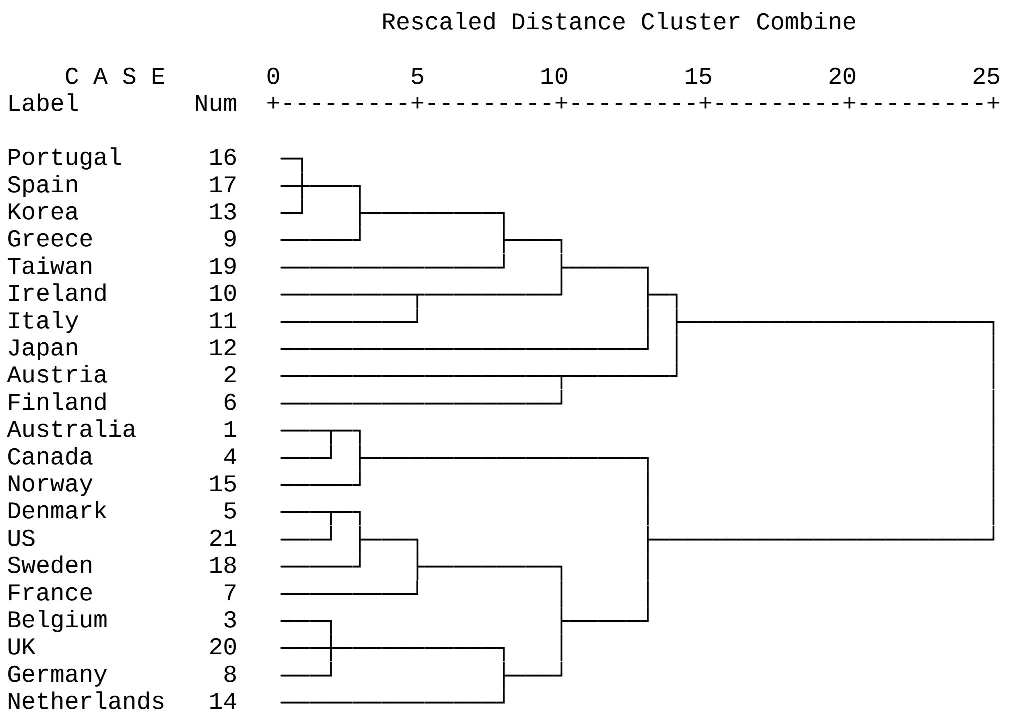

Figure 11: Dendrogram using average linkage between groups and the cosine similarity measure (1979)

Generally, a good cluster solution is defined as being the one which precedes a sudden gap in the similarity (or distance) coefficient. In this case, the larger distance between

[9] These are not the actual distances, but distances rescaled into the range of 1 to 25.

sequential vertical lines occurs approximately between 15 and 25, suggesting that the best clustering solution splits the list of countries into two clusters:

- A cluster formed by Portugal, Spain, South Korea, Greece, Taiwan, Ireland, Italy, Japan, Austria and Finland (*Cluster 1*);
- And a cluster including Australia, Canada, Norway, Denmark, US, Sweden, France, Belgium, UK, Germany and the Netherlands (*Cluster 2*).

The same result is found when looking at the agglomeration schedule (Table 26), which presents a numerical synthesis of the clustering solution. The highest decrease in the *Coefficients* column[10] occurs between stages 19 and 20, meaning that the best representation of the data takes place when the two clusters with the above-mentioned characteristics are considered.[11]

Table 26: Agglomeration schedule

	Cluster Combined			Stage Cluster First Appears		
Stage	**Cluster 1**	**Cluster 2**	**Coefficients**	**Cluster 1**	**Cluster 2**	**Next Stage**
1	16	17	0,887	0	0	2
2	13	16	0,836	0	1	7
3	1	4	0,831	0	0	9
4	3	20	0,822	0	0	6
5	5	21	0,800	0	0	8
6	3	8	0,797	4	0	12
7	9	13	0,781	0	2	13
8	5	18	0,773	5	0	10
9	1	15	0,737	3	0	17
10	5	7	0,650	8	0	14
11	10	11	0,640	0	0	15
12	3	14	0,476	6	0	14
13	9	19	0,473	7	0	15
14	3	5	0,396	12	10	17
15	9	10	0,381	13	11	18
16	2	6	0,374	0	0	19
17	1	3	0,244	9	14	20
18	9	12	0,230	15	0	19
19	2	9	0,171	16	18	20
20	1	2	-0,439	17	19	0

[10] This column gives the value of the similarity statistic used to form the cluster.
[11] This result does not change with the consideration of different linkage rules.

The clustering solution thus separates our sample into a cluster of highly developed countries (cluster 2), characterised by high levels of education and per capita income, and relatively higher shares of innovative and high-skill industries, and a more heterogeneous cluster formed by relatively less developed countries (cluster 1).

As can be seen from Table 27, there is indeed greater dispersion within cluster 1, most particularly with regard to the per capita income variable. Countries such as Austria, Finland, Italy and Japan present considerably high values for this variable, close to the average value found for the countries included in cluster 2, whereas Spain, Ireland, Portugal, and most notably, Korea and Taiwan, are very far behind (cf. Table 28). As a matter of fact, Austria, Japan and Finland are classified in cluster 1 mainly because of their composition of economic activity, which is characterised by a greater reliance on supplier-dominated industries and the weaker relevance of high-skill industries comparatively to countries included in cluster 2. In contrast, countries such as Portugal, Korea and Taiwan present substantial differences in relation to the more developed countries in all the variables considered. These differences are particularly evident with respect to per capita income and human capital variables, and also in the (much higher) relevance of supplier-dominated industries.[12]

[12] It is worth mentioning, however, the contrasting evidence of Portugal, on the one hand, and of Taiwan and Korea, on the other, with respect to the relevance of science-based industries, which is considerably higher in these latter countries.

Table 27: Descriptive statistics - clusters 1 and 2

	Low-skill (%)		Medium-skill (%)		High-skill (%)		Sup.-Dominated (%)		Scale-intensive (%)		Spec. supplier (%)		Science-based (%)		Inf.-Intensive (%)		Non-market serv (%).		Education	PPPpcGDP
	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	YEARS	C. int. dollar
Cluster 1																				
Average	46,7	60,3	30,2	26,8	23,2	12,9	33,3	47,8	13,5	10,1	6,5	5,3	3,0	2,2	31,2	22,4	12,5	12,1	8,0	7054,7
Std. Deviation	6,0	7,0	4,9	4,1	3,2	3,3	4,4	6,5	2,2	1,7	2,3	1,9	1,2	1,0	3,8	2,7	2,2	4,0	1,5	2637,0
Coef. of variation	12,8	11,5	16,4	15,5	13,9	25,5	13,2	13,6	16,4	16,6	35,4	35,1	40,3	46,3	12,2	12,2	18,0	32,8	19,0	37,4
Cluster 2																				
Average	34,0	42,1	36,8	37,4	29,2	20,5	21,5	29,3	16,0	12,0	8,1	7,4	2,9	2,4	32,3	28,1	19,1	21,0	10,6	10420,6
Std. Deviation	3,8	3,5	3,7	2,8	2,3	2,2	2,1	2,8	3,8	2,0	2,4	1,5	1,2	0,9	3,0	2,5	2,5	3,2	1,0	1162,6
Coef. of variation	11,3	8,4	10,0	7,4	7,7	10,6	9,6	9,6	23,6	17,1	29,7	21,0	41,1	37,9	9,3	8,9	13,2	15,1	9,4	11,2

Source: *Idem* Table 23

Table 28: Absolute distances of countries included in cluster 1 relative to average values of cluster 2 (%)

	Low-skill (%)		Medium-skill (%)		High-skill (%)		Sup.-Dominated (%)		Scale-intensive (%)		Spec. supplier (%)		Science-based (%)		Inf.-Intensive (%)		Non-market serv (%).		Education	PPPpcGDP
	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	YEARS	C. int. dollar
Austria	8,0	14,4	-1,0	-9,4	-7,0	-5,0	6,7	13,5	-1,1	-0,2	-2,0	-0,9	-0,5	-0,4	-0,4	-5,5	-2,6	-6,4	-0,3	74,4
Finland	3,5	9,7	1,4	-3,8	-4,9	-5,9	11,9	14,0	-2,8	-3,3	-1,8	-1,8	-0,9	-0,9	-2,3	-4,5	-4,1	-3,4	-1,1	-1657,0
Greece	19,4	27,7	-14,9	-17,4	-4,5	-10,4	17,4	26,3	-6,5	-2,2	-5,2	-4,1	-1,9	-1,4	2,3	-7,5	-6,2	-11,1	-2,7	-1905,3
Ireland	15,7	13,0	-12,5	-9,2	-3,2	-3,8	14,2	13,4	-2,2	1,1	3,1	-2,3	0,2	-0,5	-8,0	-6,8	-7,4	-4,9	-2,2	-3808,2
Italy	8,2	9,9	-5,7	-6,0	-2,5	-3,9	8,4	11,1	-2,6	-0,1	1,1	-0,5	0,8	0,3	-1,3	-5,8	-6,4	-5,0	-3,3	-1421,3
Japan	7,7	15,7	-4,7	-10,0	-3,0	-5,7	7,5	16,4	-2,6	-3,5	-1,7	-0,3	1,0	0,1	5,4	1,0	-9,7	-13,7	-0,5	-1519,3
Korea	23,2	29,6	-10,5	-16,6	-12,8	-13,0	20,2	30,4	-3,4	-4,1	-3,3	-3,1	1,4	0,0	-5,2	-8,5	-9,6	-14,6	-3,8	-7933,8
Portugal	15,3	22,1	-6,3	-11,3	-9,0	-10,7	11,9	25,1	-4,3	-2,3	-2,0	-5,0	-0,7	-0,7	1,5	-8,2	-6,3	-8,9	-3,7	-5290,5
Spain	12,6	18,7	-7,0	-11,4	-5,6	-7,3	10,6	17,1	-1,2	-1,0	-2,8	-3,4	0,0	-0,4	-0,4	-4,4	-6,2	-7,9	-4,3	-3133,1
Taiwan	13,0	21,4	-4,9	-10,7	-8,1	-10,7	8,8	18,4	2,0	-2,5	-1,6	0,9	2,1	2,3	-3,0	-6,6	-8,4	-12,5	-4,2	-7064,9

Source: *Idem* Table 23. Notes: Absolute distance is calculated as the difference between the country's variable value and the corresponding average value of cluster 2.

7.3. Descriptive characterisation of the growth and structural change processes of the selected countries between 1979 and 2003

In the late 1970s, Portugal shared similar structural characteristics with countries such as Spain, Korea and Greece (the most similar ones), and also with Taiwan, Ireland, Italy, Japan, Austria and Finland. From that time onwards, however, the countries experienced very different processes of growth and structural change, which gave rise to an increase in their dissimilarities. Differences in per capita GDP, for example, were strongly amplified (see standard deviation figures in Table 29), given the profound differences in average growth rates of real GDP during this period. Korea, Ireland and Taiwan experienced very high GDP growth rates, whereas in the other countries, average GDP growth did not surpass 3% per annum (cf. Table 29).

Table 29: GDP at constant prices and GDP per capita based on purchasing-power-parity (annual % change; 1980-2003)

	GDP constant prices				**GDP per capita (PPP)**			
	1980-86	**1987-94**	**1995-03**	**1980-03**	**1980-86**	**1987-94**	**1995-03**	**1980-03**
Austria	1,6	2,6	2,2	**2,2**	6,3	5,0	3,8	**4,9**
Finland	2,7	0,8	3,8	**2,4**	7,0	3,4	5,4	**5,1**
Greece	0,2	1,4	3,6	**2,0**	4,3	3,5	5,0	**4,3**
Ireland	1,5	4,2	8,2	**5,0**	5,5	7,1	9,0	**7,4**
Italy	1,9	2,0	1,6	**1,8**	6,6	5,0	3,4	**4,8**
Japan	3,1	3,3	1,0	**2,3**	7,2	6,0	2,6	**5,0**
Korea	8,3	8,4	5,0	**7,0**	11,9	10,6	6,1	**9,1**
Portugal	**1,8**	**4,3**	**2,7**	**3,0**	**6,3**	**7,4**	**4,0**	**5,8**
Spain	1,7	3,0	3,8	**3,0**	5,9	5,8	4,9	**5,5**
Taiwan	7,5	8,1	4,6	**6,5**	10,9	10,2	5,7	**8,6**
Std deviation GDP per capita PPP								
1980	2637,0							
2003	5081,6							

Source: International Monetary Fund, World Economic Outlook Database, April 2008

Considerable differences arose, at the same time, with respect to labour productivity growth (cf. Table 30). Once again, higher growth rates occurred in Korea, Taiwan and Ireland, well above the ones observed in the other countries considered.

Table 30: Annual average labour productivity growth (%; 1979-2003)

	1979-1986	1987-1994	1995-2003	1979-2003
Austria	2,36	2,81	2,69	**2,63**
Finland	2,98	3,43	2,58	**2,98**
Greece	1,04	0,69	2,83	**1,59**
Ireland	3,61	4,29	6,78	**5,02**
Italy	1,84	2,20	0,78	**1,56**
Japan	3,41	4,05	2,63	**3,36**
Korea	5,55	6,24	5,20	**5,67**
Portugal	**3,71**	**2,89**	**1,81**	**2,72**
Spain	4,22	1,54	0,74	**2,01**
Taiwan	6,15	7,11	7,24	**6,86**

Source: GGDC 60-Industry Database
Notes: 1) Reference period: 1995-2002; 2) Reference period: 1979-2002.

Furthermore, rapid growth experiences were intimately connected with strong structural transformation. The computation of Nickell and Lilien indices of structural change (cf. Table 31) reveals that the fastest growth countries – Korea, Taiwan and Ireland – were simultaneously the countries with more rapid structural change during the period under study.[13] In contrast, slow-growing countries such as Greece or Italy experienced much more modest changes. This is in broad agreement with the views expressed by the authors from the new structuralist approach (e.g., Pieper, 2000; Rada and Taylor, 2006), according to which rapid growth requires profound changes in the composition of economic activity and external trade.[14]

[13] See Part II for details on the computation of these indices.
[14] See our discussion in Part I.

Table 31: Nickell and Lilien indices of structural change (1979-2003)[1]

	1979-1986	1987-1994	1995-2003	1979-2003
Nickell index				
Austria	0,185	0,188	0,214	**0,527**
Finland	0,213	0,227	0,318	**0,735**
Greece	0,166	0,187	0,386	**0,475**
Ireland	0,313	0,265	0,526	**0,885**
Italy	0,200	0,143	0,207	**0,505**
Japan	0,234	0,188	0,190[2]	**0,463**[3]
Korea	0,389	0,367	0,317[2]	**0,882**[3]
Portugal	**0,223**	**0,310**	**0,245**	**0,601**
Spain	0,242	0,182	0,187	**0,472**
Taiwan	0,277	0,359	0,283[2]	**0,807**[3]
Lilien index				
Austria	0,138	0,132	0,139	**0,274**
Finland	0,162	0,176	0,190	**0,404**
Greece	0,119	0,136	0,205	**0,315**
Ireland	0,243	0,214	0,364	**0,566**
Italy	0,169	0,111	0,136	**0,381**
Japan	0,163	0,128	0,164[2]	**0,352**[3]
Korea	0,281	0,298	0,224[2]	**0,635**[3]
Portugal	**0,164**	**0,258**	**0,184**	**0,477**
Spain	0,189	0,138	0,128	**0,346**
Taiwan	0,195	0,307	0,205[2]	**0,574**[3]

Source: GGDC 60-Industry Database

Notes: 1) The calculus procedure of these indices is explained in Part II, p. 70; indices are calculated considering 56 sectors and sectoral proportions in value added. 2) Reference period: 1995-2002. 3) Reference period: 1979-2002.

The countries with faster structural change were also the ones experiencing more profound changes in the relative importance of the industry groups defined earlier. Korea, Ireland and Taiwan were the countries in which the decrease in the relative share of low-skill industries was more intense. The lower importance of these industries was compensated by a substantial increase in high-skill industries, particularly in the cases of Ireland and Korea. Ireland, Korea and Taiwan also presented the largest decrease in supplier-dominated industries, which, as indicated earlier, are the industries facing lower technological opportunities. In contrast, relative shares of specialised supplier and science-based industries – Pavitt's top categories in technological and innovativeness potential – increased substantially (cf. Table 32).[15]

Given the profound changes in the structure of their economies, it is no surprise that Korea, Ireland and Taiwan have been able to significantly modify their situation in

[15] In Taiwan and Korea there was however a small decline in the relative importance of science based industries.

comparison to the more developed countries included in cluster 2. Indeed, as can be seen from Table 33, these countries have severely reduced the gap regarding the relative importance of low-skill and supplier-dominated industries, and converged, at the same time, in the more technological and skill-intensive categories. In the case of Ireland, in particular, there was not only a drastic reduction in the low-tech and low-skill industries distances, but also a substantial increase in the already positive gap with respect to specialised supplier and science-based industries.

Tables 32 and 33 confirm, furthermore, the earlier findings regarding the Portuguese economy presented in Part II. Despite showing fast structural change between 1979 and 2003, Portugal did not significantly change the structure of its economy. The country was able to reduce the relative importance of low-skill and supplier-dominated industries and to increase high-skill industry shares, but the rate at which this transformation took place was relatively low. Moreover, and quite significantly, the most important change observed during this period refers to non-market services, which increased their relative importance in about 11 percentage points. This has probably had an influence on the globally poor performance of Portuguese TFP growth during this period.

Table 32: Industry shares in VAB in 2003 and variation between 1979 and 2003 (%)

	Low-skill		Medium-skill		High-skill		Sup.-Dominated		Scale-intensive		Spec. supplier		Science-based		Inf.-Intensive		Non-market serv.	
	VAB	Var. 79-03	VAB	Var. 79-03	VAB	Var. 79-03	VAB	Var. 79-03	VAB	Var. 79-03	VAB	Var. 79-03	VAB	Var. 79-03	VAB	Var. 79-03	VAB	Var. 79-03
Austria	33,4	**-8,6**	35,6	**-0,1**	31,0	**8,7**	24,3	**-3,9**	11,1	**-3,7**	10,8	**4,7**	2,0	**-0,4**	35,9	**4,0**	16,0	**-0,6**
Finland	24,2	**-13,3**	41,9	**3,7**	33,9	**9,6**	22,2	**-11,2**	8,7	**-4,5**	13,2	**6,9**	2,2	**0,2**	35,2	**5,1**	18,5	**3,4**
Greece	42,4	**-10,9**	29,1	**7,2**	28,5	**3,8**	31,5	**-7,4**	8,4	**-1,1**	3,1	**0,2**	0,8	**-0,1**	38,8	**4,1**	17,3	**4,4**
Ireland	28,1	**-21,5**	28,9	**4,6**	42,9	**16,9**	21,3	**-14,5**	8,2	**-5,6**	16,8	**5,5**	14,6	**11,6**	24,5	**0,2**	14,6	**2,8**
Italy	31,9	**-10,4**	32,3	**1,2**	35,8	**9,1**	22,8	**-7,2**	10,2	**-3,2**	11,1	**1,8**	2,2	**-1,5**	38,1	**7,1**	15,6	**2,8**
Japan[1]	31,1	**-10,6**	34,2	**2,2**	34,7	**8,5**	23,5	**-5,6**	10,3	**-3,1**	8,0	**1,5**	2,7	**-1,2**	44,7	**7,0**	10,8	**1,4**
Korea[1]	33,6	**-23,6**	34,0	**7,7**	32,4	**16,0**	24,2	**-17,5**	17,1	**4,6**	9,5	**4,8**	3,7	**-0,6**	32,1	**4,9**	13,3	**3,8**
Portugal	**34,2**	**-15,1**	**36,8**	**6,3**	**29,1**	**8,8**	**24,9**	**-8,5**	**9,9**	**-1,7**	**4,6**	**-1,5**	**1,4**	**-0,7**	**35,7**	**1,9**	**23,5**	**10,7**
Spain	39,8	-6,8	30,3	0,6	29,9	6,2	30,4	**-1,7**	10,5	**-4,3**	7,1	**1,8**	2,2	**-0,7**	33,5	**1,6**	16,3	**3,4**
Taiwan[1]	26,9	**-20,1**	42,2	**10,3**	30,9	**9,8**	15,3	**-15,0**	12,3	**-5,7**	10,7	**4,2**	3,1	**-1,9**	43,9	**14,5**	14,7	**3,9**

Note: 1) Reference period: 1979-2002.

Table 33: Absolute differences in VAB industry group shares of countries included in cluster 1 relative to average values of cluster 2 (1979, 2003; %)

	Low-skill		Medium-skill		High-skill		Sup.-Dominated		Scale-intensive		Spec. supplier		Science-based		Inf.-Intensive		Non-market serv.	
	1979	2003	1979	2003	1979	2003	1979	2003	1979	2003	1979	2003	1979	2003	1979	2003	1979	2003
Austria	8,0	6,2	-1,0	-1,0	-7,0	-5,2	6,7	6,3	-1,1	-1,4	-2,0	0,4	-0,5	-0,4	-0,4	-1,3	-2,6	-3,7
Finland	3,5	-3,0	1,4	5,2	-4,9	-2,2	11,9	4,3	-2,8	-3,8	-1,8	2,9	-0,9	-0,2	-2,3	-2,0	-4,1	-1,2
Greece	19,4	15,2	-14,9	-7,6	-4,5	-7,7	17,4	13,6	-6,5	-4,1	-5,2	-7,2	-1,9	-1,6	2,3	1,6	-6,2	-2,3
Ireland	15,7	0,9	-12,5	-7,7	-3,2	6,8	14,2	3,3	-2,2	-4,3	3,1	6,5	0,2	12,2	-8,0	-12,6	-7,4	-5,1
Italy	8,2	4,7	-5,7	-4,4	-2,5	-0,3	8,4	4,8	-2,6	-2,3	1,1	0,8	0,8	-0,2	-1,3	1,0	-6,4	-4,1
Japan[1]	7,7	3,9	-4,7	-2,4	-3,0	-1,5	7,5	5,6	-2,6	-2,2	-1,7	-2,4	1,0	0,3	5,4	7,6	-9,7	-8,9
Korea[1]	23,2	6,4	-10,5	-2,7	-12,8	-3,7	20,2	6,3	-3,4	4,6	-3,3	-0,8	1,4	1,3	-5,2	-5,1	-9,6	-6,4
Portugal	**15,3**	**7,0**	**-6,3**	**0,1**	**-9,0**	**-7,1**	**11,9**	**7,0**	**-4,3**	**-2,6**	**-2,0**	**-5,7**	**-0,7**	**-1,0**	**1,5**	**-1,5**	**-6,3**	**3,8**
Spain	12,6	12,6	-7,0	-6,3	-5,6	-6,3	10,6	12,5	-1,2	-2,0	-2,8	-3,2	0,0	-0,2	-0,4	-3,6	-6,2	-3,4
Taiwan[1]	13,0	-0,3	-4,9	5,6	-8,1	-5,2	8,8	-2,6	2,0	-0,2	-1,6	0,4	2,1	0,7	-3,0	6,7	-8,4	-5,0

Note: 1) Reference period: 1979-2002.

Considerable changes in education also came into play during this period.[16] All the countries increased the average number of years of formal education of the working age population, expanding human capital stocks (cf. Table 34). However, the rates at which this increase took place differed significantly across countries. Korea shows once more an impressive performance, along with Spain, Italy and Taiwan. Portugal, on the other hand, presents the weakest increase in the average number of years of formal education, and is the only country which widens the gap in comparison to the countries in cluster 2. This strengthens the hypothesis put forward earlier, according to which the relative inertia in educational achievements has played a significant role in hampering wider changes in the composition of the economy.

Table 34: Average number of years of formal education of the working age population (25-64 years) (1979-2003)

	Years		**% change**	**Education gap[1]**		
	1979	**2003**	**1979-2003**	**1979**	**2003**	**Var. (years)**
Austria	10,3	12,2	**18,8**	-0,3	-0,1	0,2
Finland	9,5	12,5	**31,3**	-1,1	0,1	1,2
Greece	7,9	10,4	**32,0**	-2,7	-1,9	0,8
Ireland	8,4	10,9	**29,7**	-2,2	-1,5	0,7
Italy	7,3	10,4	**42,7**	-3,3	-1,9	1,4
Japan	10,1	12,7	**25,8**	-0,5	0,3	0,8
Korea	6,8	10,8	**59,3**	-3,8	-1,5	2,3
Portugal	**6,9**	**8,0**	**16,6**	**-3,7**	**-4,3**	**-0,6**
Spain	6,3	9,7	**54,4**	-4,3	-2,6	1,7
Taiwan	6,4	8,8	**38,9**	-4,2	-3,5	0,7

Notes: 1) The education gap is defined as the difference between the country's value and the average of countries included in cluster 2.

The significant changes taking place during the period under study in each of the individual dimensions considered led to a substantial modification in the comparative situation of countries. This becomes more evident when cluster analysis is performed once more, this time considering 2003 figures.[17] In this case, the splitting of countries into two clusters is no longer clear-cut (cf. Figure 12). As a matter of fact, the clustering solution is somewhat unsatisfactory, since it does not provide a strong classification. A quite different outcome is now also admissible, characterised by four clusters with the following composition:

[16] In order to get a full series of education data we extended Bassanini and Scarpetta's (2001) estimates up to 2003 using the author's methodology. We also applied this procedure to Korean and Taiwanese data, considering Barro and Lee's (2001) estimates. See Annex 13 for the complete data set and for details in the calculus procedure.
[17] Data used to perform cluster analysis for 2003 can be found in Annex 14.

1) Greece, Spain, Portugal, Austria, Japan, Korea, Italy and Taiwan;
2) Australia, Canada, Norway;
3) Denmark, Netherlands, US, France, UK, Finland, Sweden, Belgium and Germany;
4) Ireland.

Overall there is an increase in the countries' dissimilarities and some countries experience considerable changes, moving to very different clusters in comparison to the initial ones. This is the case of Finland, for example, and Ireland, which now stands alone in cluster 4.[18]

With reference to the Portuguese case, the situation of relative proximity to Spain and Greece is maintained, although the relative distances widen across countries. More importantly, there is a substantial increase in dissimilarity with regard to Korea, which was initially very close. This latter country experiences a profound change, and is now quite distant from Portugal and Spain (very similar countries in 1979), and converging to Japan, which was initially at a considerably distance.

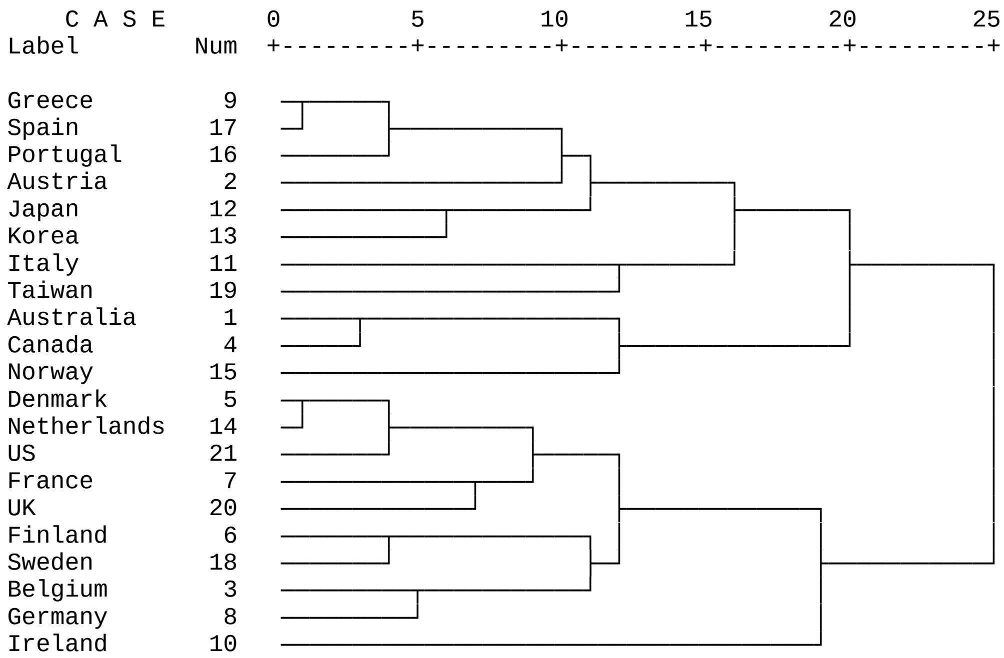

Figure 12: Dendrogram using average linkage between groups and the cosine similarity measure (2003)

[18] As already noted, the initial inclusion of Finland in the cluster of relatively less developed countries was due to differences in the composition of economic activity, and particularly its stronger reliance on low-skill and supplier-dominated industries, and correlative deficit in high-skill and high technological opportunities industries. An analysis of the overall evolution of the country during this period, and particularly, of Tables 31, 32 and 33, reveals, however, that Finland underwent profound structural transformation between 1979 and 2003, coming quite close to the structure of the countries initially included in cluster 2, while maintaining relative closeness in relation to the other dimensions considered (education and per capita income).

7.4. Regression analysis

The descriptive analysis developed so far suggests that an explanation for the widely different growth patterns observed between 1979 and 2003 for countries included in the relatively less developed cluster may reside in their differing ability to promote changes in the economic structure towards more skilled and technology-intensive activities. In the present section we go a step further in the examination of this hypothesis by regressing actual productivity growth in the VAB shares of some of the categories in the considered taxonomies (i.e., specialised suppliers, science-based, supplier-dominated and high-skill industries), and their changes over time. More precisely, we estimate the following fixed effects panel regression:

$$\Delta y_{it} = \alpha + \delta_j \Delta x_{i,t-1} + \chi_j x_{i,t-1} + \gamma EDUC_{i,t-1} + \beta \Delta EDUC_{i,t-1} + \varphi INV_{i,t-1} + \psi \Delta INV_{i,t-1} + \omega EMP_{it} + \eta_t + \mu_i + \varepsilon_{it} \quad (1)$$

i = country index ($i = 1, \ldots, N$)

j = industry group(s) considered

t = time

ε_{it}= error term

In this expression, y_{it} is the logarithm of value added over employment (in hours) for country i in period t, N is the number of countries and x_i represents the VAB shares of the selected groups of industries in country i. The symbol Δ denotes first differences, for example, Δy_{it} is the change in the logarithm of value added per hour over a one-year period, or y_{it} - $y_{i,t-1}$.[19] Industry group shares (x_i) and their annual changes (Δx_i) are expressed in lagged values so that causality runs from industrial structure to productivity growth, and not the other way around. δ and χ are expected to be positive when industry shares refer to high-skill, specialised supplier and science-based industries, given their high productivity growth rates and the indirect positive effects they generate to other industries, through producer and user-related spillovers. More precisely, products and innovations originating in skills and technology-intensive sectors are likely to be conducive to productivity gains in other industries which use these products or find new applications for the innovations developed, and therefore increase productivity. Inversely, a negative sign is expected when supplier-dominated industry shares are considered.

[19] Although other time intervals could be considered, such as 5-year or 10-year intervals, only the use of annual data can take into account all the available information.

A number of control variables are also included. The first of such variables is education (*EDUC*), expressed by the average years of education of the working age population, and its growth rate ($\Delta EDUC$). Once again these variables are expressed in lagged values in order to mitigate possible endogeneity problems. An extensive and ever-growing literature (e.g., Temple 1999, 2000; Lucas, 1998; Nelson and Phelps, 1966) attests the virtuous effects of the rise in human capital stock on growth, and therefore we expect both γ and β to be positive.

The influence of physical capital accumulation is also taken into account through the inclusion of both the lagged values of the share of investment in GDP ($INV_{i,t-1}$) and its growth rate. The renewal rate of capital stock may influence positively productivity growth in various ways, namely through the embodiment of technology and innovation,[20] and consequently coefficients φ and ψ are expected to be positive.

Finally, we control for business cycle effects including time dummies (η_t), and using the employment rate (*EMP*) to account for country-specific economic fluctuations.[21] Given the procyclical nature of labour productivity, we expect ω to be positive.

The estimations are carried out considering the sample of countries included in cluster 1 over the 1980-2003 period.[22] The data source of industry VAB shares is the 60-Industry GGDC Database. Data on education were taken from Bassanini and Scarpetta (2001) and Barro and Lee (2001), and extended up to 2003 using OECD *Education at a Glance* data, as indicated in the previous section. Data on GDP and gross fixed capital formation are from the *OECD Factbook 2008: Economic, Environmental and Social Statistics*, with the exception of Taiwan, whose data was taken from the Taiwanese government official statistics.[23] Finally, employment rates are taken from the *World Economic Outlook Database (April 2008)*, developed by the International Monetary Fund.

Table 35 presents the estimation results.

[20] See in this respect Kaldor (1957) and, more recently, DeLong and Summers (1991).
[21] Both variables have been used previously in the literature to account for the influence of business cycle effects. See, for example, Peneder (2003).
[22] One observation was lost (1979), because data on employment and investment variables was only available from 1980 onwards. Data regarding Taiwan, Korea and Japan refer to the 1980-2002 period.
[23] Available on-line at http://eng.dgbas.gov.tw.

Table 35: The effect of structural change on productivity growth

Variable	Parameter	(i)		(ii)		(iii)		(iv)	
Δx_high skill *(t-1)*	δ			0.139**	(2.188)			0.146*	(1.868)
Δx_science-based *(t-1)*	δ					0.001	(0.035)	-0.001	(-0.063)
Δx_spec. supplier *(t-1)*	δ					0.006	(0.186)	0.005	(0.171)
Δx_sup.-dominated *(t-1)*	δ					-0.0983	(-1.399)	-0.0172	(-0.208)
x_high-skill *(t-1)*	χ			0.125	(1.008)			-0.253	(-1.315)
x_science-based *(t-1)*	χ					0.351**	(2.545)	0.316**	(2.182)
x_specialised supplier *(t-1)*	χ					-0.122	(-0.753)	-0.058	(-0.356)
x_supplier-dominated *(t-1)*	χ					-0.148	(-1.279)	-0.322**	(-2.021)
$EDUC_{t-1}$	γ	-0.504	(-0.961)	-0.544	(-1.044)	-0.421	(-0.745)	-0.545	(-0.962)
$\Delta EDUC_{t-1}$	β	0.037	(0.163)	0.105	(0.437)	0.128	(0.531)	0.109	(0.450)
INV_{t-1}	φ	-0.042	(-0.564)	-0.028	(-0.373)	0.044	(0.544)	0.076	(0.905)
ΔINV_{t-1}	ψ	0.072***	(2.674)	0.077***	(2.903)	0.066**	(2.387)	0.054*	(1.887)
EMP	ω	0.001	(0.013)	-0.023	(0.7410)	-0.103	(-1.342)	-0.083	(-1.090)
R^2		**0,52**		**0,55**		**0,56**		**0,57**	
Nr. of observations		**227**		**227**		**227**		**227**	
Nr. of countries		**10**		**10**		**10**		**10**	

Notes: The dependent variable is the change in the logarithm of value added per hour worked; Δvar, variable in first differences; $\Delta var_{(t-1)}$ lagged differences. Time dummies (η_t) included. *T*-values between brackets. ***, **, * Significance at the 1, 5 and 10% significance level.

The results confirm our hypothesis according to which structure influences (labour) productivity growth. In global terms, the coefficients for the structural variables turn up with the expected signs and are significant, even when all the variables are included in the regression (Specification iv). The lagged change in high-skill industries share affects positively labour productivity growth, which also applies with respect to the lagged share of science-based industries. Regarding the latter, an increase in one percentage point results in additional productivity growth of about 0.3 percentage points (Specifications iii and iv), which is a rather strong impact. In contrast, and as expected, an increase in the VAB share of supplier-dominated industries results in a decline in labour productivity growth.[24] Only variables for specialised supplier industries are deemed to be non-significant.

Regarding the conditioning variables, only the coefficient for the lagged variation of the share of investment in GDP turns up significant. This variable shows strong robustness, presenting coefficients ranging between 0.05 and 0.08, approximately, which are significant in all the specifications estimated. The employment rate, used to control for the influence of country-specific business cycles, is always non-significant.

In terms of education, the level variable (EDUC) presents a negative sign, although it is never statistically significant. When variation in educational achievements is considered, however, the coefficient for the education variable turns up with the right sign, although it is not statistically significant. The negative sign (although insignificant) of the EDUC variable may be due to the fact that countries with relatively poor educational achievements (in levels) in our sample were simultaneously the ones experiencing higher productivity growth performances. Furthermore, the overall counterintuitive result of education having an insignificant impact on productivity growth may result from the fact that our education indicator takes solely into account advances in formal education, excluding other forms of learning, and neglecting, at the same time, differences in the quality of educational attainments. [25]

The positive effect of both high-skill and science-based industries on productivity growth, controlling for the influence of other variables that might also influence growth, and particularly its strong impact, considerably above investment in physical capital, gives empirical support to our hypothesis according to which substantial benefits have

[24] The coefficient regarding this variable turns up insignificant, however, in specification iii.

[25] The insignificant contribution of human capital to productivity growth appears many times in the literature, especially when panel data is used. See Temple (1999) for a detailed analysis of the possible causes behind this counterintuitive result.

accrued to countries that successfully changed their structure towards more technologically advanced industries. Moreover, the fact that two of the three industries included within the science-based group are ICT-related industries ("Radio and television receivers", and "Other electronic machinery and apparatus") seems to be in global agreement with the techno-economic paradigm conceptualisations developed within the evolutionary strands previously described in Part I. As indicated earlier, those theories strongly emphasise the links between the *local* development of industries associated with the dominant technological paradigm, which in this period is represented by the so-called 'electronic revolution', and the overall growth prospects of the economy. Technical change is conceived as a cumulative and path-dependent 'learning' process that is strongly embedded in organisational and institutional structures. Consequently, in order to fully exploit the benefits arising from new techno-economic paradigms, changes must occur in the industrial composition of the economy, along with wider changes in institutional and socio-economic levels.

We now investigate further this hypothesis by estimating Equation (1) once more, this time considering the ICT taxonomy used by van Ark and Bartelsman (van Ark and Bartelsman, 2004), which ranks industries according to their production or use of ICT.[26] Table 36 presents the results.

[26] The classification of the list of sectors considered according to this taxonomy can be found in Annex 15.

Table 36: The effect of structure and structural change on productivity growth _ICTs

Variable	Parameter	(v)		(vi)		(vii)		(viii)		(ix)		(x)		(viii)	
Δx_ICTPM $(t-1)$	δ	-0.008	(-0.616)			-0.004	(-0.295)							-0.006	(-0.396)
Δx_ICTPS $(t-1)$	δ			0.056**	(2.185)	0.050*	(1.931)							0.049*	(1.807)
Δx_ICTUM $(t-1)$	δ							-0.001	(-0.020)			-0.007	(-0.192)	0.011	(0.288)
Δx_ICTUS $(t-1)$	δ									-0.037	(-0.707)	-0.040	(-0.722)	-0.021	(-0.375)
x_ICTPM $(t-1)$	χ	0.361*	(1.675)			0.311	(1.392)							0.346	(1.450)
x_ICTPS $(t-1)$	χ			-0.218	(-0.548)	-0.324	(-0.802)							-0.328	(-0.742)
x_ICTUM $(t-1)$	χ							-0.106	(-0.416)			0.042	(0.122)	-0.139	(-0.379)
x_ICTUS $(t-1)$	χ									0.086	(0.724)	0.098	(0.590)	-0.022	(-0.125)
$EDUC_{t-1}$	γ	-0.653	(-1.228)	-0.381	(-0.725)	-0.538	(-1.003)	-0.526	(-0.987)	-0.566	(-1.058)	-0.556	(-1.028)	-0.575	(-1.040)
$\Delta EDUC_{t-1}$	β	0.067	(0.288)	0.072	0.303	0.114	(0.473)	0.014	(0.057)	0.052	(0.223)	0.064	(0.255)	0.088	(0.342)
INV_{t-1}	φ	-0.011	(-0.139)	-0.037	(-0.500)	-0.008	(-0.097)	-0.053	(-0.671)	-0.050	(-0.644)	-0.048	(-0.597)	-0.010	(-0.126)
ΔINV_{t-1}	ψ	0.069**	(2.554)	0.066**	(2.378)	0.061**	(2.192)	0.074***	2.694	0.076***	(2.776)	0.076***	(2.718)	0.064**	(2.186)
EMP	ω	-0.023	(-0.337)	0.002	(0.036)	-0.012	(-0.171)	0.019	(0.236)	0.013	(0.179)	0.007	(0.078)	0.005	(0.054)
R^2		**0,54**		**0,54**		**0,55**		**0,53**		**0,53**		**0,53**		**0,55**	
Nr. of observations		**227**		**227**		**227**				**227**		**227**		**227**	
Nr. of countries		**10**				**10**		**10**		**10**		**10**		**10**	

Notes: The dependent variable is the change in the logarithm of value added per hour worked; Δvar, variable in first differences; $\Delta var_{(t-1)}$ lagged differences.
ICTPM- ICT producing manufacturing; ICTPS – ICT producing services; ICTUM – ICT using manufacturing; ICTUS – ICT using services. Time dummies (η_t) included.
T-values between brackets. ***, **, * Significance at the 1, 5 and 10% significance level.

As in the previous regressions, an increase in the investment growth rate exerts a positive influence on productivity growth. More precisely, an increase in the growth rate of investment by one percentage point amounts to an increase in labour productivity growth of about 0.07 percentage points. The other control variables are once again statistically insignificant.

The contribution of the lagged share of ICT-producing manufacturing industries is significantly positive when taken in isolation, and has a strong impact on the growth of productivity. A difference of one percentage point in the ICT-producing manufacturing lagged share gives a difference of over 0.3 percentage points in the annual productivity growth rate. However, when ICT-producing services are included, the χ coefficient ceases to be significant at the conventional significance levels, although keeping the correct sign and the relative magnitude. This might be due to a multicollinearity problem.

The coefficients for the lagged change in the share of ICT-producing services industries are always positive and statistically significant. In contrast, there is no significant impact of ICT-using industries on annual productivity growth.

Taken as a whole, these results lend some support to the view that ICT-related industries are strategic branches of economic activity, but only when *producing industries* are considered. This accentuates the fact that most spillovers from advanced industries, and particularly ICT-producing industries are *local* and national in character, and therefore that ‘buying’ is not the same as ‘producing’. Hence, our results may be seen as reinforcing previous empirical evidence indicating that the gains from the diffusion of new technologies are especially relevant in economies which produce these technologies (e.g., Henderson *et al.*, 1993; Maurseth and Verspagen, 1999).

This being the case, the relative weakness of Portugal in the specific ICT-producing area, and in technology and skill-intensive industries in general, will probably imply a reduction in its long-term growth prospects.

This result does not necessarily contradict the findings of Barros (2002), according to which the convergence of Portugal and other cohesion countries (Spain and Greece) in comparison to more developed European countries has been mostly achieved through traditional, rather than progressive, industries. In fact, this seems to be the most probable outcome, given the difficulties experienced by these countries in promoting more radical changes in the structure of their economies. [27]

The evidence found in the present work reveals furthermore that the transformation required in order to fully exploit the benefits from the recent technological breakthroughs was not unreachable. Other countries that started in very similar conditions to the Portuguese case with regard to education, per capita income, labour productivity, and the composition of economic activity, were able to effectively promote remarkable changes in the composition of their economies and experience impressive rates of productivity growth. The most striking case is Korea. Having a very similar situation relative to Portugal in the late 1970s, Korea boosted major transformations in education and in the composition of economic activity which are probably at the basis of its spectacular growth performance. Contrarily to the conclusions presented in other studies (e.g., Barros, 2002), we therefore argue that the implementation of industrial policies aimed at changing the pattern of specialisation towards the promotion of leading technology sectors[28] may pay-off. Naturally, for these policies to become effective, a drastic change has to occur in terms of Portuguese educational attainments. Although we do not find a significant relationship between the growth of the human capital variable and the increase in the rate of productivity growth,[29] it is obvious that average educational levels have to rise, if a specialisation in skills and technology-intensive industries is to be achieved. As seen previously (cf. Table 34), Portugal was the only country during the 1979-2003 period that did not narrow the education gap compared with the cluster 2 reference group. It is also the country that presents in 2003 the lowest average number of years of formal education of the working age population. Narrowing the gap vis-à-vis the other countries seems to be a national imperative, not only to improve productivity in the existing industries, but also as a pre-requisite to promote significant structural change in the Portuguese economy and benefit from the consequent productivity gains.

[27] We wonder, however, if this result would be maintained if another 'cohesion country', namely Ireland, were included in the analysis.
[28] Not necessarily ICT industries, since leading technologies change over time.
[29] See footnote 25 for possible causes explaining this counterintuitive result.

Conclusion

The main purpose of the present study was to contribute for a deeper understanding of the growth process of the Portuguese economy over the last three decades, by explicitly taking into account the relationship between changes occurring at the industry level of the economy and overall macroeconomic changes. A few empirical studies had addressed this issue for the Portuguese case, but they have been mostly concentrated on the assessment of the relative contribution of the three macro-sectors (primary, manufacturing and services), and on the analysis of the contribution of manufacturing industries to aggregate productivity growth, without taking explicitly into account the relationship between structural change and technological progress. Furthermore, given the accounting nature of the methodologies used, the analysis was performed in essentially descriptive terms, with no attempt to analyse causality chains, or to assess the influence of additional variables and of their interaction with structural change in the growth process. In this context, a deeper understanding of the relationship between technology, structural change and economic growth for the Portuguese economy seemed to be in order. We specifically addressed this issue by attempting to provide answers to the following questions:

- To what extent has structural change influenced Portuguese aggregate productivity performance over the last three decades?
- Which industry branches have contributed most extensively to overall economic growth? Is there any relationship with their technological content?
- How does the Portuguese experience compares with other countries that in the late 1970s shared a relatively similar economic structure? Can the differences in overall economic performance among these countries be explained by different paces of structural change, especially in what relates to the relative importance of technologically-oriented sectors?

The empirical analysis of the connection between processes of change at micro and industrial levels and overall macroeconomic dynamics has a long tradition in the economic literature. Early applied work on the topic can be found as far back as Fabricant’s (1942), Maddison’s (1952) and Kuznets’ (1961) works. More recently, empirical work on the field has shown a new impetus, which is apparent by the proliferation of studies focusing on the role played by technical change as a major source of structural transformation, and on the relationship between economic growth and technologically leading industries (e.g., Quah, 1997; Fagerberg, 2000; Timmer and Szirmai, 2000; Peneder, 2003). The present work can be included in this latter stream of research, by attempting to explore technological aspects of structural change and their connection with economic growth, taking the Portuguese economy as the benchmark case.

Being essentially an empirical work, the investigation carried out has nevertheless been related to a specific theoretical frame of analysis, included within the structural change approach. This approach is based on the assumption that the infinite multiplicity of reality can be studied by focusing on a relatively small number of groups or activities that comprise the economic system, and thus form the economic structure. In contrast to mainstream (neoclassical) theories of economic growth, which exclude almost entirely structural change from the analysis, this approach addresses explicitly the connection between processes of change at micro and industrial levels and overall macroeconomic dynamics. This allows for a more realistic account of the process of economic growth, while emphasizing, at the same time, the sequential and path-dependent nature of economic change.

In order to organize the literature on the field and clarify the theoretical foundations of our empirical work, in Part I a comprehensive survey of the economic literature on structural change was performed, covering the early foundations until the more recent years. Despite the long tradition of structural change analysis in the economic literature, to the best of our knowledge, such a survey had not yet been undertaken in the literature. In order to accomplish such a formidable task, we started by briefly reviewing the earlier foundations of structural change analysis, covering the Classical authors and Schumpeter (Section 1). We then investigated and discussed the relatively separate fields of pure theoretical and applied/historical approaches within the realm of structural change analysis (Section 2). Finally in Section 3, and which is probably the most innovative element of the survey undertaken, we provided an interpretation for the recent upsurge of interest in the field, taking into account the changes that have been occurring both at the general level of economic theory and within the realm of structural change analysis. In our perspective, the rise of interest on the topic from the late 1980s onwards is closely related with an attempt to develop an alternative to mainstream economics for the analysis of the relationship between technical change and economic growth. We contend that the changing perspective of economic theory relative to the study of technical change in the 1980s and 1990s has opened the way for the resurgence of structural change analysis as a powerful analytical tool for the study of innovation and technical change. Deficiencies associated with blind aggregate production function models have made clear the necessity of an approach capable of establishing links between changes at the level of microstructures and higher-level changes, as that developed by the structural change perspective.

The survey of the literature on the economics of structural change allowed us to locate the research interests of the present study within the economic realm of structural change analysis. As indicated earlier, the main purpose of the present work was to investigate the impact of structural and technical change on Portuguese economic growth in the last three decades. The relationship between innovation, technical change and the restructuring of the economy constitutes the core of analysis of neo-Schumpeterian streams of research, which thus constitute the theoretical foundation of the present work. Neo-Schumpeterian theory elaborates on the original contribution of Schumpeter relating innovation with renewed economic growth and 'creative destruction'. A major emphasis is put on the relationship between the emergence of major technological breakthroughs and the restructuring of the techno-economic and the socio-institutional spheres of the economy. With respect to the sectoral composition of the economy, the introduction of a new technological paradigm originates significant changes, with the dynamic set of industries that is more closely related with its exploitation assuming progressively higher importance and stimulating growth, whereas sectors associated with older technologies see their relative influence diminish. There seems to be, therefore, a close correspondence of theoretical insights from this stream of research and our own research concerns.

In order to answer to the aforementioned research questions, in Part II we used shift-share analysis, which is a well-suited technique to analyze the restructuring of the economy in terms of the (possibly) higher significance of leading technological sectors, and make a preliminary assessment of the impact of structural change on economic growth. In relation to other studies that had already applied this technique in the context of the Portuguese economy, our analysis presented a number of significant improvements. First, and most importantly, a wider perspective on the measurement of structural change effects has been adopted, by considering a more complete structural change measure that accounts simultaneously for shifts in labour and capital. This seems to be particularly important when taking into account the Portuguese case, which, as indicated in Part II, has continuously experienced capital deepening during the period under study. Secondly, we used a rather high sectoral disaggregation level, extending the higher breakdown of economic activity to the services sector. We also applied shift-share analysis to a relatively long time-span that covers the last thirty years, and provided a contextualisation of our findings taking into account the different phases of growth of the Portuguese economy. Moreover, we addressed explicitly the connection between technological progress and structural change by using industrial taxonomies that reflect the technological and innovativeness features of industries. Finally, we improved the accuracy of results by taking into account Verdoorn effects in the measurement of the overall impact of structural change on total factor productivity growth.

The adoption of a more complete approach in the measurement of the impact of structural change on Portuguese economic growth has led to an entirely new perspective regarding the sources of Portuguese productivity growth over the last three decades. The explicit consideration of capital movements across sectors, together with the use of a relatively high sectoral desegregation level, led to the conclusion that structural change was the major source of productivity growth during the period under analysis, well above intra-productivity gains. Furthermore, our results reveal that whereas the intra-branch component had a marked pro-cyclical behaviour, reaching the highest values in expansionary periods, and presenting negative values in phases of economic recession, the structural change component has been rather stable, contributing positively to total factor productivity growth during the whole period under study, although its influence has declined in the more recent years. The results change somewhat when the Peneder (2002) and Tidd *et al.* (2001) taxonomies are used in the breakdown of economic activity. The structural change component ceases to be the dominant effect and reduces its influence in all subperiods under study, despite maintaining an overall significant impact. These findings suggest that most of the structural change gains experienced by the Portuguese economy between 1977 and 2003 took place within the broad industry groups of the selected taxonomies. As a matter of fact, when the employment and VAB shares of these groups are taken into consideration, it becomes clear that they changed very little during the period under study. In particular, the industry groups that accounted for the overwhelming part of Portuguese output and labour in 1977 (supplier-dominated and information-intensive industries), showed only modest changes. The same happens with regard to industry groups organised in terms of the qualification of the workforce, despite the overall positive movement towards a relative decline of low-skill industries and the correspondent rise of higher-skill industries. In other words, the Portuguese economy was able to reap some gains from the movement of capital and labour towards industries with a higher level, or a higher growth rate of productivity, but these gains occurred within the broad industry groups considered in the taxonomies, which means that the core characteristics of the Portuguese economic structure, namely the strong bias towards traditional and low-skilled activities, were maintained.

Part III of the present work complemented the shift-share analysis by adopting a wider perspective, using econometric methods and analysing the Portuguese case with reference to a number of other countries. The inclusion of capital in the measurement of productivity growth in Part II has shown that the performance of the Portuguese economy was globally mediocre in the period under scrutiny, which was characterised by very slow rates of TFP growth. In light of this result, in the last part of the thesis we investigated whether the disappointing performance of Portuguese growth had been, to some extent, related to the country's relative incapacity to boost major changes in the composition of economic activity and to benefit from the more technologically dynamic industries. According to the neo-Schumpeterian theses, there are indeed reasons to expect technological leading industries, and particularly those more closely related to new technological paradigms, to have a major influence on growth. We therefore included in the analysis a number of countries with structural characteristics similar to the Portuguese case in the late 1970s, and examined their performances between 1979 and 2003 in terms of economic and productivity growth, relating the evidence found with changes taking place in the composition of their economies. The preliminary descriptive analysis undertaken revealed that rapid growth experiences were intimately connected with strong structural transformation, measured by the computation of Nickell and Lilien indices. Furthermore, the countries with faster structural change were also the ones experiencing more profound increases in the relative importance of skills and innovation-intensive industries, and the largest decreases in low-skill and supplier-dominated industries. These results suggested that an explanation for the widely different growth patterns observed between 1979 and 2003 for countries which had structural characteristics similar to Portugal in the late 1970s, might reside in their differing ability to promote changes in the economic structure towards more skilled and innovation-intensive activities. This hypothesis has been put under examination in the last section of Part III, through the estimation of a panel data regression, considering fixed effects methods. This regression took the actual productivity growth of countries as the dependent variable, and the VAB shares of some of the categories in the considered taxonomies, and their changes over time, as the explanatory variables, controlling for the influence of other variables that might also influence growth, such as education and investment in physical capital. According to our findings, high-skill and science-based industries have a positive and significant impact on productivity growth, considerably above the influence of investment in physical capital. The results thus provide empirical support to the hypothesis according to which substantial benefits have accrued to countries that successfully changed their structure towards more technologically advanced industries. Moreover, when ICT-related industries – the industries underlying the technological revolution of the period under analysis – are explicitly included in the estimation, the coefficients on ICT-producing industries are positive and statistically significant. This result lends some support to the view that ICT-related industries are strategic branches of economic activity, but only when *producing industries* are considered. This accentuates the fact that most spillovers from advanced industries, and particularly ICT producing industries are *local* and national in character, and therefore that 'buying' is not the same as 'producing'. As indicated earlier, this being the case, the relative weakness of Portugal in the specific ICT-producing area, and in technology and skill intensive industries in general will probably imply a reduction in its long-term growth prospects.

The evidence found reveals furthermore that the transformation required in order to fully exploit the benefits from the recent technological breakthroughs was not unreachable for the Portuguese case, given that other countries that started in conditions very similar to Portugal were able to effectively promote remarkable changes in the composition of their economies and experience impressive rates of productivity growth. We therefore argue that the implementation of industrial policies aimed at changing the pattern of specialization towards the promotion of technology-leading sectors may in fact pay-off. Naturally, for these policies to become effective, a drastic change has to occur regarding Portuguese educational attainments. Although we do not find a significant relationship between the growth of the human capital variable and the increase in the rate of productivity growth, it is obvious that average educational levels have to rise, if a specialization in skills and technology intensive industries is to be achieved. Portugal presented in 2003 the lower average number of years in formal education of the working age population of all countries included in the analysis, and according to the OECD *Education at a Glance*, the achievements of Portuguese students measured by PISA (the OECD Programme for International Student Assessment) are among the weakest in the OECD. Narrowing the gap vis-à-vis the other countries seems therefore to be a national imperative, not only to improve productivity in the existing industries, but also as a pre-requisite to promote significant structural change in the Portuguese economy and benefit from the consequent productivity gains.

Directions for future research

In our perspective, the investigation carried out has proven useful in providing answers for the major research questions addressed, contributing in this way for a greater understanding of the growth process of the Portuguese economy over the last three decades. In attempting to fulfil our research goals, we have also obtained a number of by-product results, such as the measurement of capital services at the sectoral level for the Portuguese economy over the 1977-2003 period, and a more accurate measurement of Portuguese TFP growth.[1] Nevertheless, there are several ways in which the present investigation can be improved. With regard to capital, which influences the quality of TFP results and of its decomposition in terms of intra-sectoral and structural change effects, there are several improvements that can be made. Better measures will be obtained if service lives of assets specific to the Portuguese case are used, and if assets include a separate category for computers and software investment. With regard to the latter, although the necessary data are not immediately available in the Portuguese case, they probably can be estimated by using supply and use tables and input-output tables. Furthermore, we considered that depreciation rates did not vary over time, and used a price index to deflate investment which did not correct for quality change. The relaxation of some of these restrictive assumptions will naturally provide better measures of capital services.

[1] Despite their major importance in the analysis of growth patterns, to the best of our knowledge, until now no attempt had been made to provide a measure of capital services for the Portuguese economy.

With regard to the specific calculus of TFP change, there are also significant improvements that can be made. They include the adoption of a more sophisticated methodology for determining TFP growth, and the use of a more complete measure of the labour input. As indicated earlier, ideally the labour input should take into account quality changes in labour force, which were overlooked in the present work. Once more, information required for an improvement of this kind is not automatically available for the Portuguese case, but some progress can possibly be made if an estimation of experience, education, and gender composition of the work force is taken into account in the measurement of labour.

Finally, with respect to the last part of the thesis, some improvements can also be attempted. The econometric estimation procedure, for example, could probably benefit from the conduction of sensitivity analysis, in order to assess the robustness of results to variation of country coverage. The use of different proxies for the educational variable may also be used to check for the resilience of our counterintuitive result according to which education has an insignificant impact on productivity growth.

In more general terms, important advances can be also achieved by complementing our results with the analysis of changes occurring at the micro level of the economy. The focus of our work has been on the impact of variations at the level of individual industries and industry groups upon aggregate development, but this should not obscure the relations between micro and meso levels of the economy. Therefore, a quite interesting and ambitious plan for complementary research would be to consider also the connection between heterogeneity at the firm level and relative performances at the meso and macro levels of the economy.

References

Abramovitz, M. (1986), ‘Catching Up, Forging Ahead, and Falling Behind’. *Journal of Economic History*, 46(2): 385-406.

Abramovitz, M. (1994), ‘The Origins of the Postwar Catch-Up and Convergence Boom’, in Fagerberg, J.. B. Verspagen and N. von Tunzelmann (eds.) The Dynamics of Technology, Trade and Growth, Aldershot: Edward Elgar, 21-52

Afonso, O. (1999), *Contributo do comércio externo para o crescimento económico português, 1960-93*, Conselho Económico e Social, Lisbon.

Aghion, P., Howitt, P. (1992), ‘A Model of Growth Through Creative Destruction’, *Econometrica*, vol. 60 (2): 323-351

Aguiar, A. and M. M. F. Martins (2004), 'O Crescimento da Produtividade da. Indústria Portuguesa no Século XX'. FEP Working Paper nº 145, Faculdade de Economia do Porto

Aldenderfer, M. S., and R. K. Blashfield (1985), *Cluster Analysis*. Newbury Park: Sage Publications.

Amable, B. (1993), ‘Catch-up and convergence: a model of cumulative growth’, *International Review of Applied Economics*, vol. 7 (1): 1 - 25

Amable, B. (2000), ‘International specialisation and growth’, *Structural Change and Economic Dynamics*, vol. 11(1-2): 413-431

Amaral, L. (2002), How a country catches up. Explaining economic growth in Portugal in the post-war period, Unpublished PhD Dissertation, European University Institute, Florence.

Amendola, M. (1984), ‘Towards a dynamic analysis of the ‘traverse’’, *Eastern Economic Journal*, 10: 203-10.

Amendola, M., Gaffard J.L. (1998), *Out of Equilibrium*, Oxford: Clarendon Press.

Amendola, M., Gaffard J.L., Saraceno F. (2005), ‘Technical Progress, Accumulation and Financial Constraints: Is the Productivity Paradox Really a Paradox?’, *Structural Change and Economic Dynamics*, 16: 243-261.

Andergassen, R., Nardini, F. (2005), Endogenous innovation waves and economic growth, *Structural Change and Economic Dynamics*, vol. 16 (4): 522-539

Andersen, B., Howells, J., Hull, R., Miles, I. and Roberts, J. (eds) (2000), *Knowledge and Innovation in the New Service Economy*, Cheltenham, Edward Elgar

Andersen, E.S. (2001), 'Satiation in an evolutionary model of structural economic dynamics', *Journal of Evolutionary Economics* 11, 143–164.

Andreosso-O'Callaghan, B. and Y. Guokiang (2002), 'Sources of output change in China: 1987-1997: Application of a structural decomposition analysis', *Applied Economics*, 34:2227–2237.

Araújo, R., Teixeira, J. (2002), 'Structural change and decisions on investment allocation', *Structural Change and Economic Dynamics*, vol. 13: (2): 249-258

Archibugi, D. (2001), 'Pavitt's Taxonomy Sixteen Years on: A Review Article', *Economics of Innovation and New Technology*, 10, 5: 415-425.

Ark, B. van (1996), 'Sectoral growth accounting and structural change in post-war Europe', in van Ark, B., Crafts, N. (Eds.) *Quantitative Aspects of Post-War European Economic Growth*. Cambridge University Press, Cambridge, 84-164.

Ark, B. van and E. Bartelsman (2004), 'Fostering excellence: Challenges for productivity growth in Europe', Background document for the Informal Competitiveness Council Maastricht, 1st-3rd July 2004, Netherlands' Ministry of Economic Affairs.

Ark, B. van, L. Broersma and G. de Jong (1999), 'Innovation in Services. Overview of Data Sources and Analytical Structures', Research Memorandum GD-44, Groningen Growth and Development Centre.

Arrow, K.J. (1962), 'The Economic Implications of Learning by Doing', *The Review of Economic Studies*, Vol. 29, No. 3: 155-173.

Arthur, W.B. (1988), 'Self-Reinforcing Mechanisms in Economics', in P.W. Anderson, K.J. Arrow and D. Pines (eds.), *The Economy as an Evolving Complex System*, Addison Wesley.

Arthur, W.B. (1989), 'Competing Technologies, Increasing Returns and Lock In by Historical Events', *Economic Journal*, 99: 116-131.

Arthur, W.B. (1994), *Increasing returns and path dependency in the economy,* The University of Michigan Press, Ann Arbor.

Ascher, W. (1996), ‘The evolution of post-war doctrines in development economics’, in A.W. Coats (ed) *The Post-1945 Internationalization of Economics*, Durham, NC: Duke University Press.

Backhouse, R.E. (1990) *Economists and the Economy: The Evolution of Economic Ideas*. Rutgers, NJ: Transaction Press.

Bai, J, and P. Perron (2003), ‘Computation and Analysis of Multiple Structural Change Models’, *Journal of Applied Econometrics*, 18: 1-22.

Bai, J. and P. Perron (1998), ‘Estimating and Testing Linear Models with Multiple Structural Changes’, *Econometrica*, 66: 47-78.

Baily, M. and Gordon, R. (1988), ‘The Productivity Slowdown, Measurement Issues, and the Explosion of Computer Power’, in Brookings Papers on Economic Activity, W. C. Brainard, & G. L. Perry. The Brookings Institution, Washington, DC.

Baldone, S. (1996) 'Vertical Integration, the Temporal Structure of Production Processes, and Transition between Techniques', in M.A. Landesmann and R. Scazzieri (eds.), *Production and Economic Dynamics*, Cambridge, Cambridge University Press: 81-104.

Baranzini, M. and R. Scazzieri (Eds.) (1990) *The Economic Theory of Structure and Change*, Cambridge: Cambridge University Press.

Barata, E. (2002), *Solid Waste Policy in Portugal: An environmental I/O approach*, PhD Thesis, SPIRE, Keele University, UK.

Barff, R. and P. III Knight (1988), ‘Dynamic shift-share analysis’, *Growth and Change*, Vol. 19, No.2: 1-9

Barreto, J. (1990), ‘Os primórdios da Intersindical’, *Análise Social*, nº 105-106: 57-117.

Barros, P. P. (2002), ‘Convergence and information technologies: the experience of Greece, Portugal and Spain’. *Applied Economics Letters*, 9: 675-80.

Bassanini, A. and S. Scarpetta (2001), ‘Does human capital matter for growth in OECD countries? Evidence from pooled mean-group estimates’, *OECD Economics Department Working Paper*, No. 282, OECD Publishing. doi: 10.1787/424300244276.

Baumol, W.J. (1967) ‘Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis’, *American Economic Review*, 57 (3), June: 415-426.

Baumol, W.J. (2001), 'Paradox of the Services: Exploding Costs, Persistent Demand', in Ten Raa, T. and Schettkat, R. (eds.) *The Growth of Service Industries: The Paradox of Exploding Costs and Persistent Demand*. Cheltenham: Edward Elgar, pp. 3-28.

Baumol, W.J. (2002), *The Free-Market Innovation Machine: Analysing the Growth Miracle of Capitalism*, Princeton, New Jersey: Princeton University Press

Baumol, W.J., Blackman, S.A.B. E Wolff, E.N. (1989), *Productivity and American Leadership: The Long View*. Cambridge, MA. MIT Press,

Beira, E., C Crespo, N Gomes, J Menezes (2003), 'Dos moldes à engenharia do produto, a trajectória de um cluster', WP 34 (2003) Working papers *Mercados e Negócios*.

Beira, E.J.C, and J. Menezes (2001), 'Inovação e indústria de moldes em Portugal: a introdução do CAD/CAM/CAE nos anos 80', Working Papers *Mercados e Negócios* TSI, WP 6b.

Belloc, B. (1980), *Croissance économique et adaptation du capital productif*, Paris, Economica.

Bernard, A.B. and C.I. Jones (1996), 'Productivity Across Industries and Countries: Time Series Theory and Evidence', *The Review of Economics and Statistics*, vol. 78: 135-146.

Berzeg, K. (1984), 'A note on statistical approaches to shift-share analysis', *Journal of Regional Science*, 24(2), pp.277–85.

Blanchard, O. (2006), 'Adjustment within the Euro. The difficult case of Portugal'. http://econ-www.mit.edu/faculty/download_pdf.php?id=1295.

Blien, U. and A. Haas (2005), 'Service industries and regional development: an analysis for Eastern Germany', *The Service Industries Journal*, Vol. 25, No.8:979-997.

Brito V. (2005), 'Perfil temporal de eficiência dos bens de capital em Portugal', *Prospectiva e Planeamento*, no. 12.

Brus, D. (1998), 'Baumol's disease in the Netherlands', CPB Report, No. 1998/4: 35-38.

Cardoso, A.R. and Portugal, P. (2005), 'Contractual wages and the wage cushion under different bargaining settings', *Journal of Labor Economics*, 23(4):875–902.

Carree, M. (2003), ‘Technological progress, structural change and productivity growth: a comment’, *Structural Change and Economic Dynamics*, Vol. 14 (1):109-115

Castellacci, F. (2008), Technological paradigms, regimes and trajectories: Manufacturing and service industries in a new taxonomy of sectoral patterns of innovation, forthcoming in *Research Policy*, doi:10.1016/j.respol.2008.03.011.

Chenery, H.B. (1960) ‘Patterns of industrial growth’, *American Economic Review*, 50: 624-654.

Chenery, H.B. (1988), ‘Introduction to Part 2’, in H. Chenery and T. Srinivasan, eds. *Handbook of Development Economics*, Vol. 1. Amsterdam: North-Holland.

Chenery, H.B. and Syrquin, M. (1975), *Patterns of Development, 1957-1970,* London: Oxford University Press.

Chenery, H.B. and T. Watanabe (1958), ‘International Comparisons of the Structure of Production’, *Econometrica*, Vol. 26, No. 4: 487-521.

Chenery, H.B. and Taylor, L. (1968), ‘Development Patterns: Among Countries and Over Time’, in Hagemann, H. Landesmann, M., Scazzieri, R., *The Economics of Structural Change*, Volume III, Critical Writings, Aldershot: Edward Elgar.

Chiaromonte, F. and Dosi, G. (1993), ‘Heterogeneity competition and macroeconomic dynamics’, *Structural Change and Economic Dynamics*, 4, 39-63

Clark, B. (1938), ‘International comparison of national income’, *Weltwirtschaftliches Archiv*, 47 (1): 51-76.

Clark, J., Freeman, C. and Soete, L., (1981), ‘Long waves, Inventions and Innovations’, *Futures*, 13, 4: 308–322.

Cornwall, J. (1976), ‘Diffusion, Convergence and Kaldor's Laws’, *Economic Journal*, 86: 307-314.

Cornwall, J. (1977), *Modern Capitalism. Its Growth and Transformation*. London, Martin Robertson.

Cozzi, N. (1990), ‘A Comparison between Goodwin's Normalised General Coordinates and Pasinetti's Vertical Integration Methods’ in K Velupillai (ed.) *Nonlinear and Multisectoral Macrodynamics*, London, Macmillan.

Cruz, L. (2002), *A Portuguese Energy-Economy-Environment I/O Model: Policy Applications*, PhD Thesis, SPIRE, Keele University, UK.

Cruz, L. and E. Barata (2007), 'Estrutura económica, intensidade energética e emissões de CO2: Uma abordagem Input-Output, Estudos do GEMF, N.º 8.

David, P. (1975), *Technical Choice, Innovative and Economic Growth: Essays on American and British Experience in the Nineteenth Century*, Cambridge University Press

David, P. (1985), 'CLIO and the Economics of QWERTY', *Papers and Proceedings of the American Economic Association*, 75: 332-336

David, P.A. (1990), 'The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox', *American Economic Review*, 80 (2): 355-361.

de Jong, J. and Marsili, O. (2006), 'The fruit flies of innovations: A taxonomy of innovative small firms", *Research Policy*, 35: 213-229Marsili, 2006

de la Fuente, A. and R. Doménech (2000), 'Human capital in growth regressions: How much difference does data quality make?', *OECD Economics Department Working Papers* No. 262.

DeLong, J.B. and L.H. Summers (1991), 'Equipment Investment and Economic Growth', *Quarterly Journal of Economics*, 106: 2 (May): 445-502.

Dietzenbacher, E. and B. Los, (1998), 'Structural decomposition techniques: sense and sensitivity', *Economic Systems Research*, 10: 307-323.

Dobb, M.H. (1960), *An Essay on Economic Growth and Planning*. London: Routledge & Kegan Paul.

Dosi, G. (1982), 'Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change', *Research Policy*, 11 (3), June: 147-162.

Dosi, G. (1988), 'Sources, procedures, and microeconomic effects of innovation', *Journal of Economic Literature*, vol. 26: 1120-71

Dosi, G., Freeman, C., Nelson, R., Silverberg, G. and Soete, L. (eds.) (1988), *Technical Change and Economic Theory*, London: Pinter.

Dosi, G.; Pavitt, K.; Soete, L. (1990), 'Markets, institutions and technical change in open economies: some policy implications', in *The economics of technical change and international trade*, Great British: Harvester Wheatsheaf, pp.237-263.

Doyle, E. and E. O'Leary (1999), 'The role of structural change in labour productivity convergence among European Union countries: 1970-1990', Journal of Economic Studies, 26, No. 2: 106-20.

Durlauf, S., P. Jonhson (1992), 'Local versus global convergence across national economies', *NBER Working Paper*, no. 3996.

Easterley, W. (2002), *The Elusive Quest for Growth: Economists' Adventures and Misadventures in the Tropics*. Cambridge, MA: MIT Press.

Eliasson, G. (1984), 'Micro heterogeneity of firms and stability of growth', *Journal of Behavior and Economic Organization*, 5(3/4): 249-298

Eliasson, G. (1991), 'Modeling the experimentally organized economy', *Journal of Economic Behavior and Organization*, 16(1-2): 153-182.

Eliasson, G., Johansson, D., Taymaz, E. (2004), 'Simulating the New Economy', *Structural Change and Economic Dynamics*, 15: 289-314.

Elmslie, B. (1994), 'International Trade and Technical Progress: The Role of Capital Good Imports in Portugal', *International Review of Applied Economics*, vol. 8, no.3: 227-249.

Evangelista, R. (2000), 'Sectoral patterns of technological change in services', *Economics of Innovation and New Technology*, 9, 183–221.

Everitt, B. S., Leese, M. and S. Landau (2001), *Cluster Analysis*, Hodder Arnold, 4th Edition

Fabricant, S. (1942), 'Employment in manufacturing, 1899-1939', National Bureau of Economic Research, New York.

Fagerberg, J. (1987), 'A technology gap approach to why growth rates differ', *Research Policy*, 16 (2-4): 87-99.

Fagerberg, J. (1988), 'International Competitiveness', *The Economic Journal*, 98: 355-374.

Fagerberg, J. (1994), 'Technology and International Differences in Growth Rates', Journal of Economic Literature, XXXII (3): 1147-1175.

Fagerberg, J. (2000), 'Technological progress, structural change and productivity growth: a comparative study', *Structural Change and Economic Dynamics*, 11: 393-411.

Fagerberg, J. (2000), 'Technological progress, structural change and productivity growth: a comparative study', *Structural Change and Economic Dynamics*, 11, 393-411.

Fagerberg, J. (2003), 'Schumpeter and the Revival of Evolutionary Economics: An Appraisal of the Literature', *Journal of Evolutionary Economics*, 13, 125-159.

Fagerberg, J. and Verspagen, B. (1999), 'Modern Capitalism' in the 1970s and 1980s', in Setterfield, M. (ed.), *Growth, Employment and Inflation*, Macmillan, London, pp. 113-126.

Fagerberg, J. and Verspagen, B. (2002), 'Technology-gaps, innovation-diffusion and transformation: an evolutionary approach', *Research Policy*, 31: 1291-1304.

Fagerberg, J., Guerrieri, P., and Verspagen, (eds.) (1999), *The Economic Challenge of Europe: Adapting to Innovation-Based Growth*, Cheltenham: Edward Elgar.

Färe, R., S. Grosskopf and D. Margaritis (2006), 'Productivity growth and convergence in the European Union', *Journal of Productivity Analysis*, 25: 111-141.

Färe, R., S. Grosskopf and D. Margaritis (2006), 'Productivity growth and convergence in the European Union', *Journal of Productivity Analysis*, 25: 111-141.

Feldman, G. (1928), On the Theory of Growth Rates of National. Income', in N. Spulber (ed.), *Foundations of Soviet Strategy for Economic Growth*, Bloomington, Indiana.

Fisher, A.G.B. (1939), 'Production, primary, secondary and tertiary', *Economic Record*, 15: 24-38.

Forrester, J. W. (1981), 'Innovation and economic change', *Futures*, 13, 4: 323-331

Franke, R. and Kalmbach, P. (2005), 'Structural change in the manufacturing sector and its impact on business-related services: an input-output study for Germany', Structural Change and Economic Dynamics, 16 (2005): 467-488.

Freeman C. (1987), *Technology Policy and Economic Performance*, London, Pinter Publishers.

Freeman, C. (1982), 'Science, technology and unemployment', papers in Science, technology and public policy, no.1, London, SPRU.

Freeman, C. (1991), 'Innovation, changes of techno-economic paradigm and biological analogies in economics.', Revue Économique, 42: 211–232.

Freeman, C. (1992), ‘Formal scientific and technical institutions in the national system of innovation’ in Lundvall, B-E (ed.). *National systems of innovation: towards a theory of innovation and interactive learning*. London: Pinter Publishers.

Freeman, C. (1994), ‘The economics of technical change’, *Cambridge Journal of Economics*, 18: 463-514.

Freeman, C. (2001), ‘A hard landing for the ‘new economy’? Information Technology and the United States National System of Innovation’, *Structural Change and Economic Dynamics*, 12: 115-39.

Freeman, C. and Perez, C. (1988), ‘Structural crisis of adjustment, business cycles and investiment behaviour’. In: Dosi, G. et alii (eds.) *Technical Change and Economic Theory*. London: Pinter Publishers.

Freeman, C. and Soete, L. (1997), *The economics of industrial innovation*. London: Pinter.

Freeman, C., Clark, J. and Soete, L. (1982), *Unemployment and Technical Innovation*, Pinter, London.

Furtado, C. (1967), *Teoria e política do desenvolvimento económico*, Companhia Editora Nacional, São Paulo.

Gehrke, C. and Hagemann, H. (1996) 'Efficient Traverses and Bottlenecks: a Structural Approach', in M.A. Landesmann and R. Scazzieri (eds.), Production and Economic Dynamics, Cambridge, Cambridge University Press, pp. 140-66.

Georgescu-Roegen, N. (1971), *The Entropy Law and the Economic Process*, Mass./London: Harvard UP.

Gershenkron, A. (1962) *Economic backwardness in historical perspective*, Cambridge, MA: Belknap.

Godinho, M.M. and R.P. Mamede, (2004). ‘Convergência e mudança estrutural no âmbito dos “países da coesão”’, *Análise Social* 38: 1069-90.

Goodwin, R.M. (1976), ‘Use of Normalized General Coordinates in Linear Value and Distribution Theory’, in Polenske and Skolka (eds), Advances in Input-Output Analysis.

Goodwin, R.M. (1983), *Essays in Linear Economic Structures*. Macmillan, London.

Goodwin, R.M. (1991), 'Schumpeter, Keynes and the Theory of Economic Evolution', *Journal of Evolutionary Economics*, 1 (1): 29-47.

Goodwin, R.M. and L. F. Punzo (1987), *The Dynamics of a Capitalist Society*. Polity Press in association with Basil Blackwell, Cambridge.

Goodwin, R.M.. (1987), 'The Economy as an Evolutionary Pulsator', in T. Vasko (ed.), *The Long-Wave Debate*. Springer-Verlag, Berlin

Griliches, Zvi (1990), "Hedonic Price Indexes and the Measurement of Capital and Productivity: Some Historical Reflections", in Ernst R. Berndt and Jack E. Triplett (eds.), *Fifty Years of Economic Measurement*, Studies in Income and Wealth 54, National Bureau of Economic Research.

Griliches, Zvi (1990); "Hedonic Price Indexes and the Measurement of Capital and Productivity: Some Historical Reflections"; in: Berndt, Ernst R. and Jack E. Triplett (eds.); *Fifty Years of Economic Measurement; Studies in Income and Wealth* 54, National Bureau of Economic Research.

Grossman, G., H. Helpman (1991), *Innovation and Growth in the Global Economy*, Cambridge, Mass: MIT Press.

Gualerzi, D. (2001), *Consumption and growth: Recovery and structural. Change in the US economy*. Edward Elgar, Cheltenham, UK

Hagemann, H. (1990), 'The Structural Theory of Economic Growth', in M. Baranzini and R. Scazzieri (Eds.) *The Economic Theory of Structure and Change*, Chapter 6, Cambridge: Cambridge University Press: 144-171.

Hagemann, H., M. Landesmann, R. Scazzieri (2003) 'Introduction', in H. Hagemann, M. Landesmann, R. Scazzieri (Eds.), *The Economics of Structural Change*, vol. I, Elgar, Cheltenham, UK, xi-xiii.

Halevi, J. (1996) 'The Significance of the Theory of Vertically Integrated Processes for the Problem of Economic Development'. *Structural Change and Economic Dynamics* 7: 163–71.

Harris, D. (1982), 'Structural change and Economic Growth: A Review Article'. *Contributions to Political Economy*, 1: 25-45.

Hatzichronoglou, T. (1997), 'Revision of the High-Technology Sector and Product Classification', STI Working Paper 1997/2.

Haynes, K.E. and F.Y. Phillips (1982), 'Constrained minimum discrimination information: a unifying tool for modelling spatial and individual choice behaviour', *Environment and Planning*, 14: 1341-1354.

Haynes, K.E. and Z.B. Machunda, (1988), 'Decomposition of change in spatial employment concentration: an information-theoretic extension of shift-share analysis', *Papers of the Regional Science Association*, 65: 101-113.

Hicks, J. (1965), *Capital and Growth*, Oxford: Clarendon Press.

Hicks, J. (1973), *Capital and Time: A Neo-Austrian Theory*, Oxford: Clarendon Press.

Hicks, J. (1977), *Economic Perspectives*. Oxford: Clarendon Press.

Hicks, J. (1985), *Methods of Dynamic Economics*, Oxford: Clarendon Press.

Hoffmann, W. ([1931]/1958), 'The Pattern of Industrial Growth', in Hagemann, H. Landesmann, M., Scazzieri, R., *The Economics of Structural Change*, Volume III, Critical Writings, Aldershot: Edward Elgar.

Hölzl, W. and Reinstaller, A. (2007), 'The impact of productivity and demand shocks on structural dynamics: Evidence from Austrian manufacturing,' *Structural Change and Economic Dynamics*, 18(2): 145-166.

IAPMEI (2007), *Contributos para o conhecimento no contexto Internacional do Sector Outros Produtos Minerais Não Metálicos*, Ministério da Economia e da Inovação, Lisboa.

INE (2007), *Portugal agrícola* : *1980-2006* , Instituto Nacional de Estatística, Lisboa.

Ishikawa, S. (1987), 'Structural Change' an entry of: *The New Palgrave. A Dictionary of Economics*, Macmillan, London, IV, 523-5.

Jacob V, Sharma S C, Grabowski R, (1997), 'Capital stock estimates for major sectors and disaggregated manufacturing in selected OECD countries', *Applied Economics*, 29: 563-579.

Jorgenson, D., F. Gollop and B. Fraumeni (1987), *Productivity and U.S. Economic Growth*, Harvard University Press, Ma.

Jorgenson, D.W. (1989), 'Capital as a Factor of Production'; in: D.W. Jorgenson and R. Landau (eds.) *Technology and Capital Formation*, Cambridge Mass.: MIT Press.

Jorgenson, Dale (1995a), *Productivity Volume 1: Postwar U.S. Economic Growth*, MIT Press.

Jorgenson, Dale and Zvi Griliches (1967), "The Explanation of Productivity Change", *Review of* Economic *Studies* 34.

Kaldor, N. (1957), 'A model of economic growth', *Economic Journal*, LXVII: 591-624.

Kaldor, N. (1966), *Causes of the Slow Rate of Growth in the United Kingdom*, Cambridge University Press, Cambridge.

Kaldor, N. (1970), 'The Case for Regional Policies', *Scottish Journal of Political Economy*, XVII: 337-348.

Kaldor, N. (1975), 'Economic growth and the verdoorn law: A comment on mr. Rowthorn's article', *Economic Journal*, 85(340):891–896.

Kamien, M. and N. Schwartz (1982), *Market structure and innovation*, Cambridge University Press, Cambridge.

Kamps, C. (2006), 'New Estimates of Government Net Capital Stocks for 22 OECD Countries 1960-2001', *IMF Staff Papers*, vol. 53, no.1: 120-150.

Kleinknecht, A. (1990), 'Are there Schumpeterian waves of innovations?', Cambridge Journal of Economics, vol. 14, n. 1 pp. 81-92

Kleinknecht, A., (1986), 'Long waves, depressions and innovations', *De Economist*, 134, 1: 84–108.

Kleinknecht, A., Montfort, K. and E. Brouwer (2002), 'The non-trivial choice between innovation indicators', *Economics of Innovation and New Technology*, 11 (2), 109-121.

Klepper, S. (1997), 'Industry life cycle', *Industrial and Corporate Change*, 6 (1), 145–181.

Knudsen, D.C. (2000), 'Shift-share analysis: further examination of models for the description off economic change', *Socio-Economic Planning Sciences*, 34: 177-198.

Kobayashi, N. (2004), 'Industrial structure and manufacturing growth during Japan's bubble and post-bubble economies', *Regional Studies*, Vol. 38, No.4: 429-444(16)

Korres, G.M. (1996), 'Sources of structural change: An input-output decomposition analysis for Greece', *Applied Economics Letters*, 3:707–710.

Kristensen, F. (1999), 'Towards a taxonomy and theory of the interdependence between learning regimes and sectorial patterns of innovation and competition: an empirical analysis of an elaborated Pavitt taxonomy applying Danish data', Paper presented in the DRUID 1999 Winter Conference.

Kuznets, S. (1940), 'Schumpeter's business cycles', *American Economic Review*, 30: 257–271.

Kuznets, S. (1961), 'Quantitative aspects of the economic growth of nations: IV. Long term trends in capital formation proportions', *Economic Development and Cultural Change* 9: 1-124.

Kuznets, S. (1971), *Economic growth of nations: Total output and production structure*. Cambridge, MA: Harvard University Press.

Lains, P. (2003), Catching up to the European core: Portuguese economic growth, 1910-1990. *Explorations in Economic History*, 40: 369-386.

Lains, P. (2004), 'Structural change and economic growth in Portugal, 1950-1990'. *Unpublished paper*.

Lains, P. (2008), 'The Portuguese Economy in the Irish mirror, 1960-2004', *forthcoming in Open Economies Review*.

Landesmann, M. and R. Goodwin (1994), 'Productivity growth, structural change and macroeconomic stability', in Pasinetti, L., Solow, R. (Eds.), *Economic Growth and the Structure of Long-Term Development*. Macmillan Press, London.

Landesmann, M. and Scazzieri, R. (eds.) (1996) *Production and Economic Dynamics*, Cambridge University Press, Cambridge.

Landesmann, M., R. Scazzieri (1990) 'Specification of Structure and Economic Dynamics', in M. Baranzini and R. Scazzieri (Eds.), *The Economic Theory of Structure and Change*, Chapter 4, Cambridge: Cambridge University Press: 95-121.

Leite, J. and Almeida, F. J. (2001), *Legislação do Trabalho. Revista e Actualizada*, Coimbra, Coimbra Editora.

Leon, P. (1967), *Structural Change and Growth in Capitalism*, Baltimore, Johns Hopkins.

Leontief, W. (1928), ‘The economy as a circular flow’, reprinted in *Structural Change and Economic Dynamics*, Volume 2, Issue 1, June 1991: 181-212.

Leontief, W. (1941), *The Structure of American Economy, 1919-29*, Cambridge: Harvard University Press.

Leontief, W. (1951), *The Structure of the American Economy*. New York: Oxford University Press.

Leontief, W. (1953), ‘Dynamic Analysis’, in W. Leontief et al., *Studies in the Structure of the American Economy*, Oxford University Press, New York: 53-90.

Leontief, W. (1970), ‘The Dynamic Inverse’, in *Contributions to Input-Output Analysis*, A. P. Carter and A. Brody (eds.), North-Holland Publishing Company, Amsterdam.

Leontief, W. (1987), ‘Input-output analysis’, an entry of: *The New Palgrave. A Dictionary of Economics*, Macmillan, London: 860-4.

Lewis, A. (1954) ‘Economic development with unlimited supplies of labor’, *Manchester School of Economic and Social Studies*, 28: 139-191

Leydesdorff, L. (2007), ‘Visualization of the Citation Impact Environments of Scientific Journals: An online mapping exercise’. *Journal of the American Society of Information Science and Technology*, 58(1), 207-222.

Little, I.M.D.(1982), *Economic Development*. Basic Books.

Lopes, J.S. (1996), *A Economia Portuguesa desde 1960*, Gradiva.

Los, B., Verspagen, B. (2006), ‘The evolution of productivity gaps and specialization patterns’, *Metroeconomica*, 57-4: 464-493.

Lowe, A. (1955) ‘Structural Analysis of Real Capital Formation’, in *Capital Formation and Economic Growth: A Conference of the Universities – National Bureau Committee for Economic Research*, Princeton, NJ: Princeton University Press, 581-634.

Lowe, A. (1976), *The Path of Economic Growth*, Cambridge: Cambridge University Press.

Lucas, R. (1988), ‘On the Mechanics of Economic Development’, Journal of Monetary economics, Vol.22, pp. 3-42.

Lucas, R. (1993), ‘Making a Miracle’, *Econometrica*, 61, 251-272

Lumpkin, G. T., and G.G. Dess (1996), ‘Clarifying the entrepreneurial orientation construct and linking it to performance’, *The Academy of Management Review*, 21(1): 135-172.

Lundvall, B-A. (1992), *National systems of innovation: towards a theory of innovation and interactive learning*. London: Pinter Publishers

Machlup, F. (1991) *Economic Semantics*, 2nd Edition, Transaction Pub.

Maddison, A. (1952), ‘Productivity in an expanding economy’, *Economic Journal*, September: 584-594.

Mahalanobis, P.C. (1955), ‘The Approach of Operational Research to 44 Planning in India,’ Sankhya: The Indian Journal or Statistics, Vol. 16, Parts 1 and 2, pp. 3-62

Malerba, F., and L. Orsenigo (1996), ‘Schumpeterian patterns of innovation are technology-specific’, *Research Policy*, 25 (3), 451–478.

Marques, J., Martins J. and E. Castro (2006), ‘Análise Input-Output rectangular inter-regional - Emissões de CO2 em Portugal e o Protocolo de Quioto’, *Revista Portuguesa de Estudos Regionais*, APDR, nº11.

Marsili, O. (2001), *The Anatomy and Evolution of Industries: Technological Change and Industrial Dynamics*, Edward Elgar, Cheltenham, UK and Northampton, MA, USA.

Marx, K. ([1885]/1956), ‘III: Schematic Presentation of Accumulation’ and ‘Supplementary Remarks’, in Hagemann, H. Landesmann, M., Scazzieri, R., *The Economics of Structural Change*, Volume I, Critical Writings, Aldershot: Edward Elgar.

McDonald R.E. (2007), ‘An investigation of innovation in nonprofit organizations : The role of organizational mission’, *Nonprofit and Voluntary Sector Quarterly*, vol. 36, no2: 256-281

Meinen, G. (1998), ‘Lives of capital goods’, Statistics Netherlands.

Meinen, G. Verbiest, P. and P. de Wolf (1998), ‘Service lives, discard patterns and depreciation methods’, Statistics Netherlands.

Mendi, P. (2007), ‘Trade in disembodied technology and total factor productivity in OECD countries’, *Research Policy*, vol. 36(1): 121-133.

Mensch, G., (1979), *Stalemate in technology*. Ballinger, Cambridge, MA.

Metcalfe, J.S. (1998), *Evolutionary Economics and Creative Destruction*. Routledge, London.

Metcalfe, J.S., Foster, J., Ramlogan, R., 2006. Adaptive economic growth. *Cambridge Journal of Economics* 30, 7–32.

Metcalfe, J.S.1998. *Evolutionary Economics and Creative Destruction*, Routledge: London.

Milberg (2004), 'The changing structure of international trade linked to global production systems: what are the policy implications?' *International Labour Review*, 143: 45-90.

Miles, 1996; 'Infrastructure and the delivery of new services', in OECD *Employment and growth in the knowledge-based economy*, OECD, Paris.

Miles, I. (1993), 'Services in the new industrial economy', *Futures*, 25 (6), 653–672.

Miles, I. (2005), Innovation in services. In: Fagerberg, J., Mowery, D.C., Nelson, R.R. (Eds.), *The Oxford Handbook of Innovation*. Oxford University Press, Oxford.

Miles, I. and Tomlinson, M. (2000), 'Intangible Assets and Service Sectors: The Challenges of Service Industries', in Buiges, P, Jacquemin, A, Marchipont, J (ed), *Competitiveness and the Value of Intangible Assets* , Edward Elgar.

Mirowski, P. (2002), *Machine Dreams: How Economics Became a Cyborg Science*, Cambridge Univ. Press: NY.

Montobbio, F., (2002), 'An evolutionary model of industrial growth and structural change', *Structural Change and Economic Dynamics*, 13, 387–414.

Murphy, K., A. Shleifer and R. Vishny (1989), 'Industrialization and the Big Push' in Hagemann, H. Landesmann, M., Scazzieri, R., *The Economics of Structural Change*, Volume III, Critical Writings, Aldershot: Edward Elgar.

Naqvi, K. (1963), 'Machine Tools and Machines: A Physical Interpretation of the Marginal Rate of Saving', *Indian Economic Review*, 6: 19-28.

Nelson, R and Wright, G. (1992), 'The Rise and Fall of American Technological Leadership: The Postwar Era in Historical Perspective' *Journal of Economic Literature*, vol. 30(4): 1931-64

Nelson, R. and E. Phelps (1966), 'Investment in humans, technological diffusion, and economic growth', *American Economic Review: Papers and Proceedings*, 51 (2): 69-75.

Nelson, R. and S. Winter (1982), *An Evolutionary Theory of Economic Change*, Cambridge, MA: Harvard University Press

Nelson, R.R. (ed.) (1993), *National Innovation Systems: A Comparative Analysis*, New York: Oxford University Press.

Nelson, R.R. and S.G. Winter (1977), 'In search of a useful theory of innovation', *Research Policy*, 6 (1), 36–76.

Neves, J.C. (1994), *The Portuguese economy: A Picture in Figures. XIX and XX centuries*, Universidade Católica Editora, Lisbon.

Nickell, S. (1985), 'The government's policy for jobs: an analysis', *Oxford Review of Economic Policy*, 1.

Notarangelo, M. (1999), 'Unbalanced growth: a case of structural dynamics'. *Structural Change and Economic Dynamics* 10, 209–223.

Nurkse, R. (1953), *Problems of capital formation in underdeveloped countries*, Oxford: Basil Blakwell.

O' Leary, E. (2003), 'Aggregate and sectoral convergence among Irish regions: the role of structural change, 1960-96', International Regional Science Review, 26, 4: 483-501.

O'Mahony, M. (1999), *Britain's Productivity Performance 1950-1996. An International perspective*, National Institute of Economic and Social Research, London.

O'Mahony, M. and Vecchi, M. (2002), 'Knowledge based capital and economic performance', NIESR, (mimeo).

OECD - EUROSTAT (2005), *Oslo Manual - Guidelines for Collecting and Interpreting Innovation Data*, third edition, OECD, Paris.

OECD (1997), *Information technology outlook*, OECD, Paris.

OECD (1998), *Education at a Glance 1997*. Paris.

OECD (2001a), *Measuring Productivity – OECD Manual: Measurement of Aggregate and Industry-Level Productivity Growth*, Paris.

OECD (2001b), *Measuring Capital – OECD Manual: Measurement of Capital Stocks, Consumption of Fixed Capital and Capital Services*, Paris.

OECD (2002), *The measurement of scientific and technological activities. Proposed standard practice for surveys on research and experimental development – Frascati Manual*, OECD, Paris

Oosterhaven, J. and Hoen, A. (1998), 'Original: Preferences, technology, trade and real income changes in the European Union. An intercountry decomposition analysis for 1975-1985', *The Annals of Regional Science*, 32(4): 505-524.

Osada, H. (1994),'Trade Liberalization and FDI Incentives in Indonesia: The Impact on Industrial Productivity', *The Developing Economies*, XXXII-4: 479-491

Pasinetti, L. (1973), 'The notion of vertical integration on economic analysis', *Metroeconomica* 25: 1–29.

Pasinetti, L. (1990), 'Normalised general coordinates and vertically integrated sectors in a simple case', in K. Velupillai (ed.) *Nonlinear and multisectoral macrodynamics: Essays in honour of Richard Goodwin*, Macmillan, Basingstoke, p. 151-164.

Pasinetti, L., (1981), *Structural Change and Economic Growth. A Theoretical Essay on the Dynamics of the wealth of Nations*, Cambridge University Press, Cambridge.

Pasinetti, L.L. (1993), *Structural Economic Dynamics: A Theory of the Economic Consequences of Human Learning*, Cambridge, Cambridge University Press.

Pasinetti, L.L., R. Scazzieri (1987), 'Structural Economic Dynamics', an entry of: *The New Palgrave. A Dictionary of Economics*, Macmillan, London, IV: 525-8.

Patterson, M.G. (1991), 'A Note on the formulation of the full-analogue regression model of the shift-share method', *Journal of Regional Science*, 31(2): 211–16.

Pavitt, K. (1984), 'Sectoral patterns of technical change: towards a taxonomy and a theory', *Research Policy*, 13: 353-369.

Pavitt, K. (1990), 'What we know about the strategic management of technology', *California Management Review*, Spring: 17-26.

Pavitt, K., M. Robson and J. Townsend (1989), 'Technological accumulation, diversification and organization in UK companies, 1945-83', *Management Science*, 35: 81-99.

Peneder, M. (2002), ‘Industrial structure and aggregate growth’, WIFO Working Papers, 182, Vienna.

Peneder, M. (2002), ‘Intangible investment and human resources’, *Journal of Evolutionary Economics*, 12, 107–134.

Peneder, M., (2003), ‘Industrial structure and aggregate growth’, *Structural Change and Economic Dynamics*, 14: 427-448.

Peneder, M., Kaniovski S., Dachs B. (2003), ‘What Follows Tertiarisation? Structural Change and the Role of Knowledge Based Services’, *The Service Industry Journal*, Vol. 23: 47-66.

Perez, C. (1983), ‘Structural change and assimilation of new technologies. in the economic and social systems’ Futures 15(5): 357-375.

Perez, C. (1985), ‘Microelectronics, long waves and world structural change: New perspectives for developing countries’, *World Development*, Vol.13, No.3: 441-463.

Peterson, W., (1979), ‘Total factor productivity in the UK: a disaggregated analysis’, in Patterson, K.D., Schott, K. (Eds.), *The Measurement of Capital: Theory and Practice*. Macmillan, London.

Petit, P. (2002), ‘Growth and Productivity in a Knowledge-Based Service Economy’, in: Gadrey, J., Gallouj, F. (Eds.), *Productivity, Innovation and Knowledge in Services*, Elgar, Cheltenham.

Petit, P. and L. Soete (2000), ‘Technical change and employment growth in services: analytical and policy challenges’, in *Technology and the future of European employment*. P. Petit and L. Soete.Aldershot, Edward Elgar.

Piacentini, P. (1995), ‘Time-explicit theory of production: analytical and operational suggestions following a ‘fund–flow’ approach’, *Structural Change and Economic Dynamics*, 6, 461–483.

Pieper, U. (2000), ‘Deindustrialization and the social and economic sustainability nexus in developing countries: Cross-country evidence on productivity and employment’, *Journal of Development Studies*, v. 36, no. 4, April: 66-99.

Pina, A. and M. St. Aubyn (2004), ‘Comparing macroeconomic returns on human and public capital: An empirical analysis of the Portuguese case (1960-2001)’, *Working Paper*, ISEG.

Prebisch, R. (1950), *The Economic Development of Latin America and its Principal Problems*, New York: United Nations.

Quadrio-Curzio, A. (1986), 'Technological Scarcity: an Essay on Production and Structural Change', in M. Baranzini and R. Scazzieri (eds) *Foundations of Economics: Structures of Inquiry and Economic Theory*, Chapter 10, Oxford and New York: Basil Blackwell: 311-338.

Quadrio-Curzio, A.and Pellizzari, F. (1999), *Rent, Resources, Technologies*, Springer.

Quah, D. (1997), 'Increasingly Weightless Economies' in Hagemann, H. Landesmann, M., Scazzieri, R., *The Economics of Structural Change*, Volume II, Critical Writings, Aldershot: Edward Elgar.

Quesnay, F. ([1758]/1972), 'Tableau Économique', Third Edition, in Hagemann, H. Landesmann, M., Scazzieri, R., *The Economics of Structural Change*, Volume I, Critical Writings, Aldershot: Edward Elgar.

Rada, C. and L. Taylor (2006), 'Developing and transition economies in the late 20th century: Diverging growth rates, economic structures, and sources of demand', SCEPA Working Paper 2006-1.

Rae, J. (1834), 'Of the Principle of the Division of Labor'in Hagemann, H. Landesmann, M., Scazzieri, R., *The Economics of Structural Change*, Volume I, Critical Writings, Aldershot: Edward Elgar.

Raiser, M., M. Schaffer and J. Schuchhardt (2004), 'Benchmarking structural change in transition', *Structural Change and Economic Dynamics*, vol. 15 (1): 47-81.

Ramos, P. and A. Sargento (2003), Matriz Input-Output e comércio inter-regional da Região Centro, Revista Portuguesa de Estudos Regionais, no. 3.

Raymond, W., Mohnen, P., Palm, F., Schim van der Loeff, S. (2004), 'An Empirically-Based Taxonomy of Dutch Manufacturing: Innovation Policy Implications'. CESifo Working Paper Series No.1230.

Reati, A. (1998a), 'Technological revolutions in Pasinetti's model of structural change: productivity and prices', Structural Change and Economic Dynamics, 9: 245-62.

Reati, A. (1998b), 'A Long-Wave Pattern for Output and Employment in Pasinetti's Model of Structural Change', *Economie Appliquée*, tome LI, no. 2: 29-77

Ricardo, D. ([1817]/1951), ‘On Rent’, in Hagemann, H. Landesmann, M., Scazzieri, R., *The Economics of Structural Change*, Volume I, Critical Writings, Aldershot: Edward Elgar.

Robson, M. and J. Townsend (1984), ‘Users Manual for ESRC Archive File on Innovations in Britain since 1945: 1984 update’, Science Policy Research Unit.

Romer, P.M (1990) ‘Endogenous Technical Change’, *Journal of Political Economy*, 98: 71-102.

Ros, J. (2000), *Development Theory and the Economics of Growth*, University of Michigan Press.

Rose, A. and S. Casler (1996), ‘Input-output structural decomposition analysis: a critical reappraisal, *Economic Systems Research*, 8 (1):33–62.

Rose, A. and W. Miernyk (1989), 'Input-Output Analysis: The First Fifty Years', *Economic Systems Research*, 1:2, 229 - 272

Rosenberg, N. (1963), ‘Capital Goods, Technology, and Economic Growth’, in Hagemann, H. Landesmann, M., Scazzieri, R., *The Economics of Structural Change*, Volume I, Critical Writings, Aldershot: Edward Elgar.

Rosenberg, N. (1982), *Inside the Black Box: Technology and Economics*, Cambridge University Press, New York.

Rosenberg, N. and C.R. Frischtak, (1984). Technological innovation and long waves,. *Cambridge Journal of Economics*, Vol. 8: 7-24.

Rosenstein-Rodan, P. (1943), ‘Problems of industrialization in Eastern and South-Eastern Europe’, *Economic Journal*, 53: 202-211.

Rosenstein-Rodan, P. (1961), ‘Notes on the theory of the ‘big-push’’, in H.S. Ellis and H.C. Wallich (Eds.) *Economic Development for Latin America*. London: Macmillan.

Rostow, W.W. (1960), *The stages of economic growth: A non-communist manifesto*. Cambridge: Cambridge University Press.

Sakurai, N., Ioannidis, E. and Papaconstantinou, G. (1997), The Impact of R&D and Technology Diffusion on Productivity Growth: Evidence for 10 OECD Countries, *Economic Systems Research*, 9: 81-109.

Sánchez Chóliz, J. and Duarte, R. (2006), 'The effect of structural change on the self-reliance and interdependence of aggregate sectors: the case of Spain, 1980–1994', *Structural Change and Economic Dynamics*, 17(1): 27-45.

Santos, S. (2004), 'Portuguese net borrowing and the government budget balance: A SAM approach', *Journal of Policy Modeling*, vol. 26(6): 703-717.

Santos, S. (2007), 'Modelling Economic Circuit Flows in a Social Accounting Matrix framework. An application to Portugal', *Applied Economics*, 39: 1753-1771.

Saviotti, P. and Pyka, A. (2004a), 'Economic development by the creation of new sectors,' *Journal of Evolutionary Economics*, 14(1): 1-35.

Saviotti, P.P, Pyka, A. (2004b), 'Economic development, qualitative change and employment creation', *Structural Change and Economic Dynamics* 15: 265-287.

Savona, M. and A. Lorentz (2006), 'Demand and Technology Contribution to Structural Change and Tertiarisation: An Input-Output Structural Decomposition', Working Paper BETA no. 2006-01.

Schettkat, R., and Yocarini, L. (2006), 'The Shift to Services Employment: A Review of the Literature', *Structural Change and Economic Dynamics*, 17: 127–147.

Schmookler, J. (1966), *Invention and Economic Growth*. Cambridge, Mass.: Harvard University Press.

Schreyer, P. (2003), 'Capital Stocks, Capital Services and Multi-factor Productivity Measures', *OECD Economic Studies*, 37(2): 163-184.

Schreyer, P., P. Bignon and J. Dupont (2003), 'OECD Capital Services Estimates: Methodology and a First Set of Results'; OECD *Statistics Working Paper*.

Schumpeter, J. (1928), 'The Instability of Capitalism' in Hagemann, H. Landesmann, M., Scazzieri, R., *The Economics of Structural Change*, Volume I, Critical Writings, Aldershot: Edward Elgar.

Schumpeter, J.A. (1934), *The Theory of Economic Development*, Harvard Economic Studies, Cambridge, Mass.

Schumpeter, J.A. (1939), *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process*, New York and London: McGraw-Hill.

Schumpeter, J.A. (1942), *Capitalism Socialism and Democracy*, Harper & Row, New York.

Sen, A. (1960), *Choice of Techniques*. Oxford: Basil Blackwell.

Silva, E.G. and A.C. Teixeira (2008), 'Surveying structural change: Seminal contributions and a bibliometric account', *Structural Change and Economic Dynamics*, 19: 273–300

Silverberg, G. (2002), 'The discrete charm of the bourgeoisie: quantum and continuous perspectives on innovation and growth', *Research Policy*, 31(8-9): 1275-1289.

Silverberg, G. and Lehnert, D. (1993), 'Long waves and 'evolutionary chaos' in a simple Schumpeterian model of embodied technical change', *Structural Change and Economic Dynamics*, 4(1): 9-37.

Silverberg, G., (1988), 'Modelling economic dynamics and technical change: mathematical approaches to self-organisation and evolution', in Dosi, G.,Freeman, C.,Nelson, R.,Silverberg, G. and Soete, L., (eds), *Technical Change and Economic Theory*, London: Pinter.

Silverberg, G., Dosi, G. and Orsenigo, L. (1988), 'Innovation, Diversity and Diffusion: A Self-Organisation Model', *Economic Journal*, 98: 1032-54.

Smith, A. ([1763] 1978), 'Division of Labour', in R.L. Meek, D.D. Raphael and P.G. Stein (Eds.) *Lectures on Jurisprudence*, Lecture of Tuesday, 29 March 1763, Oxford: Clarendon Press: 340-49.

Smith, A. ([1776] 1976), *An Inquiry into the Nature and Causes of the Wealth of Nations*, edited by R.H. Campbell, A.S. Skinner and W.B. Todd, Oxford: Clarendon Press.

Smith, K. (2005), 'Measuring innovation', in J. Fagerberg, D. Mowery and R. Nelson (Eds), *The Oxford Handbook of Innovation*, Chapter 6, Oxford, Oxford University Press.

Solomou, S. (1987), 'Kondratieff long waves in economic growth, 1850-1913', *Review*, Vol. X No.3, pp.507-34.

Solow, R. (1957), "Technical Change and the Aggregate Production Function", *Review of Economics and Statistics*, Vol. 39: 312-320.

Sraffa, P. (1960), 'On 'Sub-Systems'', in Hagemann, H. Landesmann, M., Scazzieri, R., *The Economics of Structural Change*, Volume I, Critical Writings, Aldershot: Edward Elgar.

Steuart, J. ([1767] 1966), *An Inquiry into the Principles of the Political Oeconomy*, edited by A.S. Skinner, Edinburgh and London: Oliver and Boyd.

Svennilson, I. (1954), 'The Process of Economic Growth', in Hagemann, H. Landesmann, M., Scazzieri, R., *The Economics of Structural Change*, Volume III, Critical Writings, Aldershot: Edward Elgar.

Tani, P., (1988), 'Flows, funds, and sectoral interdependence in the theory of production', *Political Economy Studies in the Surplus Approach*, 4, 3–21.

Teixeira, A. (2002), *Fission risk or inertia? Human capital decisions in the Portuguese textile industry during the eighties and nineties*, PhD Thesis, University of Sussex, UK.

Teixeira, A. and N. Fortuna, 'Human capital, trade and long-run productivity. Testing the technological absorption hypothesis for the Portuguese economy, 1960-2001', forthcoming in *Research Policy*.

Temple, J. (1999), 'A positive effect of human capital on growth', *Economics Letters* 65: 131-134.

Temple, J. (2000), 'Growth effects of education and social capital in the OECD countries', *Economics department working papers* No. 263, OECD, Paris.

Ten Raa, T. and Wolff, E. (2000), 'Engines of growth in the US economy', *Structural Change and Economic Dynamics*, Vol. 11 (1-2): 473-489

Tidd, J., J. Bessant and K. Pavitt (2001), *Managing innovation - integrating technological, market and organizational change*, 2nd ed., England: John Wiley & Sons Ltd.

Timmer, M.P., Szirmai, A. (2000), 'Productivity in Asian manufacturing: The unimportance of structural change', *Structural Change and Economic Dynamics*, 11: 371-92.

Tinbergen, J. (1942), 'Zur Theorie der langfristigen Wirtschaftsentwicklung', *Weltwirtschaftliches Archiv*, Band 55:1.

Townsend, J., F. Henwood, G. Thomas, K. Pavitt and S. Wyatt (1981), 'Innovation in Britain since 1945', Occasional Paper No. 16, Science Policy Research Unit, University of Sussex.

Turgot, A.R.J. ([1766] 1973), 'Reflections on the Formation and the Distribution of Wealth', in R.L. Meek (Ed.) *Turgot on Progress, Sociology and Economics*, Cambridge: Cambridge University Press: 119-34.

Utterback, J.M., and W.J. Abernathy (1975), 'A dynamic model of process and product innovation', *Omega*, 3 (6), 639–656.

Verdoorn, P.J. (1949). 'Fattori che Regolano lo Sviluppo Della Produttivita del Lavoro'. *L´Industria*, 1: 3-10.

Verspagen, B. (1991), 'A New Empirical Approach to Catching up or Falling Behind', *Structural Change and Economic Dynamics*, vol. 2: 359-380

Verspagen, B. (1993), *Uneven Growth Between Interdependent Economies: An Evolutionary View on Technology Gaps, Trade and Growth*. Aldershot: Avebury

von Böhm-Bawerk, E. ([1891]/1930), 'The Theory of the Formation of Capital', in Hagemann, H. Landesmann, M., Scazzieri, R., *The Economics of Structural Change*, Volume I, Critical Writings, Aldershot: Edward Elgar.

von Neumann, J. (1937), 'Über ein ökonomisches Gleichungssystem und eine Verallgemeinerung der Brouwerschen Fixpunktsatzes', in *Ergebnisse eines mathematischen Kolloquiums*, Vienna, VIII: 73-83; English translation: 'A Model of General Economic Equilibrium', *Review of Economic Studies*, 33 (1945-46): 1-9.

Wang, C. Sun, J. Chou, T. (1992), `Sources of Economic Growth and Structural Change: A Revised Approach', *Journal of Development Economics*, 38: 383-401.

Weintraub, R. (2002), *How Economics Became a Mathematical Science*, Durhman: Duke University Press.

Wilson, P. (2000), 'The export competitiveness of dynamic Asian economies 1983-1995', *Journal of Economic Studies*, Vol. 27, No. 6: 541-565.

Wilson, P., T.S. Chern, T. S. Ping, E. Robinson (2005), 'Assessing Singapore's Export Competitiveness through Dynamic Shift-Share Analysis', Asean Economic Bulletin, Vol. 22, No.2: 160-185.

Winter, S.G. (1984), 'Schumpeterian competition in alternative technological regimes'. *Journal of Economic Behavior and Organization*, 5 (3–4), 287–320.

Wolff, E. (1985), ‘Industrial composition, interindustry effects and the U.S. productivity slowdown’, *Review of Economics and Statistics*, 67: 268–277.

You, J. and J. Lee (2000), ‘Economic and social consequences of globalization: The case of South Korea’, SCEPA Working Paper No. 17.

Young, A. (1928), ‘Increasing Returns and Economic Progress’, *The Economic Journal*. Vol. 38, No. 152: 527-542.

Zamagni, S. (1984), ‘Ricardo and Hayek effects in a fixwage model of traverse’, in *Economic Theory and Hicksian Themes*, ed. D. A. Collard et al., Clarendon Press, Oxford: 135-51.

ANNEXES

Annex 1: Price deflators of investment

Table A.1. Price deflators of investment by asset type (base year: 1977)

	Machinery and equipment	Vehicles	Buildings	Other investment	GFCF
1977	1	1	1	1	1
1978	1,18	1,34	1,17	1,17	1,20
1979	1,42	1,79	1,48	1,44	1,51
1980	1,78	2,14	1,85	1,71	1,87
1981	2,00	2,57	2,28	2,07	2,24
1982	2,37	2,74	2,71	2,54	2,61
1983	2,92	3,29	3,39	3,44	3,25
1984	3,70	3,96	4,08	4,46	3,99
1985	4,17	4,40	4,86	5,23	4,63
1986	4,62	4,94	5,35	6,42	5,17
1987	4,88	5,54	5,88	6,78	5,61
1988	5,41	6,03	6,51	7,73	6,21
1989	5,82	6,64	7,43	8,55	6,90
1990	5,80	6,91	8,56	9,24	7,44
1991	5,95	6,88	9,71	9,43	7,95
1992	5,69	7,19	10,51	9,72	8,24
1993	5,66	7,24	11,23	10,18	8,55
1994	5,90	7,27	11,75	10,32	8,86
1995	5,95	7,52	12,27	10,63	9,15
1996	6,25	7,47	12,62	11,03	9,44
1997	6,41	7,70	13,11	11,82	9,79
1998	6,45	7,70	13,43	12,75	10,02
1999	6,34	8,03	13,69	13,92	10,23
2000	6,73	8,50	14,50	14,71	10,85
2001	6,57	8,65	15,02	15,33	11,04
2002	6,35	8,54	15,56	16,19	11,26
2003	6,23	8,49	15,91	17,29	11,46

Source: 1977–1995: Banco de Portugal (http://www.bportugal.pt); 1995-2003, INE.

Annex 2: INE's correspondence table between NPCN95 and NCN86

Annex 2: INE's correspondence table between NPCN 95 and NCN 86

NOMENCLATURA DE PRODUTOS - BASE 95

CÓDIGO: Divisão	Grupo / Classe	Subclasse	Categoria / Subcategoria	Posição / Subposição	Segmento / Subsegmento	DESIGNAÇÃO	EQUIVALÊNCIA: NACE Rev.1 R31	NPCN 95	NCN 86
01						Produtos da agricultura, da produção animal, da caça e dos serviços relacionados			
	.1					Produtos agrícolas			
	.11					Cereais e outros produtos agrícolas n.e.			
		.1				Produtos da cerealicultura			
			.1			Cereais para grão	AA	01.11.1.1	01.01.01 01.01.02 01.01.03 01.01.04 01.01.05 01.01.06 01.02
		.2				Produtos agrícolas n.e.			
			.2			Raízes, tubérculos e leguminosas secas			
			.21			Batata	AA	01.11.2.21	01.04.01
			.22			Leguminosas secas para grão	AA	01.11.2.22	01.03.01 01.03.02 01.03.03 01.03.04 01.03.05
			.23			Raízes e tubérculos comestíveis com elevado teor de amido e inulina	AA	01.11.2.23	01.04.03
			.3			Sementes e frutos oleaginosos	AA	01.11.2.3	01.05.01 01.14.01
			.4			Tabaco não manufacturado	AA	01.11.2.4	01.05.03
			.5			Plantas utilizadas para o fabrico de açúcar			
			.51			Beterraba sacarina	AA	01.11.2.51	01.04.02
			.52			Cana-de-açúcar	AA	01.11.2.52	01.05.04 01.14.03
			.6			Produtos forrageiros e palhas	AA	01.11.2.6	01.09.01
			.7			Matérias-primas vegetais para usos têxteis	AA	01.11.2.7	01.05.02 01.14.02
			.8			Borracha natural	AA	01.11.2.8	01.14.03
			.9			Plantas utilizadas principalmente em perfumaria, farmácia e para fins semelhantes; sementes de beterraba, sementes de plantas forrageiras; outras matérias-primas vegetais	AA	01.11.2.9	01.05.02 01.09.05
	.12					Produtos hortícolas, flores, sementes e produtos de viveiro			
		.0				Produtos hortícolas, flores, sementes e produtos de viveiro			
			.1			Produtos hortícolas, frescos ou refrigerados	AA	01.12.0.1	01.06.01 01.06.02 01.07.07
			.2			Plantas vivas; flores e botões de flores de corte; sementes de flores e frutos; sementes de produtos hortícolas			
			.21			Flores e botões de flores de corte (01.12.0.2)	AA	01.12.0.21	01.09.04

NOMENCLATURA DE PRODUTOS - BASE 95									
CÓDIGO						DESIGNAÇÃO	EQUIVALÊNCIA		
DIVISÃO	GRUPO / CLASSE	SUBCLASSE	CATEGORIA / SUBCATEGORIA	POSIÇÃO / SUBPOSIÇÃO	SEGMENTO / SUBSEGMENTO		NACE Rev.1 R31	NPCN 95	NCN 86
01	.12	.0	.22			Plantas vivas; sementes de flores e frutos; sementes de produtos hortícolas (01.12.0.2)	AA	01.12.0.22	01.09.02 01.09.05 01.09.06
	.13					Frutos e plantas para a preparação de bebidas e de especiarias			
		.0				Frutos e plantas para a preparação de bebidas e de especiarias			
			.1			Uvas			
			.11			Uvas de mesa	AA	01.13.0.11	01.08.01
			.12			Outras uvas, frescas	AA	01.13.0.12	01.08.01 01.10.01 01.10.02 01.10.03
			.2			Frutos			
			.21			Tâmaras, figos, bananas, cocos, castanhas do Brasil, castanha de caju, ananases ou abacaxis, abacates, mangas, goiabas	AA	01.13.0.21	01.07.06 01.14.04
			.22			Citrinos	AA	01.13.0.22	01.07.04
			.23			Outros frutos frescos	AA	01.13.0.23	01.07.01 01.07.02 01.07.03 01.07.07
			.24			Frutos de casca rija e azeitonas			
				.0		Frutos de casca rija e azeitonas			
				.00		Frutos de casca rija e azeitonas			
					.1	Frutos de casca rija	AA	01.13.0.24.00.1	01.07.05
					.2	Azeitonas			
					.21	Azeitonas de mesa	AA	01.13.0.24.00.21	01.08.02
					.22	Azeitonas para produção de azeite	AA	01.13.0.24.00.22	01.08.02
		.4				Produtos destinados à preparação de bebidas e especiarias			
			.3			Café, chá e cacau não transformados	AA	01.13.4.3	01.14.03
			.4			Especiarias, não transformadas	AA	01.13.4.4	01.14.03
	.2					Animais vivos e produtos de origem animal			
	.21					Gado bovino vivo e produtos destes animais			
		.0				Gado bovino vivo e produtos destes animais			
			.1			Gado bovino vivo			
			.11			Gado bovino, vivo, adulto	AA	01.21.0.11	01.12.01
			.12			Vitelos e vitelas	AA	01.21.0.12	01.12.01
			.2			Leite de vaca em natureza	AA	01.21.0.2	01.12.10
			.3			Sémen de bovino	AA	01.21.0.3	01.12.14
	.22					Ovinos, caprinos, equídeos (cavalos, asininos e muares) vivos e produtos destes animais			

NOMENCLATURA DE PRODUTOS - BASE 95

CÓDIGO: DIVISÃO	GRUPO / CLASSE	SUBCLASSE	CATEGORIA / SUBCATEGORIA	POSIÇÃO / SUBPOSIÇÃO	SEGMENTO / SUBSEGMENTO	DESIGNAÇÃO	EQUIVALÊNCIA: NACE Rev.1 R31	NPCN 95	NCN 86
01	.22	.0				Ovinos, caprinos, equídeos (cavalos, asininos e muares) vivos e produtos destes animais			
			.1			Ovinos, caprinos e equídeos, vivos			
			.11			Ovinos vivos	AA	01.22.0.11	01.12.04
			.12			Caprinos vivos	AA	01.22.0.12	01.12.05
			.13			Equídeos vivos	AA	01.22.0.13	01.12.03
			.2			Leite de ovelha e cabra	AA	01.22.0.2	01.12.10
			.3			Lã e pêlos	AA	01.22.0.3	01.12.12
	.23					Suínos, vivos (01.23.0.1)	AA	01.23	01.12.02
	.24					Aves de capoeira vivas e ovos			
		.0				Aves de capoeira vivas e ovos			
			.1			Aves de capoeira, vivas	AA	01.24.0.1	01.12.06 01.12.07
			.2			Ovos, inteiros	AA	01.24.0.2	01.12.11
	.25					Outros animais vivos e produtos de origem animal			
		.0				Outros animais vivos e produtos de origem animal			
			.1			Outros animais vivos	AA	01.25.0.1	01.12.07 01.12.08 01.14.05
			.2			Outros produtos de origem animal	AA	01.25.0.2	01.12.11 01.12.13 01.12.14
			.3			Peles com pêlo, em bruto	AA	01.25.0.3	01.12.14
	.3					Produtos de explorações mistas (produção agrícola e animal associadas)	AA	01.3	01.01 01.02 01.03 01.04 01.05 01.06 01.07 01.08 01.09 01.10 01.11 01.12 01.13
	.4					Serviços relacionados com a agricultura e a produção animal, excepto serviços de veterinária	AA	01.4	01.12 01.13
	.5					Caça, repovoamento cinegético e serviços relacionados	AA	01.5	01.12.09
02						Produtos da silvicultura, da exploração florestal e serviços relacionados			
	.0					Produtos da silvicultura, da exploração florestal e serviços relacionados			
	.01					Produtos da silvicultura e da exploração florestal			
		.0				Produtos da silvicultura e da exploração florestal			
			.1			Madeira em bruto			

NOMENCLATURA DE PRODUTOS - BASE 95

CÓDIGO: DIVISÃO	GRUPO CLASSE	SUBCLASSE	CATEGORIA SUBCATEGORIA	POSIÇÃO SUBPOSIÇÃO	SEGMENTO SUBSEGMENTO	DESIGNAÇÃO	EQUIVALÊNCIA: NACE Rev.1 R31	NPCN 95	NCN 86
02	.01	.0	.11			Toros de madeira de resinosas (coníferas)	AA	02.01.0.11	02.01.01
			.12			Toros de madeira de folhosas	AA	02.01.0.12	02.01.01
			.13			Toros de madeira tropical	AA	02.01.0.13	02.01.01
			.14			Madeira para energia (lenha)	AA	02.01.0.14	02.01.02
			.15			Outra madeira em bruto n.e.	AA	02.01.0.15	02.01.01
			.2			Gomas naturais	AA	02.01.0.2	02.03.01
			.3			Cortiça natural, em bruto	AA	02.01.0.3	02.02
			.4			Outros produtos da exploração florestal	AA	02.01.0.4	01.09.03 02.03.02
			.5			Produtos da silvicultura	AA	02.01.0.5	02.05
	.02					Serviços relacionados com a silvicultura e a exploração florestal (02.02.0.10.00)	AA	02.02	02.04
05						Produtos da pesca e da aquacultura e serviços relacionados			
	.0					Produtos da pesca e da aquacultura e serviços relacionados			
	.00					Produtos da pesca e da aquacultura e serviços relacionados			
		.0				Produtos da pesca e da aquacultura e serviços relacionados			
			.1			Peixes vivos, frescos ou refrigerados	BB	05.00.0.1	03.01.01 03.04
			.2			Crustáceos, moluscos e outros invertebrados aquáticos, vivos, frescos ou refrigerados			
			.21			Crustáceos	BB	05.00.0.21	03.01.02 03.04
			.22			Ostras	BB	05.00.0.22	03.01.03 03.04
			.23			Outros moluscos e invertebrados aquáticos, vivos, frescos ou refrigerados	BB	05.00.0.23	03.01.03 03.04
			.3			Outros produtos aquáticos	BB	05.00.0.3	03.03 03.04
			.4			Pérolas	BB	05.00.0.4	03.03 03.04
			.5			Serviços relacionados com a pesca	BB	05.00.0.5	03.01 03.02 03.03 03.04
10						Hulha (inclui antracite) e linhite; turfa	CA	10	04.01 04.03 04.06 08.04
11						Petróleo bruto e gás natural; serviços relacionados com a extracção de petróleo e gás, excepto a prospecção			
	.1					Petróleo bruto e gás natural	CA	11.1	05.01
	.2					Serviços relacionados com a extracção de petróleo e gás natural (excepto prospecção)	CA	11.2	05.01
12						Minérios e concentrados de urânio e de tório (12.00.0.10.00)	CA	12	07.06
13						Minérios metálicos			

NOMENCLATURA DE PRODUTOS - BASE 95

CÓDIGO: DIVISÃO	GRUPO / CLASSE	SUBCLASSE	CATEGORIA / SUBCATEGORIA	POSIÇÃO / SUBPOSIÇÃO	SEGMENTO / SUBSEGMENTO	DESIGNAÇÃO	EQUIVALÊNCIA: NACE Rev.1 R31	NPCN 95	NCN 86
13	.1					Minérios e concentrados de ferro (13.10.0.10)	CB	13.1	07.01
	.2					Outros minérios metálicos não ferrosos e seus concentrados (excepto minérios de urânio e de tório)	CB	13.2	07.06
14						Outros produtos das indústrias extractivas			
	.1					Pedra de construção (extraída)	CB	14.1	08.01 08.04
	.2					Areias e argilas	CB	14.2	08.01
	.3					Minerais para a indústria química e para a fabricação de adubos (14.30.0.1)	CB	14.3	08.02
	.4					Sal (14.40.0.10.0)	CB	14.4	08.03 22.13
	.5					Outros produtos das indústrias extractivas, n.e.	CB	14.5	08.04
15						Produtos alimentares e bebidas			
	.1					Carne e produtos à base de carne			
	.11					Carnes e produtos (excepto de animais de capoeira) resultantes do abate	DA	15.11	17.01 17.02 17.03
	.12					Carnes e produtos resultantes do abate de animais de capoeira	DA	15.12	17.01 17.02
	.13					Produtos à base de carne	DA	15.13	17.02 17.03
	.2					Produtos da indústria transformadora da pesca e da aquacultura			
	.20					Produtos da indústria transformadora da pesca e da aquacultura			
		.0				Produtos da indústria transformadora da pesca e da aquacultura			
			.1			Produtos da indústria transformadora da pesca e da aquacultura			
			.11			Filetes de peixe, outros pedaços de peixe, fígados e ovas de peixe, frescos ou refrigerados	DA	15.20.0.11	19.04
			.12			Peixe, filetes de peixe, outros pedaços de peixe, fígados e ovas de peixe, congelados	DA	15.20.0.12	19.02
			.13			Peixe, seco, salgado ou em salmoura; peixe fumado; farinhas de peixe comestíveis	DA	15.20.0.13	03.02 19.03 19.04
			.14			Conservas e outras preparações de peixe	DA	15.20.0.14	19.01 19.04
			.15			Crustáceos; moluscos e outros invertebrados aquáticos, congelados, secos, salgados ou em salmoura	DA	15.20.0.15	19.02 19.03
			.16			Crustáceos; moluscos e outros invertebrados aquáticos, preparados ou em conserva	DA	15.20.0.16	19.04
			.17			Farinhas, pós e pellets, de peixe, crustáceos, moluscos ou de outros invertebrados aquáticos, não comestíveis	DA	15.20.0.17	19.04
			.18			Produtos n.e., de peixe, crustáceos, moluscos ou de outros invertebrados aquáticos	DA	15.20.0.18	19.04
	.3					Produtos hortícolas e frutos preparados e conservados			
	.31					Batata preparada e conservada (15.31.0.1)	DA	15.31	22.01 22.17
	.32					Sumos de frutos e de produtos hortícolas (15.32.0.10)	DA	15.32	22.01
	.33					Frutos e produtos hortícolas preparados e conservados por processos, n.e.			
		.0				Frutos e produtos hortícolas preparados e conservados por processos, n.e.			
			.1			Produtos hortícolas preparados e conservados (excepto batatas)	DA	15.33.0.1	22.01
			.2			Frutos, incluindo os de casca rija, preparados ou conservados	DA	15.33.0.2	22.01 22.15
			.3			Desperdícios, resíduos e subprodutos vegetais para alimentação animal (bagaços)	DA	15.33.0.3	22.01 22.15 22.17

NOMENCLATURA DE PRODUTOS - BASE 95												
CÓDIGO									**DESIGNAÇÃO**	**EQUIVALÊNCIA**		
DIVISÃO	GRUPO CLASSE	SUBCLASSE	CATEGORIA	SUBCATEGORIA	POSIÇÃO	SUBPOSIÇÃO	SEGMENTO	SUBSEGMENTO		NACE Rev.1 R31	NPCN 95	NCN 86
15	.33	.0	.9						Cozimento e outros serviços de preparação de frutos e de produtos hortícolas	DA	15.33.0.9	22.17
	.4								Óleos e gorduras animais e vegetais			
	.41								Óleos e gorduras brutos e bagaços	DA	15.41	01.11.01 01.11.02 12.11 20.01
	.42								Óleos e gorduras refinados e produtos associados	DA	15.42	20.01
	.43								Margarinas de gorduras alimentares similares (15.43.0.10)	DA	15.43	20.02
	.5								Lacticínios e gelados			
	.51								Lacticínios			
		.1							Leite e natas (15.51.0.11 + 15.51.0.12 + 15.51.0.20 + 15.51.0.51)	DA	15.51.1	18.01
		.2							Manteiga, queijo, iogurtes e outros produtos lácteos n.e. (15.51.0.30 + 15.51.0.40 + 15.51.0.52 + 15.51.0.53 + 15.51.0.54 + 15.51.0.55)	DA	15.51.2	18.01
	.52								Gelados e sorvetes (15.52.0.10.00)	DA	15.52	18.02
	.6								Produtos da transformação de cereais e leguminosas; amidos, féculas e produtos afins			
	.61								Produtos da transformação de cereais e leguminosas			
		.1							Farinhas e sémolas de cereais (15.61.0.21 + 15.61.0.22)	DA	15.61.1	21.01
		.2							Arroz descascado, branqueado e glaciado (15.61.0.10 + 15.61.0.40)	DA	15.61.2	21.02
		.3							Outros produtos da transformação de cereais e leguminosas n.e. (15.61.0.23 + 15.61.0.24 + 15.61.0.31 + 15.61.0.32 + 15.61.0.33 + 15.61.0.50)	DA	15.61.3	21.03 21.04
	.62								Amidos, féculas e produtos afins	DA	15.62	22.11
	.7								Alimentos compostos para animais	DA	15.7	22.18
	.8								Outros produtos alimentares			
	.81								Pão e outros produtos de padaria e de pastelaria, frescos			
		.1							Pão e outros produtos de padaria frescos (15.81.1.11.00)	DA	15.81.1	21.05
		.2							Produtos de pastelaria frescos (15.81.2.12.00)	DA	15.81.2	21.06
	.82								Bolachas, biscoitos, tostas e pastelaria de conservação (15.82.0.1)	DA	15.82	21.07
	.83								Açúcar (15.83.0.1 + 15.83.0.2)	DA	15.83	22.03 22.04
	.84								Cacau, chocolate e produtos de confeitaria			
		.1							Cacau e chocolate (15.84.0.11 + 15.84.0.12 + 15.84.0.13 + 15.84.0.14 + 15.84.0.21 + 15.84.0.22)	DA	15.84.1	22.05
		.2							Produtos de confeitaria (15.84.0.23 + 15.84.0.24)	DA	15.84.2	22.06
	.85								Massas alimentícias, cuscus e similares (15.85.0.1)	DA	15.85	21.08
	.86								Café e chá			
		.1							Café e sucedâneos de café (15.86.0.11 + 15.86.0.12)	DA	15.86.1	22.02 22.07 22.16
		.2							Chá e sucedâneos de chá (15.86.0.13 + 15.86.0.14)	DA	15.86.2	22.08

NOMENCLATURA DE PRODUTOS - BASE 95												
CÓDIGO									DESIGNAÇÃO	EQUIVALÊNCIA		
DIVISÃO	GRUPO . CLASSE	SUBCLASSE	CATEGORIA	SUBCATEGORIA	POSIÇÃO	SUBPOSIÇÃO	SEGMENTO	SUBSEGMENTO		NACE Rev.1 R31	NPCN 95	NCN 86
15	.87								Condimentos e temperos	DA	15.87	22.09 22.17
	.88								Alimentos homogeneizados e dietéticos (15.88.0.10)	DA	15.88	18.01 22.17
	.89								Outros produtos alimentares diversos, n.e. (15.89.0.1 + 15.89.0.2)	DA	15.89	12.01 22.10 22.14 22.17
	.9								Bebidas			
	.91								Bebidas alcoólicas destiladas (15.91.0.10)	DA	15.91	23.02 23.03 23.04
	.92								Álcool etílico de fermentação (15.92.0.1)	DA	15.92	23.01
	.93								Vinhos (inclui desperdícios)			
		.0							Vinhos (inclui desperdícios)			
			.1						Vinhos			
				.11					Vinho espumante e vinho espumoso	DA	15.93.0.11	23.06
				.12					Vinho (excepto vinho espumante); mosto de uvas	DA	15.93.0.12	01.10.01 01.10.02 01.10.03 23.05
			.2						Desperdícios da produção de vinho; borras e tártaro em bruto			
				.20					Desperdícios da produção de vinho; borras e tártaro em bruto	DA	15.93.0.20	01.10.01 01.10.02 01.10.03 23.05 23.06
	.94								Cidra perada e outras bebidas fermentadas de frutos (15.94.0.10.00.00)	DA	15.94	23.08
	.95								Vermutes e outros vinhos aromatizados (15.95.0.10.00.00)	DA	15.95	01.10.04 23.07
	.96								Cerveja de malte (15.96.0.10.00 + 15.96.0.20.00.00)	DA	15.96	23.09
	.97								Malte (15.97.0.10)	DA	15.97	23.09
	.98								Águas minerais e bebidas refrescantes não alcoólicas			
		.1							Águas minerais e águas gaseificadas, sem adição de edulcorantes, nem de aromatizantes e águas de nascentes (15.98.1.11)	DA	15.98.1	23.10.01
		.2							Outras bebidas não alcoólicas, n.e. (15.98.2.12)	DA	15.98.2	23.10.01 23.10.02
16									Produtos da indústria do tabaco (16.00.0.1 + 16.00.0.20.00.00)	DA	16	24
17									Produtos têxteis			

NOMENCLATURA DE PRODUTOS - BASE 95												
CÓDIGO									**DESIGNAÇÃO**	**EQUIVALÊNCIA**		
DIVISÃO	GRUPO / CLASSE	SUBCLASSE	CATEGORIA	SUBCATEGORIA	POSIÇÃO	SUBPOSIÇÃO	SEGMENTO	SUBSEGMENTO		NACE Rev.1 R31	NPCN 95	NCN 86
17	.1								Fios e fibras têxteis	DB	17.1	25.01 25.02 25.04 25.06 25.10
	.2								Tecidos têxteis	DB	17.2	25.03 25.05 25.07 25.11
	.3								Serviços de acabamento de têxteis	DB	17.3	25.03 25.05 25.07 25.11
	.4								Artigos têxteis confeccionados, excepto vestuário	DB	17.4	25.12 25.13 25.15 25.16
	.5								Outros artigos têxteis			
	.51 .52 .53 .54								Tapetes e carpetes (17.51.0) Cordoaria e redes (17.52.0.1 + 17.52.0.20.00.00 + 17.52.0.90.00) Falsos tecidos e respectivos artigos, excepto vestuário (17.53.0.10) Outros têxteis , n.e.	DB DB DB DB	17.51 17.52 17.53 17.54	25.18 25.20 25.21 25.22 25.25 25.08 25.09 25.14 25.16 25.23 25.24 25.25
	.6								Tecidos de malha (17.60.0.1)	DB	17.6	25.17
	.7								Artigos de malha	DB	17.7	25.17
18									Artigos de vestuário e de peles com pêlo			
	.1								Artigos de vestuário de couro natural ou reconstituido (18.10.0.10.0)	DB	18.1	25.26 25.27
	.2								Outros artigos e acessórios de vestuário			
	.21 .22 .23 .24								Vestuário de trabalho e uniformes Vestuário exterior Roupa interior Outros artigos e acessórios de vestuário, n.e.	DB DB DB DB	18.21 18.22 18.23 18.24	25.26 25.27 25.26 25.27 25.26 25.27 25.28 25.29
	.3								Peles e artigos de peles com pêlo (18.30.0.1)	DB	18.3	25.26 25.27 26.01
19									Couros e peles sem pêlo; artigos de couro e de peles sem pêlo			
	.1								Couros e peles sem pêlo	DC	19.1	26.01

NOMENCLATURA DE PRODUTOS - BASE 95

CÓDIGO: DIVISÃO	GRUPO / CLASSE	SUBCLASSE	CATEGORIA	SUBCATEGORIA	POSIÇÃO	SUBPOSIÇÃO	SEGMENTO	SUBSEGMENTO	DESIGNAÇÃO	EQUIVALÊNCIA: NACE Rev.1 R31	NPCN 95	NCN 86
19	.2								Artigos de viagem e de uso pessoal, de marroquinaria, de correeiro, de seleiro e de outros artigos de couro (19.20.0.1)	DC	19.2	26.02 26.03
	.3								Calçado e suas partes	DC	19.3	26.04 27.11 29.04 29.05
20									Madeira e cortiça e suas obras (excepto mobiliário), obras de cestaria e de espartaria			
	.1								Produtos da serração, do aplainamento e da impregnação da madeira	DD	20.1	27.01 27.05
	.2								Folheados, contraplacados, lamelados, painéis de partículas, de fibras e outros painéis	DD	20.2	27.03 27.04 28.02
	.3								Obras de carpintaria para a construção	DD	20.3	27.02 27.14
	.4								Embalagens de madeira (20.40.0.1)	DD	20.4	27.07 27.08
	.5								Outras obras de madeira; obras de cortiça, cestaria e espartaria			
	.51								Outras obras de madeira (20.51.0.1)	DD	20.51	27.06 27.11
	.52								Obras de cortiça, cestaria e espartaria			
		.1							Obras de cestaria e de espartaria (20.52.0)	DD	20.52.1	25.19 27.09
		.2							Produtos da cortiça (20.52.0)	DD	20.52.2	27.10
21									Pasta, papel e seus artigos			
	.1								Pasta, papel e cartão			
	.11								Pasta	DE	21.11	28.01
	.12								Papel e cartão	DE	21.12	28.02 28.03
	.2								Artigos de papel e cartão	DE	21.2	28.02 28.03
22									Material impresso, suportes gravados e trabalhos de impressão			
	.1								Livros, jornais e outro material impresso e suportes gravados			
	.11								Livros	DE	22.11	28.05
	.12								Jornais, revistas e publicações periódicas, impressos, editadas quatro vezes ou mais por semana (22.12.0.10.00)	DE	22.12	28.05
	.13								Jornais, revistas e outras publicações periódicas, excepto as diárias editadas menos de quatro vezes por semana (22.13.0.10.00)	DE	22.13	28.05
	.14								Gravações de som (22.14.0.1)	DE	22.14	15.02 45.06
	.15								Cartões postais, cartões com mensagens, estampas e outro material impresso (22.15.0.1)	DE	22.15	28.05
	.2								Trabalhos de impressão e trabalhos relacionados com a impressão			
	.21								Trabalhos de impressão de jornais e publicações periódicas (22.21.0.10.00.00)	DE	22.21	28.04
	.22								Trabalhos de impressão, n.e.	DE	22.22	28.04
	.23								Trabalhos de encadernação e acabamento (22.23.0.10)	DE	22.23	28.04

NOMENCLATURA DE PRODUTOS - BASE 95

CÓDIGO						DESIGNAÇÃO	EQUIVALÊNCIA		
DIVISÃO	GRUPO . CLASSE	SUBCLASSE	CATEGORIA . SUBCATEGORIA	POSIÇÃO . SUBPOSIÇÃO	SEGMENTO . SUBSEGMENTO		NACE Rev.1 R31	NPCN 95	NCN 86
22	. 24					Trabalhos de composição e outras preparações da impressão (22.24.0.10.00.00 + 22.24.0.20.00.00)	DE	22.24	28.04
	. 25					Outros trabalhos relacionados com a impressão (22.25.0.10.00.00)	DE	22.25	28.04
	. 3					Trabalhos de reprodução de suportes gravados	DE	22.3	15.02 45.06
23						Coque, produtos petrolíferos refinados e combustível nuclear			
	. 1					Produtos de coqueria	DF	23.1	04.06 07.02
	. 2					Produtos petrolíferos refinados	DF	23.2	05.02.01 05.02.02 05.02.03 05.02.04 05.02.05 05.02.06 05.02.07
	. 3					Combustível nuclear	DF	23.3	12.01
24						Produtos químicos			
	. 1					Produtos químicos de base			
	. 11					Gases industriais (24.11.0.1)	DG	24.11	12.01
	. 12					Corantes e pigmentos	DG	24.12	12.01
	. 13					Outros produtos químicos inorgânicos de base	DG	24.13	04.05 04.06 12.01
	. 14					Outros produtos químicos orgânicos de base	DG	24.14	04.05 04.06 12.01 12.07.02
	. 15					Adubos e compostos azotados	DG	24.15	12.01 12.02
	. 16					Matérias plásticas em formas primárias	DG	24.16	12.04
	. 17					Borracha sintética e artificial (24.17.0.10)	DG	24.17	12.04
	. 2					Pesticidas e outros produtos agroquímicos (24.20.0.1)	DG	24.2	12.03 12.19
	. 3					Tintas, vernizes e produtos similares, mastiques e tintas de impressão	DG	24.3	12.06 12.18
	. 4					Produtos farmacêuticos			
	. 41					Produtos farmacêuticos de base	DG	24.41	12.07.02
	. 42					Preparações farmacêuticas			
		. 1				Medicamentos (24.42.1.1)	DG	24.42.1	12.07.01 12.07.02
		. 2				Outras preparações e artigos farmacêuticos (24.42.2.2)	DG	24.42.2	12.07.01 12.07.02
	. 5					Glicerina, sabões e detergentes, produtos de limpeza e de polimento; perfumes, cosméticos e produtos de higiene			
	. 51					Glicerina, sabões e detergentes, produtos de limpeza e de polimento	DG	24.51	12.08 12.10 12.17

NOMENCLATURA DE PRODUTOS - BASE 95

CÓDIGO: DIVISÃO	CÓDIGO: GRUPOS / CLASSE	DESIGNAÇÃO	EQUIVALÊNCIA: NACE Rev.1 R31	EQUIVALÊNCIA: NPCN 95	EQUIVALÊNCIA: NCN 86
24	.52	Perfumes, cosméticos e produtos de higiene (24.52.0.1)	DG	24.52	12.09.01 12.09.02
	.6	Outros produtos químicos			
	.61	Explosivos e artigos de pirotecnia (24.61.0.1)	DG	24.61	12.13.02
	.62	Colas e gelatinas (24.62.0.10)	DG	24.62	12.16
	.63	Óleos essenciais (24.63.0.10)	DG	24.63	12.12
	.64	Produtos químicos para fotografia	DG	24.64	12.14
	.65	Suportes de informação não gravados	DG	24.65	29.05
	.66	Outros produtos químicos , n.e.	DG	24.66	04.04 12.11 12.18 12.19
	.7	Fibras sintéticas ou artificiais	DG	24.7	12.05
25		Artigos de borracha e de matérias plásticas			
	.1	Artigos de borracha			
	.11	Pneus e câmaras-de-ar	DH	25.11	29.01
	.12	Pneus recauchutados e outros reconstituídos, de borracha (25.12.0.10)	DH	25.12	29.02
	.13	Outros artigos de borracha	DH	25.13	29.03 29.04
	.2	Artigos de matérias plásticas			
	.21	Chapas, folhas, tubos e perfis de matérias plásticas	DH	25.21	29.05
	.22	Embalagens de matérias plásticas (25.22.0.1)	DH	25.22	29.05
	.23	Artigos de matérias plásticas para a construção (25.23.0.1 + 25.23.0.20.0)	DH	25.23	27.14 29.05
	.24	Outros artigos de matérias plásticas, n.e.	DH	25.24	29.05
26		Outros produtos minerais não metálicos			
	.1	Vidro e artigos de vidro			
	.11	Vidro plano	DI	26.11	10.01
	.12	Vidro plano trabalhado ou transformado (26.12.0.1)	DI	26.12	10.02
	.13	Vidro de embalagem e cristalaria (vidro oco) (26.13.0.1)	DI	26.13	10.01
	.14	Fibras de vidro (26.14.0.1)	DI	26.14	10.01
	.15	Outro vidro, transformado, incluindo vidro técnico	DI	26.15	10.01 10.02
	.2	Produtos cerâmicos não refractários, excepto os destinados à construção; produtos cerâmicos refractários			
	.21	Artigos cerâmicos de uso doméstico e ornamental (26.21.0.1)	DI	26.21	09.00
	.22	Artigos cerâmicos para usos sanitários (26.22.0.10)	DI	26.22	09.00
	.23	Isoladores e peças isolantes de cerâmica (26.23.0.10)	DI	26.23	09.00
	.24	Artefactos de cerâmica para usos técnicos	DI	26.24	09.00
	.25	Artefactos cerâmicos não refractários n.e. (26.25.0.1)	DI	26.25	09.00
	.26	Produtos cerâmicos refractários (26.26.0.1)	DI	26.26	11.01
	.3	Azulejos, ladrilhos, mosaicos e placas de cerâmica (26.30.0.10)	DI	26.3	09.00
	.4	Tijolos, telhas e outros produtos de barro para a construção (26.40.0.10)	DI	26.4	11.01
	.5	Cimento, cal e gesso			
	.51	Cimento (26.51.0.1)	DI	26.51	11.02

NOMENCLATURA DE PRODUTOS - BASE 95

CÓDIGO		DESIGNAÇÃO	EQUIVALÊNCIA		
DIVISÃO	GRUPO / CLASSE / SUBCLASSE / CATEGORIA / SUBCATEGORIA / POSIÇÃO / SUBPOSIÇÃO / SEGMENTO / SUBSEGMENTO		NACE Rev.1 R31	NPCN 95	NCN 86
26	.52	Cal (26.52.0.10)	DI	26.52	11.03 11.04
	.53	Gesso (26.53.0.10)	DI	26.53	11.05
	.6	Produtos de betão, gesso, cimento e marmorite			
	.61	Produtos de betão para a construção (26.61.0.1 + 26.61.0.20.00.00)	DI	26.61	11.08
	.62	Produtos de gesso para a construção (26.62.0.1)	DI	26.62	11.05
	.63	Betão pronto (26.63.0.10.00.00)	DI	26.63	11.08
	.64	Argamassas e betões, não refractários (26.64.0.10.00.00)	DI	26.64	11.08
	.65	Produtos de fibrocimento (26.65.0.1)	DI	26.65	11.07
	.66	Outros produtos de betão, gesso, cimento e marmorite (26.66.0.1)	DI	26.66	11.05 11.08
	.7	Obras de mármore e de rochas similares (26.70.0.1)	DI	26.7	08.06 11.06
	.8	Outros produtos minerais não metálicos	DI	26.8	04.02 08.05 08.07 08.08
27		Metais de base			
	.1	Ferro e aço e ferro-ligas (CECA)	DJ	27.1	07.02
	.2	Tubos			
	.21	Tubos de ferro fundido	DJ	27.21	07.04 07.05
	.22	Tubos de aço	DJ	27.22	07.04
	.3	Outro ferro ou aço e ferro-ligas não-CECA			
	.31	Produtos estirados a frio	DJ	27.31	07.02
	.32	Produtos laminados a frio de arco ou banda	DJ	27.32	07.02
	.33	Perfis de ferro, de aço não ligado ou de aço inoxidável (27.33.0.1)	DJ	27.33	07.02
	.34	Fios trefilados (27.34.0.1)	DJ	27.34	07.03 13.10
	.35	Ferro-ligas (não CECA) e outro ferro e aço n.e.	DJ	27.35	07.02 07.05
	.4	Metais não ferrosos (obtenção e primeira transformação)			
	.41	Metais preciosos	DJ	27.41	07.07 07.08 07.09 13.11
	.42	Alumínio e produtos de alumínio	DJ	27.42	07.07 07.08 07.09 13.11
	.43	Chumbo, zinco e estanho, e produtos semi-acabados à base destes metais	DJ	27.43	07.07 07.08 07.09 13.11
	.44	Produtos de cobre	DJ	27.44	07.07 07.08 07.09 13.11

NOMENCLATURA DE PRODUTOS - BASE 95

CÓDIGO		DESIGNAÇÃO	EQUIVALÊNCIA		
DIVISÃO	GRUPO . CLASSE . SUBCLASSE . CATEGORIA . SUBCATEGORIA . POSIÇÃO . SUBPOSIÇÃO . SEGMENTO . SUBSEGMENTO		NACE Rev.1 R31	NPCN 95	NCN 86
27	.45	Outros metais não ferrosos e produtos semi-acabados destes metais	DJ	27.45	07.07 07.08 07.09 13.11
	.5	Produtos de fundição			
	.51	Produtos de fundição de ferro (27.51.0.1)	DJ	27.51	07.05
	.52	Produtos de fundição de aço (27.52.0.10)	DJ	27.52	07.05
	.53	Produtos de fundição de metais leves (27.53.0.10)	DJ	27.53	07.08 07.10
	.54	Produtos de fundição de metais não ferrosos, excepto os metais leves (27.54.0.10)	DJ	27.54	07.08 07.10
28		Produtos metálicos transformados, excepto máquinas e equipamento			
	.1	Elementos de construção em metal			
	.11	Estruturas metálicas	DJ	28.11	13.06
	.12	Portas, janelas e elementos similares em metal (28.12.0.10)	DJ	28.12	13.06 27.14
	.2	Reservatórios, recipientes, caldeiras e radiadores metálicos para aquecimento central			
	.21	Reservatórios e recipientes metálicos (28.21.0.1 + 28.21.0.90.00.00)	DJ	28.21	13.05 13.06
	.22	Caldeiras e radiadores para aquecimento central (28.22.0.1)	DJ	28.22	13.05
	.3	Geradores de vapor (28.30.0.1 + 28.30.0.2 + 28.30.0.9)	DJ	28.3	13.05 14.01
	.4	Produtos forjados, estampados e laminados de metais; metalurgia dos pós	DJ	28.4	13.02 13.03 13.12
	.5	Revestimento e tratamento de metais e de mecânica em geral			
	.51	Revestimento e tratamento de metais	DJ	28.51	13.12
	.52	Operações de mecânica geral (28.52.0.10)	DJ	28.52	13.03 13.12
	.6	Cutelaria, ferramentas e ferragens			
	.61	Cutelaria (28.61.0.1)	DJ	28.61	13.01
	.62	Ferramentas	DJ	28.62	13.02 13.12
	.63	Fechaduras, dobradiças e outras ferragens (28.63.0.1)	DJ	28.63	13.03
	.7	Outros produtos metálicos transformados			
	.71	Embalagens metálicas pesadas (28.71.0.1)	DJ	28.71	13.05 13.09
	.72	Embalagens metálicas ligeiras (28.72.0.1)	DJ	28.72	13.05 13.09
	.73	Produtos de arame (28.73.0.1)	DJ	28.73	13.08
	.74	Rebites, porcas e parafusos, molas e correntes metálicas	DJ	28.74	13.03 13.08 13.12 16.05
	.75	Outros produtos metálicos, n.e.	DJ	28.75	13.07 13.08 13.12

NOMENCLATURA DE PRODUTOS - BASE 95

CÓDIGO: Divisão	Grupo / Classe	Subclasse	DESIGNAÇÃO	EQUIVALÊNCIA: NACE Rev.1 R31	NPCN 95	NCN 86
29			Máquinas e equipamentos, n.e.			
	.1		Máquinas e equipamentos para a produção e utilização de energia mecânica, excepto motores para aeronaves, automóveis e motociclos			
	.11		Motores e turbinas	DK	29.11	14.01 16.01
	.12		Bombas e compressores	DK	29.12	14.15
	.13		Torneiras e válvulas	DK	29.13	13.12
	.14		Rolamentos, engrenagens e outros órgãos de transmissão	DK	29.14	14.14 14.15
	.2		Outras máquinas de uso geral			
	.21		Fornos e queimadores e suas partes (29.21.0.1 + 29.21.0.9)	DK	29.21	13.12 14.13 15.03
	.22		Equipamento de elevação e de movimentação	DK	29.22	14.11
	.23		Equipamento não doméstico para refrigeração e ventilação	DK	29.23	14.10
	.24		Outras máquinas de uso geral n.e.	DK	29.24	14.07 14.09 14.15
	.3		Máquinas e tractores para a agricultura, pecuária e silvicultura			
	.31		Tractores agrícolas	DK	29.31	14.02
	.32		Outras máquinas para a agricultura, pecuária e silvicultura, para a preparação e cultivo de solos (29.32.0.1 + 29.32.0.2 + 29.32.0.3 + 29.32.0.40 + 29.32.0.50 + 29.32.0.6 + 29.32.0.70)	DK	29.32	14.02
	.4		Máquinas-ferramentas	DK	29.4	14.03 14.07
	.5		Outras máquinas e equipamento para uso específico			
	.51		Máquinas para metalurgia (29.51.0.1 + 29.51.0.9)	DK	29.51	14.07
	.52		Máquinas para as indústrias extractivas e para a construção	DK	29.52	14.07
	.53		Máquinas para as indústrias alimentares, das bebidas e do tabaco (29.53.0.1 + 29.53.0.2 + 29.53.0.9)	DK	29.53	14.04 14.07
	.54		Máquinas para as indústrias têxteis, do vestuário e do couro	DK	29.54	14.05 14.06 14.07 14.15
	.55		Máquinas para as indústrias do papel e do cartão e suas partes (29.55.0.1 + 29.55.0.9)	DK	29.55	14.07
	.56		Outras máquinas e equipamento para uso específico, n.e.			
		.1	Máquinas e aparelhos para impressão e encadernação, e suas partes (2956.0.11 + 2956.0.12 + 2956.0.13 + 2956.0.14 + 2956.0.15)	DK	29.56.1	14.07
		.2	Máquinas e equipamento, para trabalhar borracha ou plástico, ou para fabricação de produtos dessas matérias, n.e. (29.56.0.23)	DK	29.56.2	14.07
		.3	Moldes, caixas de fundição, placas de fundo para moldes e modelos para moldes (29.56.0.24)	DK	29.56.3	13.12 14.07
		.4	Secadores; Máquinas e equipamento para fins especiais, n.e. (29.56.0.21 + 29.56.0.22 + 29.56.0.25)	DK	29.56.4	14.07
		.5	Partes de outras máquinas, n.e. (29.56.0.26)	DK	29.56.5	14.07
	.6		Armas e munições (29.60.0.1 + 29.60.0.9)	DK	29.6	12.13.01 12.13.02 14.12

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CÓDIGO: Divisão	CÓDIGO: Grupo / Classe	DESIGNAÇÃO	EQUIVALÊNCIA: NACE Rev.1 R31	EQUIVALÊNCIA: NPCN 95	EQUIVALÊNCIA: NCN 86
29	.7	Aparelhos domésticos n.e.			
	.71	Electrodomésticos	DK	29.71	15.03
	.72	Aparelhos não eléctricos para uso doméstico	DK	29.72	13.12 14.13
30		Máquinas de escritório e equipamento para o tratamento automático da informação			
	.0	Máquinas de escritório e equipamento para o tratamento automático da informação			
	.01	Máquinas de escritório e suas partes	DL	30.01	14.08 30.05
	.02	Computadores e outro equipamento informático	DL	30.02	14.08
31		Máquinas e aparelhos eléctricos, n.e.			
	.1	Motores, geradores e transformadores eléctricos	DL	31.1	15.01
	.2	Aparelhos de distribuição e de controlo de electricidade	DL	31.2	15.01 15.07
	.3	Fios e cabos isolados (31.30.0.1)	DL	31.3	15.04
	.4	Acumuladores, pilhas e baterias de pilhas, eléctricos	DL	31.4	15.05
	.5	Lâmpadas eléctricas e outro material de iluminação	DL	31.5	13.12 15.06 15.07 30.17
	.6	Equipamento eléctrico, n.e.			
	.61	Equipamento eléctrico para motores e veículos, n.e.	DL	31.61	15.01 15.04 15.07
	.62	Outro equipamento eléctrico, n.e. (31.62.0.1 + 31.62.0.9)	DL	31.62	15.07
32		Equipamento e aparelhos de rádio, televisão e comunicação			
	.1	Válvulas, tubos e outros componentes electrónicos	DL	32.1	15.02
	.2	Aparelhos emissores de rádio e televisão e aparelhos de telefonia e telegrafia por fios	DL	32.2	15.02
	.3	Aparelhos receptores e material de rádio e de televisão, aparelhos de gravação ou de reprodução de som e imagens e material associado	DL	32.3	15.02
33		Aparelhos e instrumentos médico-cirúrgicos, de precisão, de óptica e de relojoaria			
	.1	Material médico-cirúrgico, ortopédico e suas partes (33.10.0.1 + 33.10.0.20 + 33.10.0.9)	DL	33.1	15.02 30.01
	.2	Instrumentos e aparelhos de medida, verificação, controlo, navegação e outros fins	DL	33.2	30.02 30.03
	.3	Equipamento de controlo automático de processos industriais	DL	33.3	15.01 15.02 30.02 30.03
	.4	Material óptico, fotográfico e cinematográfico	DL	33.4	30.04 30.05 30.06
	.5	Relógios e de material de relojoaria (33.50.0.1 + 33.50.0.2 + 33.50.0.9)	DL	33.5	30.07
34		Veículos automóveis, reboques e semi-reboques			
	.1	Veículos automóveis			

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CÓDIGO: Divisão	Grupo / Classe	Subclasse	Categoria / Subcategoria	Posição / Subposição	Segmento / Subsegmento	DESIGNAÇÃO	EQUIVALÊNCIA: NACE Rev.1 R31	NPCN 95	NCN 86
34	.10					Veículos automóveis			
		.0				Veículos automóveis			
			.1			Motores de explosão, dos tipos utilizados para veículos automóveis e motociclos	DM	34.10.0.1	16.03 16.05
			.2			Veículos automóveis de passageiros	DM	34.10.0.2	16.03 16.05
			.3			Veículos automóveis para o transporte de dez ou mais passageiros (incluindo o condutor)	DM	34.10.0.3	16.03 16.05
			.4			Veículos automóveis para o transporte de mercadorias	DM	34.10.0.4	16.03 16.05
			.5			Veículos automóveis concebidos para usos especiais	DM	34.10.0.5	16.03 16.05
	.2					Carroçarias para veículos automóveis; reboques e semi-reboques	DM	34.2	16.04
	.3					Componentes e acessórios para veículos automóveis e seus motores	DM	34.3	16.05
35						Outro material de transporte			
	.1					Embarcações e reparação naval			
	.11					Embarcações e reparação naval, excepto de recreio e desporto	DM	35.11	16.01
	.12					Embarcações de recreio e de desporto	DM	35.12	16.01
	.2					Material circulante para caminhos de ferro e suas partes	DM	35.2	16.02
	.3					Produtos da construção aeronáutica e espacial	DM	35.3	16.07
	.4					Motociclos e bicicletas			
	.41					Motociclos e carros laterais (sidecars) (35.41.0.1 + 35.41.0.20)	DM	35.41	16.06
	.42					Bicicletas e outros ciclos, sem motor (35.42.0.10 + 35.42.0.20)	DM	35.42	16.06
	.43					Veículos para inválidos e suas partes (35.43.0.1)	DM	35.43	16.08
	.5					Outro material de transporte (não motorizado), n.e. (35.50.0.10.00.00)	DM	35.5	16.08
36						Mobiliário; outros produtos das indústrias transformadoras, n.e.			
	.1					Mobiliário			
	.11					Cadeiras, assentos e suas partes (36.11.0.1)	DN	36.11	08.06 13.04 16.05 27.12 27.13 27.16 29.05
	.12					Mobiliário para escritório e comércio (36.12.0.1)	DN	36.12	13.04 27.12 27.16
	.13					Mobiliário de cozinha (36.13.0.10)	DN	36.13	13.04 27.12 29.05
	.14					Mobiliário para outros fins			
		.1				Mobiliário de madeira para outros fins (36.14.0.12 + 36.14.0.13)	DN	36.14.1	27.12 27.16
		.2				Mobiliário metálico para outros fins (36.14.0.11)	DN	36.14.2	13.04

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CÓDIGO: Divisão	Grupo / Classe	Subclasse	Categoria / Subcategoria	Posição / Subposição	Segmento / Subsegmento	DESIGNAÇÃO	EQUIVALÊNCIA: NACE Rev.1 R31	NPCN 95	NCN 86
36	.14	.3				Mobiliário de outros materiais para outros fins (36.14.0.14)	DN	36.14.3	08.06 27.13 29.05
		.4				Partes de móveis (36.14.0.15)	DN	36.14.4	08.06 13.04 27.12 27.13 27.16 29.05
	.15					Suportes para colchões e colchões (36.15.0.1)	DN	36.15	27.15
	.2					Joalharia, ourivesaria e artigos similares			
	.21					Moedas e medalhas (36.21.0.10.00)	DN	36.21	30.08
	.22					Joalharia, ourivesaria e artigos similares, n.e. (36.22.0.1)	DN	36.22	30.08
	.3					Instrumentos musicais (36.30.0.1 + 36.30.0.90.00.00)	DN	36.3	30.09
	.4					Artigos de desporto (36.40.0.1)	DN	36.4	29.04 29.05 30.10
	.5					Jogos e brinquedos	DN	36.5	29.04 29.05 30.18
	.6					Produtos das indústrias transformadoras, n.e.			
	.61					Bijuterias (36.61.0.10)	DN	36.61	30.14
	.62					Vassouras, escovas e pincéis (36.62.0.1)	DN	36.62	30.13
	.63					Produtos diversos das indústrias transformadoras, n.e.			
		.1				Linóleo e outros revestimentos rígidos para o chão (36.63.0.40)	DN	36.63.1	25.23
		.2				Canetas, lápis e similares (36.63.0.21 + 36.63.0.22 + 36.63.0.23 + 36.63.0.24)	DN	36.63.2	30.12
		.3				Fechos de correr, botões e similares (36.63.0.33 + 36.63.0.34)	DN	36.63.3	13.12 30.11
		.4				Guarda-sóis e chapéus de chuva (36.63.0.31 + 36.63.0.32)	DN	36.63.4	30.16 30.18
		.5				Fósforos e outros produtos de ignição (36.63.0.61 + 36.63.0.62 + 36.63.0.63 + 36.63.0.64)	DN	36.63.5	12.15 30.18
		.6				Produtos de outras indústrias transformadoras diversas, n.e. (36.63.0.10 + 36.63.0.25 + 36.63.0.50 + 36.63.0.61 + 36.63.0.71 + 36.63.0.72 + 36.63.0.73 + 36.63.0.74 + 36.63.0.75 + 36.63.0.76 + 36.63.0.77)	DN	36.63.6	12.19 16.08 30.15 30.18
37						Materiais reciclados	DN	37	07.05 07.10 25.25 32.01 32.02 32.03
40						Electricidade, gás, vapor e água			
	.1					Electricidade (produzida, transportada e distribuída) e serviços anexos			
	.10					Electricidade (produzida, transportada e distribuída) e serviços anexos			

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CÓDIGO: DIVISÃO	GRUPO. CLASSE.	SUBCLASSE	CATEGORIA.	SUBCATEGORIA	POSIÇÃO.	SUBPOSIÇÃO	SEGMENTO.	SUBSEGMENTO	DESIGNAÇÃO	EQUIVALÊNCIA: NACE Rev.1 R31	NPCN 95	NCN 86
40	.10	.1							Electricidade e elementos de combustível irradiados	EE	40.10.1	06.01
		.2							Electricidade (transportada e distribuída) e respectivos serviços (40.10.2.10.00 + 40.10.2.30.00.00)	EE	40.10.2	06.02
	.2								Gás por conduta (produzido e distribuído) e serviços anexos			
	.20								Gás por conduta (produzido e distribuído) e serviços anexos			
		.1							Gás (produzido), excepto de refinaria e gás natural (40.20.1.10.00)	EE	40.20.1	06.03
		.2							Gás distribuído por conduta (40.20.2.10.00)	EE	40.20.2	06.04
	.3								Vapor, água quente e energia do frio (produzidos e distribuidos)	EE	40.3	06.05 22.12
41									Água captada e distribuida (41.00.0.1)	EE	41	06.06
45									Trabalhos de construção	FF	45	31.01 31.02 31.03 31.04
50									Serviços de comércio, serviços de agentes de comércio, serviços de manutenção e reparação de veículos automóveis e motociclos; serviços de comércio a retalho de combustíveis para veículos			
	.0								Serviços de comércio, serviços de agentes de comércio, serviços de manutenção e reparação de veículos automóveis e motociclos; serviços de comércio a retalho de combustíveis para veículos			
	.01								Serviços de comércio, serviços de agentes de comércio; serviços de comércio a retalho de combustíveis para veículos (50 - 50.20.0 - 50.40.2.40.00.00)	GG	50.01	33.00
	.02								Serviços de manutenção e reparação de veículos automóveis e de motociclos (50.20.0 + 50.40.2.40.00.00)	GG	50.02	29.02 32.06
51									Serviços de comércio por grosso e serviços de agentes de comércio, excepto de veículos automóveis e motociclos	GG	51	33.00
52									Serviços de comércio a retalho (excepto de veículos automóveis e motociclos e combustível para veículos); serviços de reparação de bens pessoais e domésticos			
	.0								Serviços de comércio a retalho (excepto de veículos automóveis e motociclos e combustível para veículos); serviços de reparação de bens pessoais e domésticos			
	.01								Serviços de comércio a retalho (excepto de veículos automóveis e motociclos e combustível para veículos) (52 - 52.7)	GG	52.01	33.00
	.02								Serviços de reparação de bens pessoais e domésticos (52.7)			
		.1							Serviços de reparação de calçado e outros artigos em couro (52.71.0.10.00.00)	GG	52.02.1	32.04
		.2							Serviços de reparação de electrodomésticos (52.72.0.1)	GG	52.02.2	32.05
		.3							Serviços de reparação de relógios e de artigos de relojoaria (52.73.0.10.00.00)	GG	52.02.3	32.07
		.4							Serviços de reparação de outros bens pessoais e domésticos (52.74.0.1)	GG	52.02.4	32.07
55									Serviços de alojamento, restauração e similares			
	.1								Serviços de estabelecimentos hoteleiros	HH	55.1	34.02
	.2								Serviços de parques de campismo e outros locais de alojamento de curta duração	HH	55.2	34.02 45.01 49.01
	.3								Serviços de restauração (55.30.0.1)	HH	55.3	34.01
	.4								Serviços prestados por estabelecimentos de bebidas (55.40.0.10)	HH	55.4	34.01
	.5								Serviços de cantinas e de fornecimento de refeições ao domicílio	HH	55.5	34.01

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CÓDIGO				DESIGNAÇÃO	EQUIVALÊNCIA		
DIVISÃO	GRUPO. CLASSE.	SUBCLASSE.	CATEGORIA. SUBCATEGORIA. POSIÇÃO. SUBPOSIÇÃO. SEGMENTO. SUBSEGMENTO		NACE Rev.1 R31	NPCN 95	NCN 86
60				Serviços de transporte terrestre e por condutas (pipelines)			
	.1			Serviços de transporte por caminhos-de-ferro			
	.10			Serviços de transporte por caminhos-de-ferro			
		.0		Serviços de transporte por caminhos-de-ferro			
			.1	Serviços de transporte interurbano de passageiros e de veículos acompanhados, por caminhos-de-ferro	II	60.10.0.1	35.01.02
			.2	Serviços de transporte de mercadorias por caminhos-de-ferro	II	60.10.0.2	35.01.01
			.3	Serviços de reboque por caminhos-de-ferro	II	60.10.0.3	35.01.01 35.01.02
	.2			Outros serviços de transporte terrestre			
	.21			Outros serviços regulares de transporte terrestre de passageiros	II	60.21	35.01.02 35.02 35.03
	.22			Serviços de transporte ocasional de passageiros em veículos ligeiros com condutor (60.22.0.1)	II	60.22	35.03
	.23			Outros serviços de transporte terrestre de passageiros (60.23.0.1)	II	60.23	35.03
	.24			Serviços de transporte rodoviário de mercadorias em veículos especialmente adaptados (60.24.0.1)	II	60.24	35.04
	.3			Serviços de transporte por condutas (pipelines) (60.30.0.1)	II	60.3	35.05
61				Serviços de transporte por água			
	.1			Serviços de transporte marítimo			
	.10			Serviços de transporte marítimo			
		.0		Serviços de transporte marítimo			
			.1	Serviços de transporte marítimo não costeiro, costeiro e local de passageiros	II	61.10.0.1	36.01.01 36.01.02
			.2	Serviços de transporte marítimo não costeiro, costeiro e local de mercadorias	II	61.10.0.2	36.01.01 36.01.02
			.3	Serviços de aluguer de navios com tripulação e serviços de reboque	II	61.10.0.3	36.01.01 36.01.02
	.2			Serviços de transporte por vias navegáveis interiores			
	.20			Serviços de transporte por vias navegáveis interiores			
		.0		Serviços de transporte por vias navegáveis interiores			
			.1	Serviços de transporte de passageiros em vias navegáveis interiores	II	61.20.0.1	35.06.02
			.2	Serviços de transporte de mercadorias por vias navegáveis interiores	II	61.20.0.2	35.06.01
			.3	Serviços de aluguer de embarcações em vias navegáveis interiores, com tripulação e serviços de reboque	II	61.20.0.3	35.06.01 35.06.02
62				Serviços de transporte aéreo			
	.0			Serviços de transporte aéreo			
	.01			Serviços de transporte aéreo de passageiros (regulares e não regulares) (62.10.0.10.00 + 62.20.0.10.00)	II	62.01	36.02.02
	.02			Serviços de transporte aéreo de mercadorias (regulares e não regulares) (62.10.0.2 + 62.20.0.20.00.00)	II	62.02	36.02.01
	.03			Serviços de aluguer de aeronaves com tripulação (62.20.0.30.00.00)	II	62.03	36.02.01 36.02.02
	.04			Serviços de transporte espacial (62.30.0.10.00)	II	62.04	-------

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CÓDIGO: Divisão	Grupo / Classe	Subclasse	Categoria / Subcategoria	Posição / Subposição	Segmento / Subsegmento	DESIGNAÇÃO	EQUIVALÊNCIA: NACE Rev.1 R31	NPCN 95	NCN 86
63						Serviços anexos e auxiliares dos transportes; serviços das agências de viagem e de turismo			
	.1					Serviços de manuseamento e de armazenagem	II	63.1	35.01.01 35.04 37.02 37.05 37.06
	.2					Outros serviços auxiliares dos transportes			
	.21					Outros serviços auxiliares dos transportes terrestres	II	63.21	35.02 37.01.01 37.01.02
	.22					Outros serviços auxiliares dos transportes por água (63.22.0.1)	II	63.22	37.02
	.23					Outros serviços auxiliares do transporte aéreo (63.23.0.1)	II	63.23	37.03
	.3					Serviços das agências de viagens e de turismo (63.30.0.1)	II	63.3	37.04
	.4					Serviços dos agentes transitários, aduaneiros e similares, de apoio ao transporte	II	63.4	37.04 37.05 42.03
64						Serviços de correios e telecomunicações			
	.1					Serviços de correios			
	.11					Serviços dos correios nacionais (64.11.0.1)	II	64.11	38.02
	.12					Serviços postais independentes dos correios nacionais (64.12.0.1)	II	64.12	38.02
	.2					Serviços de telecomunicações			
	.20					Serviços de telecomunicações			
		.0				Serviços de telecomunicações			
			.1			Serviços de telefone, de transmissão de dados e de mensagens	II	64.20.0.1	38.01
			.2			Outros serviços de telecomunicações	II	64.20.0.2	38.01
			.3			Serviços de transmissão por cabo de emissões de rádio e televisão	II	64.20.0.3	38.01
65						Serviços de intermediação financeira, excepto seguros e fundos de pensões			
	.1					Serviços de intermediação monetária			
	.11					Serviços do Banco Central (65.11.0.10.00.00)	JJ	65.11	39.00
	.12					Outros serviços de intermediação monetária (65.12.0.10.00)	JJ	65.12	39.00
	.2					Outros serviços de intermediação financeira (excepto seguros e fundos de pensões)			
	.21					Serviços de locação financeira (leasing) (65.21.0.10.00.00)	JJ	65.21	39.00
	.22					Outros serviços de crédito (65.22.0.10.00)	JJ	65.22	39.00 45.11
	.23					Outros serviços de intermediação financeira, excepto serviços de seguros e fundos de pensões (65.23.0.10.00)	JJ	65.23	39.00
66						Serviços de seguros e de fundos de pensões, excepto serviços de segurança social obrigatória			
	.0					Serviços de seguros e de fundos de pensões, excepto serviços de segurança social obrigatória			
	.01					Serviços de seguros de vida e serviços complementares de segurança social (66.01.0.10.00)	JJ	66.01	40.00
	.02					Serviços de fundos de pensões e regimes profissionais complementares (66.02.0.10.00.00)	JJ	66.02	42.03
	.03					Serviços de seguros não vida (66.03.0.10.00)	JJ	66.03	40.00

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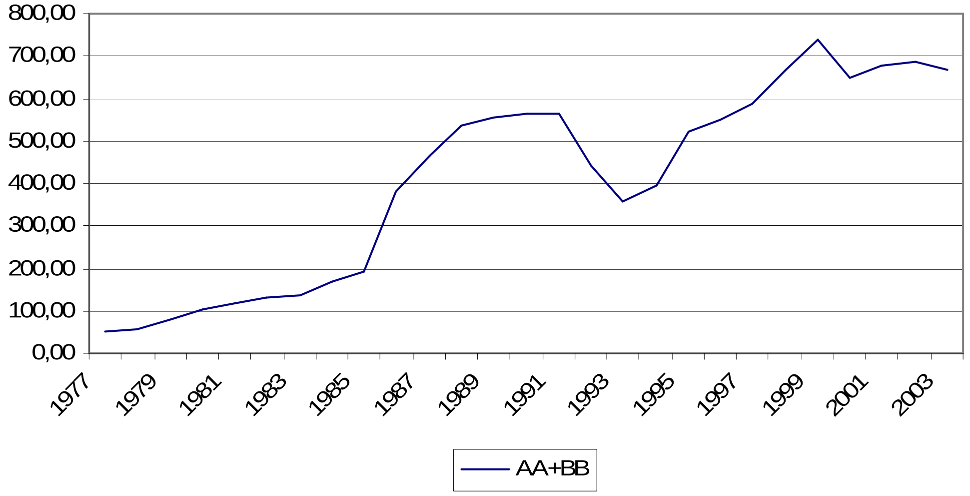
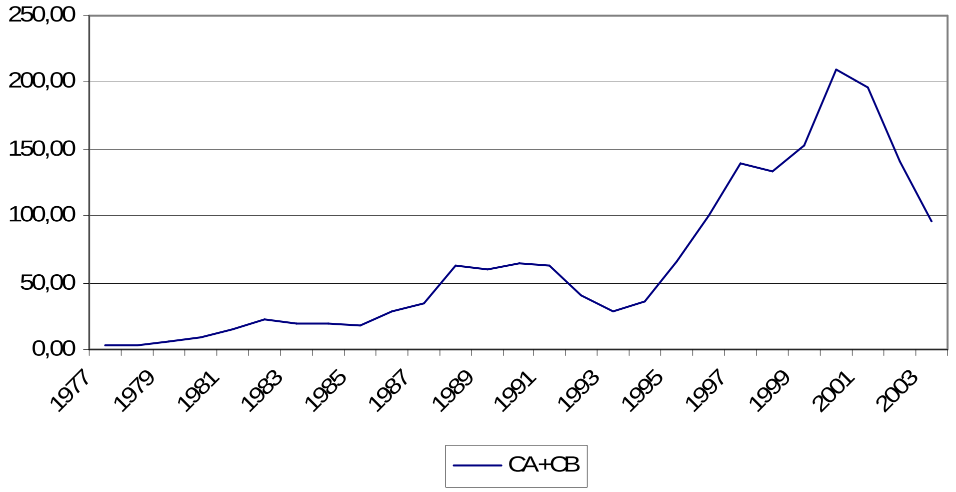
CÓDIGO							EQUIVALÊNCIA		
DIVISÃO	GRUPO . CLASSE	SUBCLASSE	CATEGORIA . SUBCATEGORIA	PRODUTO . SUBPRODUTO	SEGMENTO . SUBSEGMENTO	DESIGNAÇÃO	NACE Rev.1 R31	NPCN 95	NCN 86
67						Serviços auxiliares da intermediação financeira			
	.1					Serviços auxiliares da intermediação financeira, excepto de seguros e fundos de pensões	JJ	67.1	42.03
	.2					Serviços auxiliares de seguros e fundos de pensões (67.20.0.10.00)	JJ	67.2	42.03
70						Serviços imobiliários			
	.1					Serviços imobiliários sobre bens próprios	KK	70.1	41.00 42.02
	.2					Serviços de arrendamento de bens imobiliários, próprios			
	.20					Serviços de arrendamento de bens imobiliários, próprios			
		.0				Serviços de arrendamento de bens imobiliários, próprios			
			.1			Serviços de arrendamento de bens imobiliários, próprios			
			.11			Serviços de arrendamento de edifícios residenciais, próprios	KK	70.20.0.11	42.02
			.12			Serviços de arrendamento de terrenos e outros bens imóveis, não residenciais, por conta própria	KK	70.20.0.12	42.02
	.3					Serviços imobilários por conta de outrém	KK	70.3	42.02
71						Serviços de aluguer de máquinas e de equipamentos sem pessoal e de bens pessoais e domésticos			
	.1					Serviços de aluguer de veículos automóveis ligeiros e carrinhas até 3500 kg, sem operador (71.10.0.10.00)	KK	71.1	42.01
	.2					Serviços de aluguer de outro meio de transporte	KK	71.2	35.01.01 35.01.02 37.02 37.03 42.01 45.09
	.3					Serviços de aluguer de máquinas e de equipamentos	KK	71.3	42.04
	.4					Serviços de aluguer de bens de uso pessoal e doméstico, n.e. (71.40.0.1)	KK	71.4	45.03 45.09 45.11 49.05
72						Serviços informáticos e conexos	KK	72	14.08 32.07 42.03
73						Serviços de investigação e desenvolvimento	KK	73	43.02 46.01 47.02
74						Outros serviços prestados principalmente às empresas			
	.1					Serviços jurídicos, contabílisticos, de auditoria, de consultoria fiscal, de estudos de mercado e sondagens de opinião; serviços de consultoria empresarial e gestão (inclui gestão das SGPS - holdings)	KK	74.1	42.03
	.2					Serviços de arquitectura, de engenharia e de técnicas afins	KK	74.2	42.03
	.3					Serviços de ensaios e análises técnicas (74.30.0.1)	KK	74.3	42.03
	.4					Serviços de publicidade (74.40.0.1)	KK	74.4	30.17 42.03
	.5					Serviços de selecção e colocação de pessoal	KK	74.5	42.03 45.11
	.6					Serviços de investigação e segurança (74.60.0.1)	KK	74.6	42.03

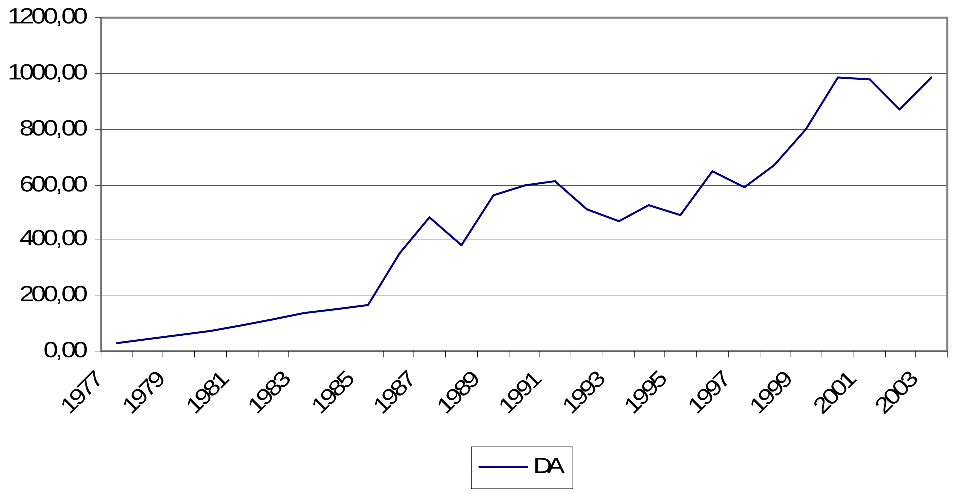
NOMENCLATURA DE PRODUTOS - BASE 95													
CÓDIGO										DESIGNAÇÃO	EQUIVALÊNCIA		
DIVISÃO	.	GRUPOS / CLASSE	.	SUBCLASSE	.	CATEGORIA / SUBCATEGORIA	.	POSIÇÃO / SUBPOSIÇÃO	SEGMENTO / SUBSEGMENTO		NACE Rev.1 R31	NPCN 95	NCN 86
74	.	7								Serviços de limpeza industrial (74.70.0.1)	KK	74.7	42.03 45.11 46.03
	.	8								Outros serviços prestados principalmente às empresas	KK	74.8	37.05 42.03 45.02 45.06 45.11
75										Serviços da administração pública, defesa e segurança social obrigatória			
	.	1								Serviços da administração pública em geral, económica e social	LL	75.1	46.01
	.	2								Serviços dos negócios estrangeiros, defesa, justiça, segurança, ordem pública e protecção civil	LL	75.2	45.01 46.01 46.02 49.01
	.	3								Serviços dos regimes de segurança social em geral (inclui da função pública) (75.30.0.1)	LL	75.3	46.01
80										Serviços de educação	MM	80	43.01 47.01
85										Serviços de saúde e acção social			
	.	1								Serviços de saúde humana	NN	85.1	44.00 48.00
	.	2								Serviços veterinários (85.20.0.1)	NN	85.2	44.00 48.00
	.	3								Serviços de acção social	NN	85.3	45.01 49.01
90										Serviços de saneamento, de tratamento de resíduos, higiene pública e serviços similares	OO	90	44.00 45.11 46.03 48.00
91										Serviços prestados por organizações associativas, n.e.			
	.	1								Serviços prestados por organizações económicas, patronais e profissionais			
	.	11								Serviços prestados por organizações económicas e patronais (91.11.0.10.00.00)	OO	91.11	42.05 49.02
	.	12								Serviços prestados por organizações profissionais (91.12.0.10.00.00)	OO	91.12	49.02 49.03
	.	2								Serviços prestados por organizações sindicais (91.20.0.10.00.00)	OO	91.2	49.02
	.	3								Serviços prestados por outras organizações associativas	OO	91.3	49.02 49.03
92										Serviços recreativos, culturais e desportivos			
	.	1								Serviços cinematográficos e de vídeo	OO	92.1	45.02 45.03
	.	2								Serviços de rádio e televisão (92.20.0.1)	OO	92.2	45.05
	.	3								Outros serviços artísticos e de espectáculo	OO	92.3	45.04 45.06 45.07 45.09 49.05 49.08
	.	4								Serviços das agências de notícias (92.40.0.10.00)	OO	92.4	42.03
	.	5								Serviços das bibliotecas, arquivos, museus e outros serviços culturais	OO	92.5	45.08

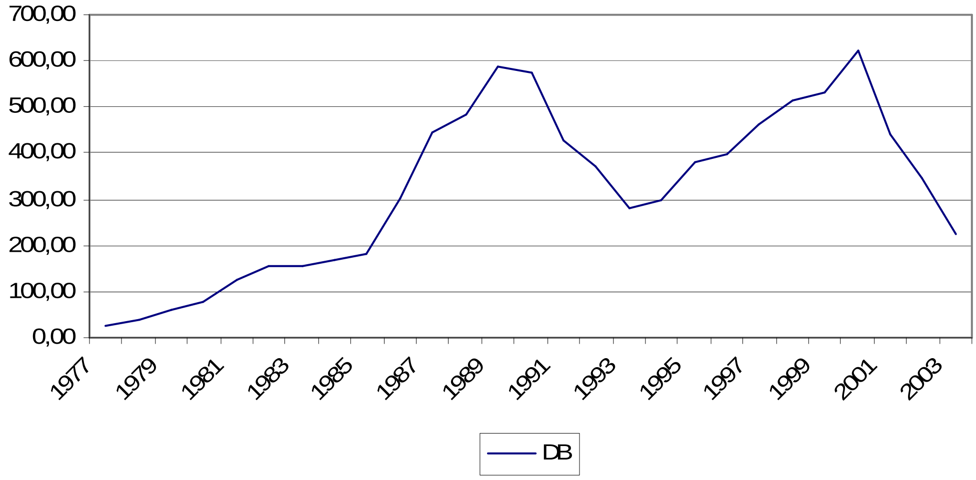
NOMENCLATURA DE PRODUTOS - BASE 95																		
CÓDIGO															DESIGNAÇÃO	EQUIVALÊNCIA		
DIVISÃO	.	GRUPO	CLASSE	.	SUBCLASSE	.	CATEGORIA	SUBCATEGORIA	.	POSIÇÃO	SUBPOSIÇÃO	.	SEGMENTO	SUBSEGMENTO		NACE Rev.1 R31	NPCN 95	NCN 86
92	.	6													Serviços relacionados com o desporto	OO	92.6	49.04 45.09 49.05
	.	7													Outros serviços recreativos	OO	92.7	45.09 45.11 49.05
93															Outros serviços	OO	93	44.00 45.10 45.11 48.00 49.07
95															Serviços prestados às famílias por empregados domésticos (95.00.0.10.00.00)	PP	95	45.11 49.06

Annex 3: GFCF in individual sectors, current prices, 1977-2003





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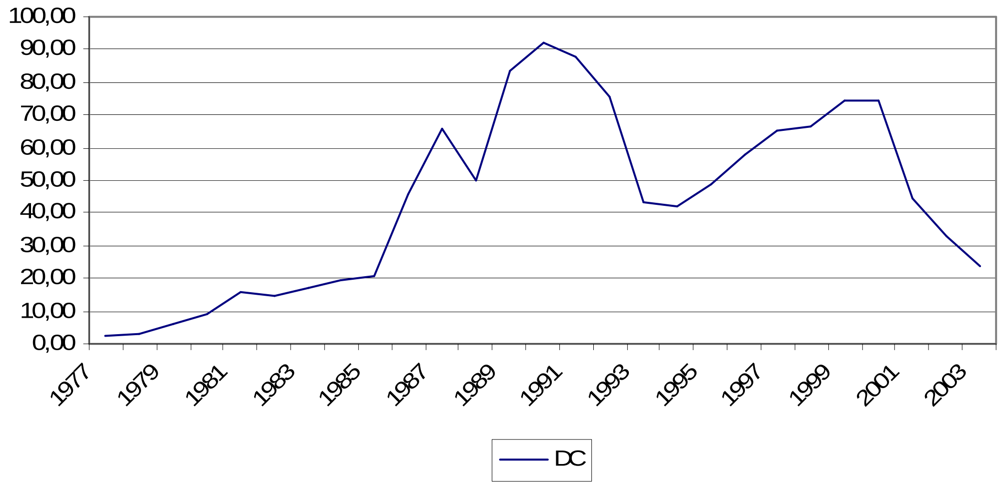
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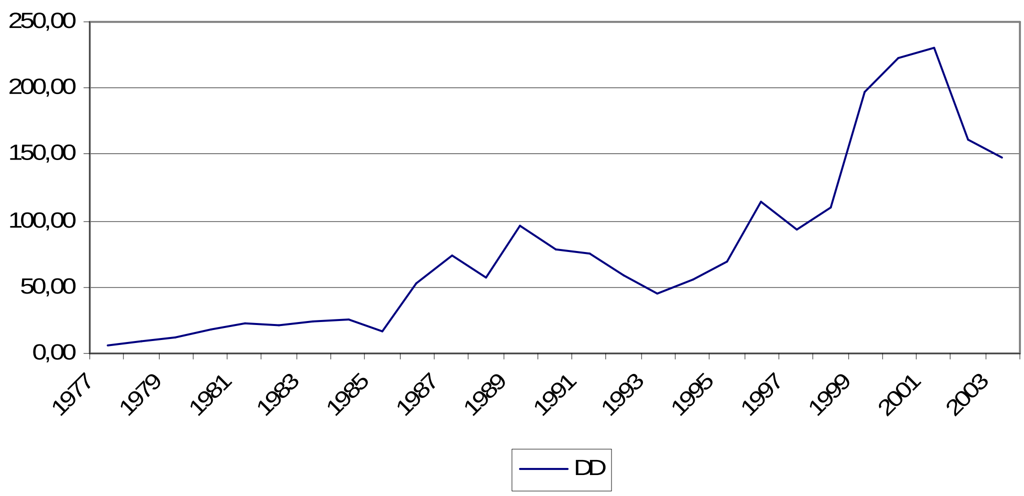
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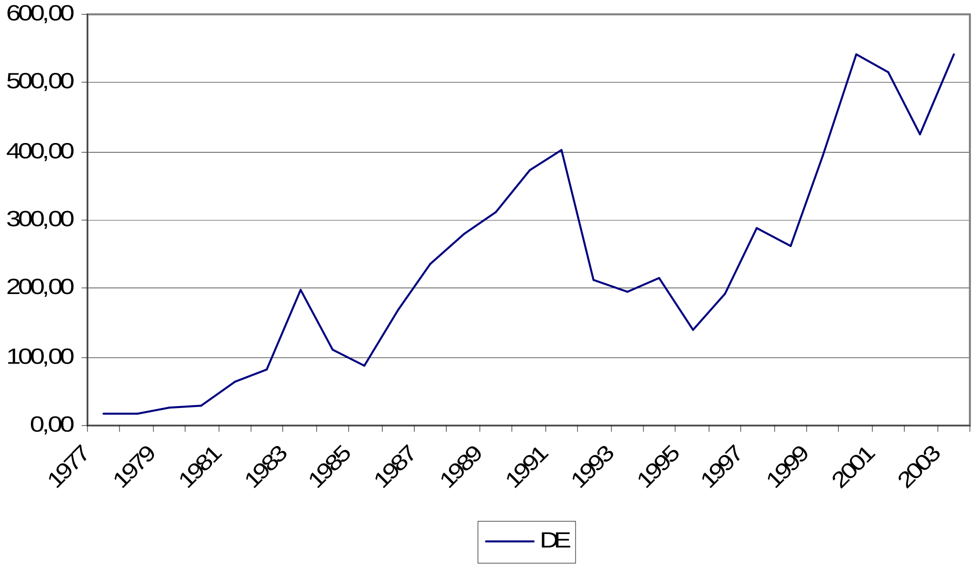
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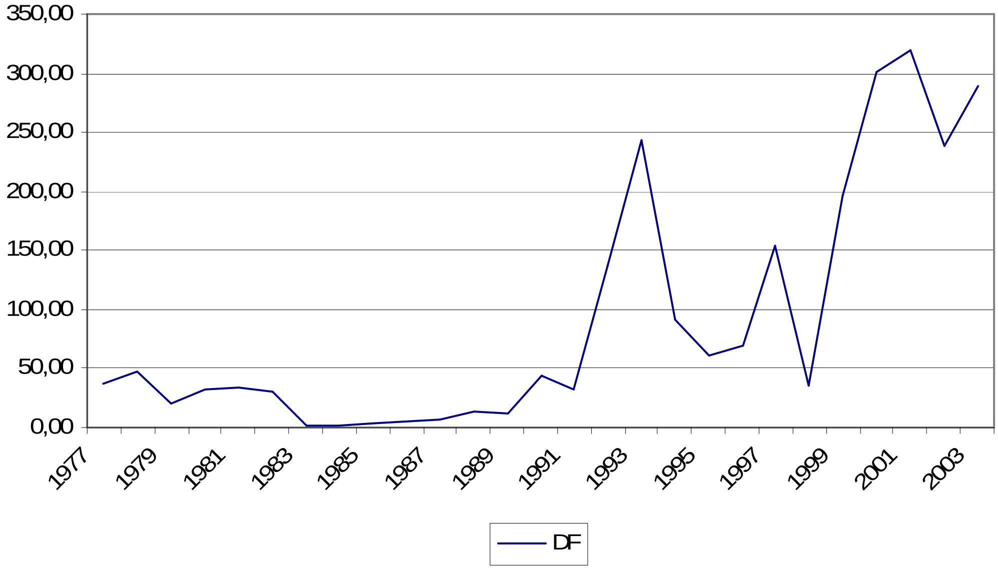
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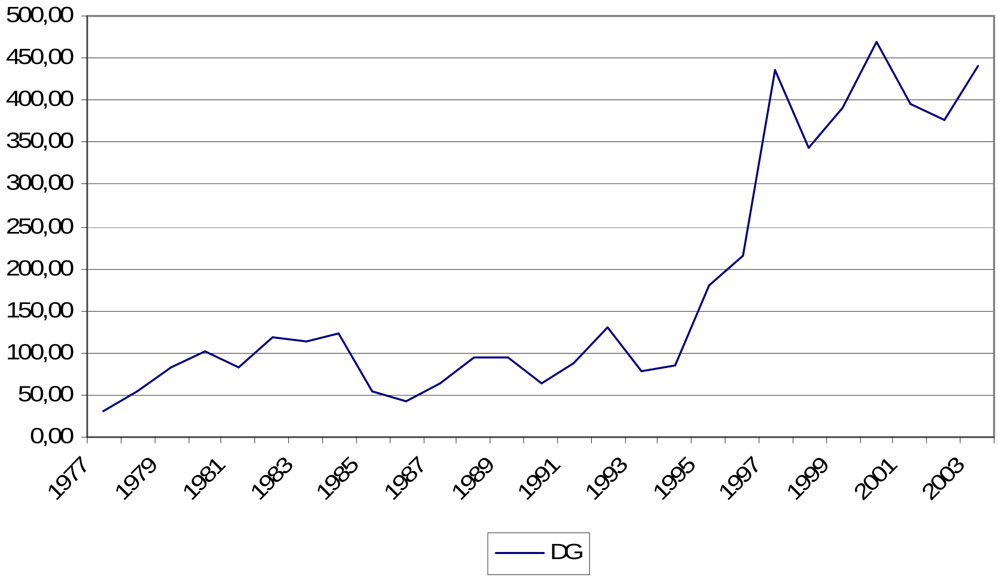
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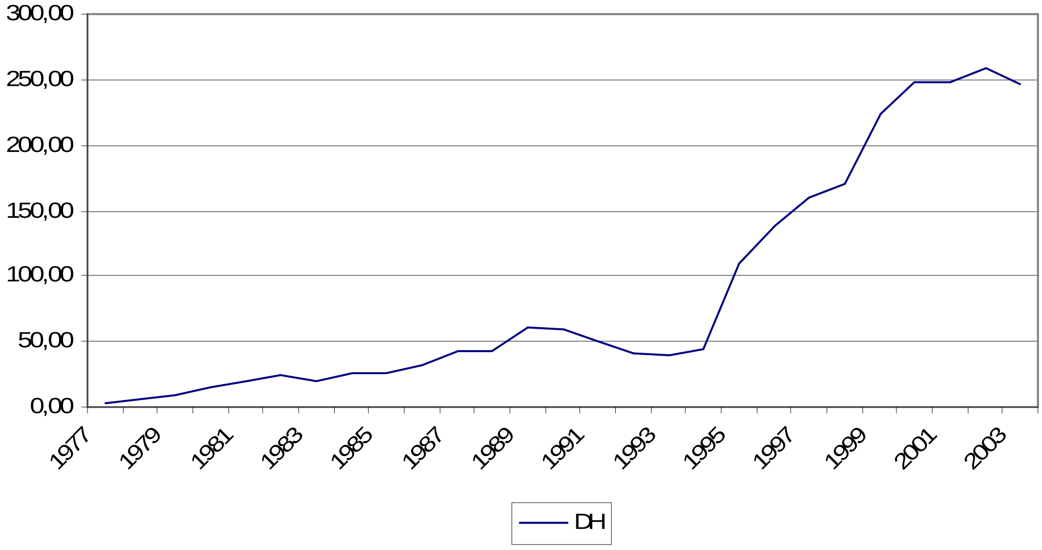
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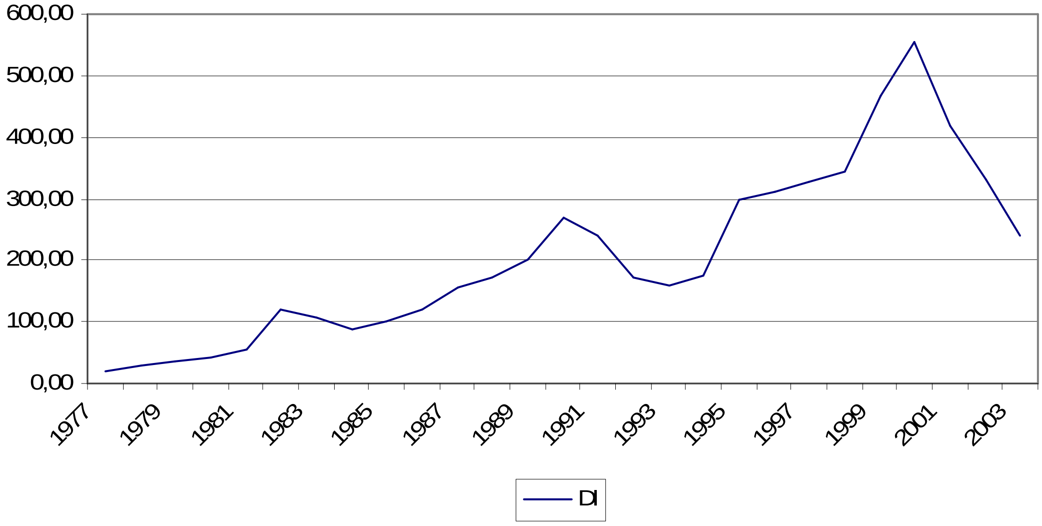
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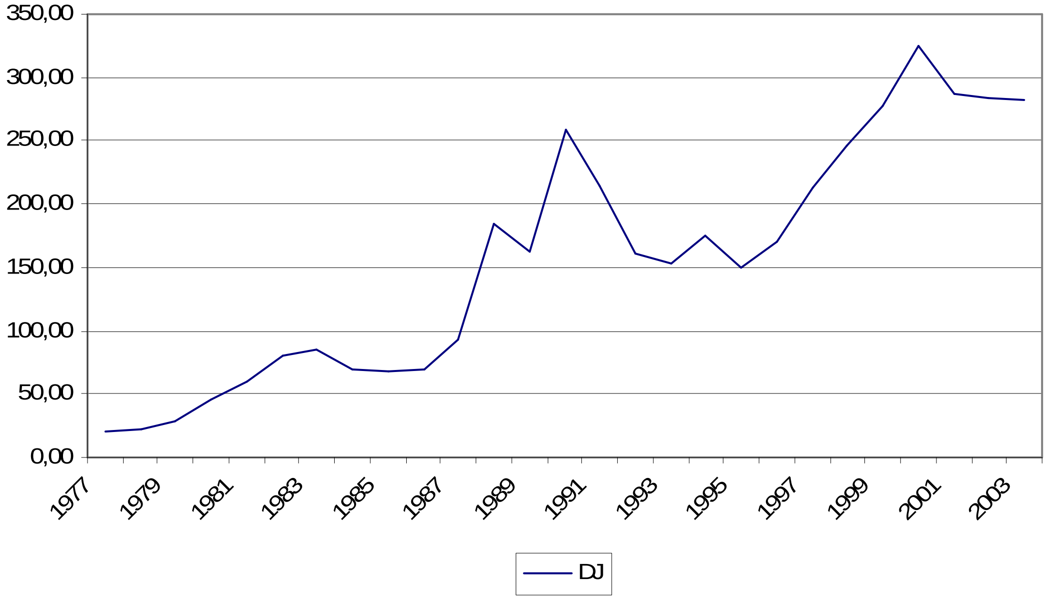
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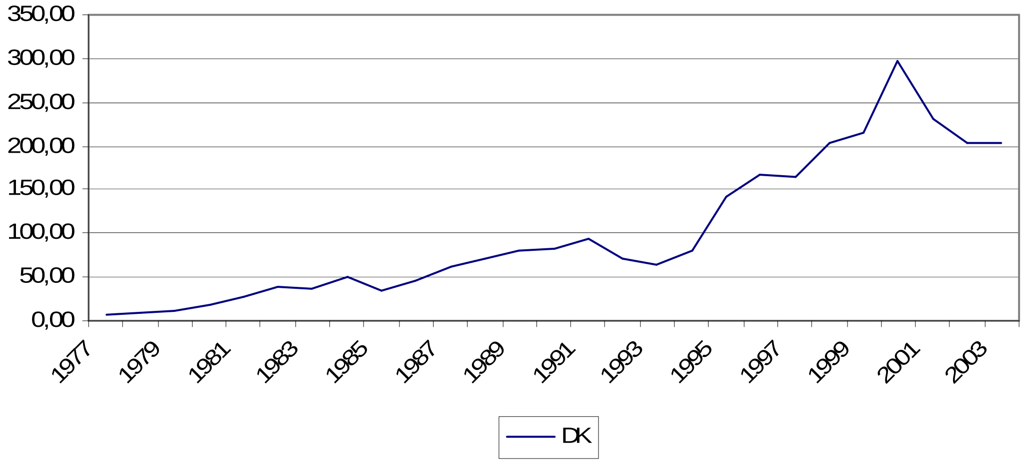
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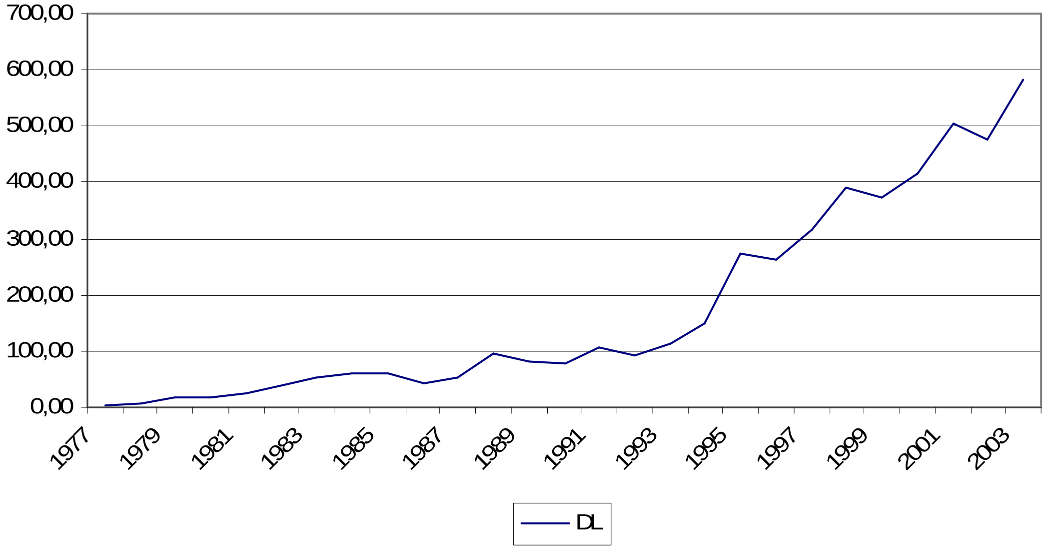
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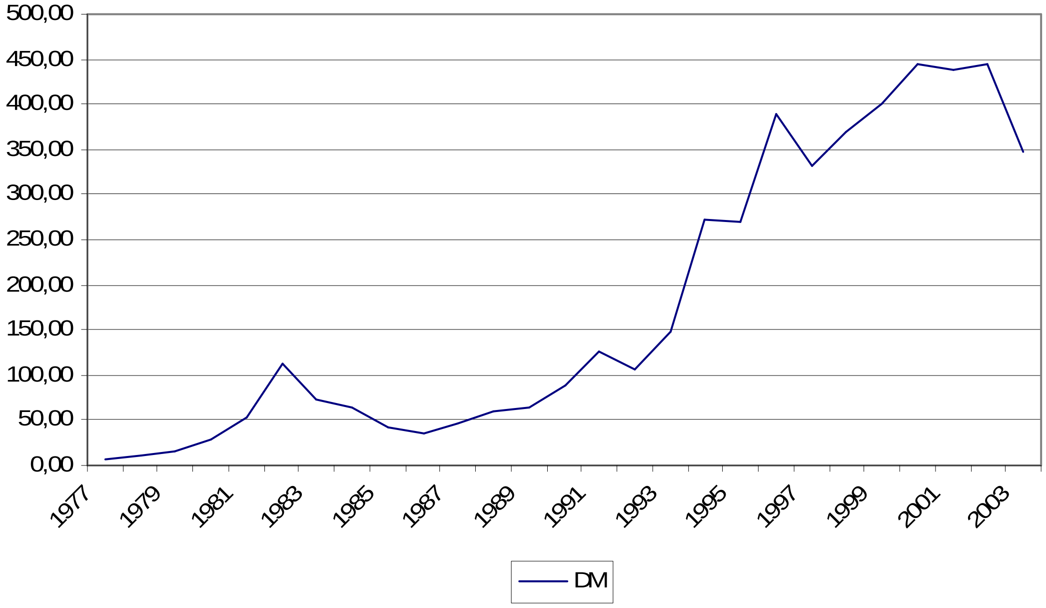
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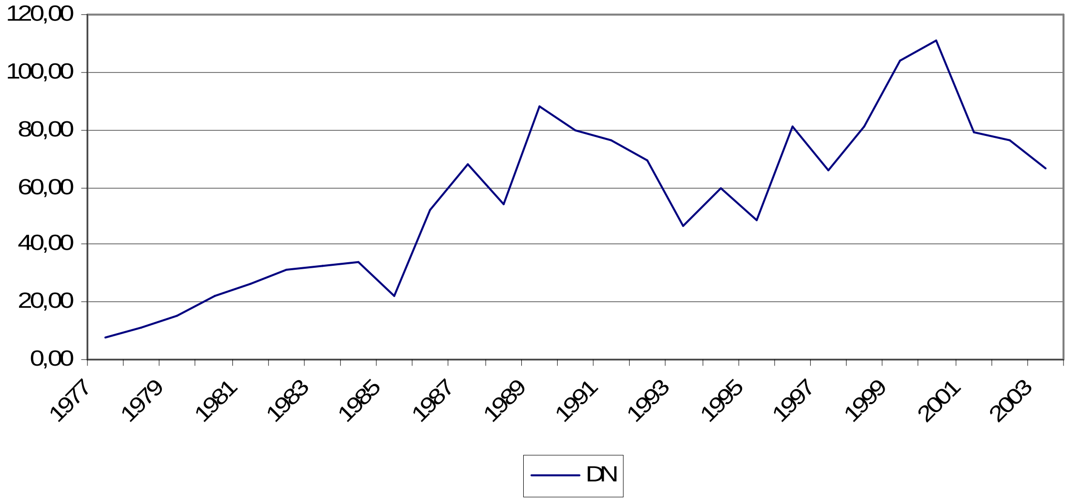
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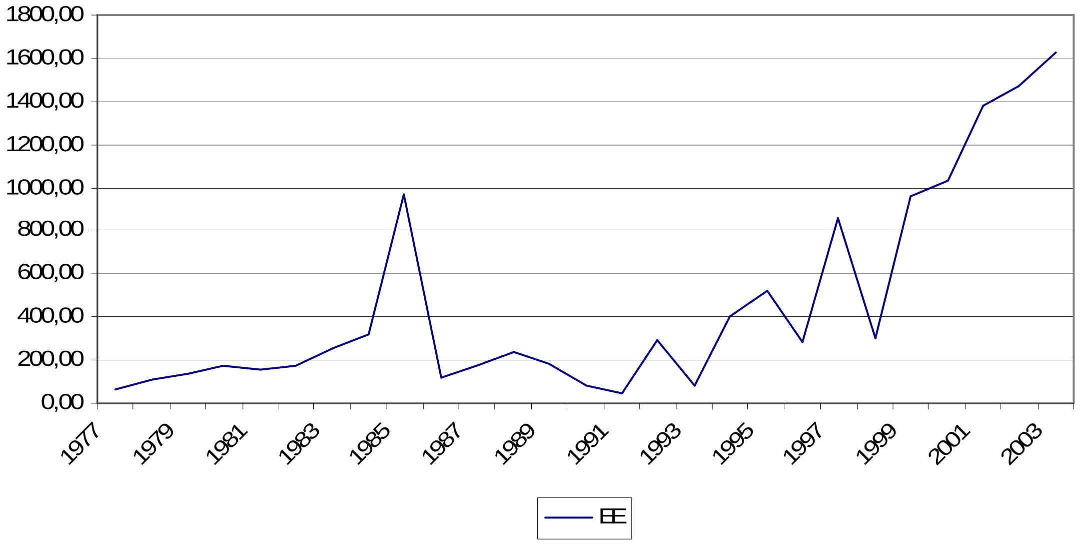
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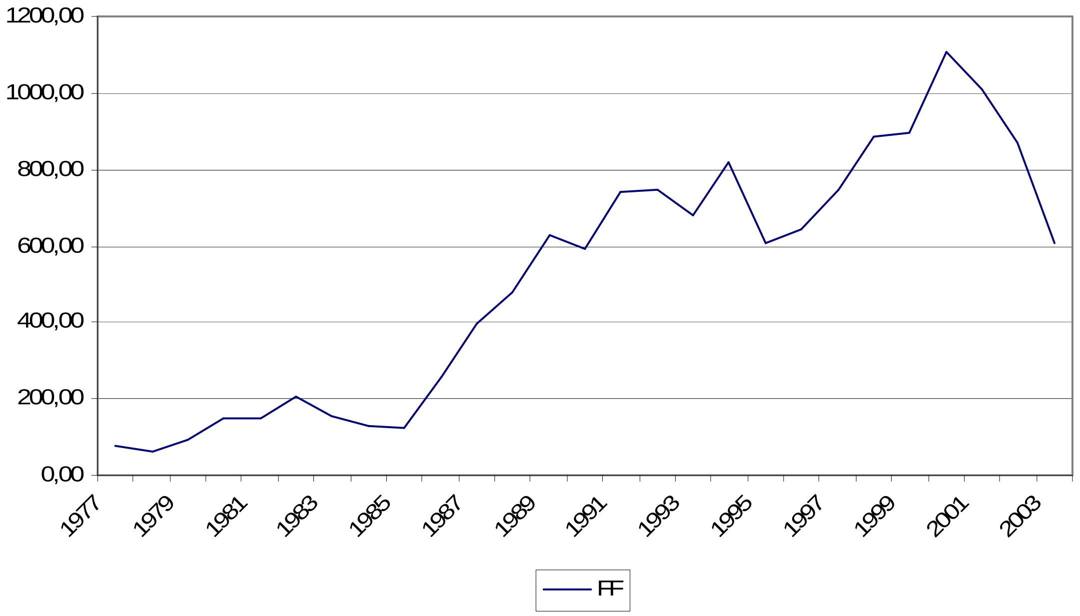
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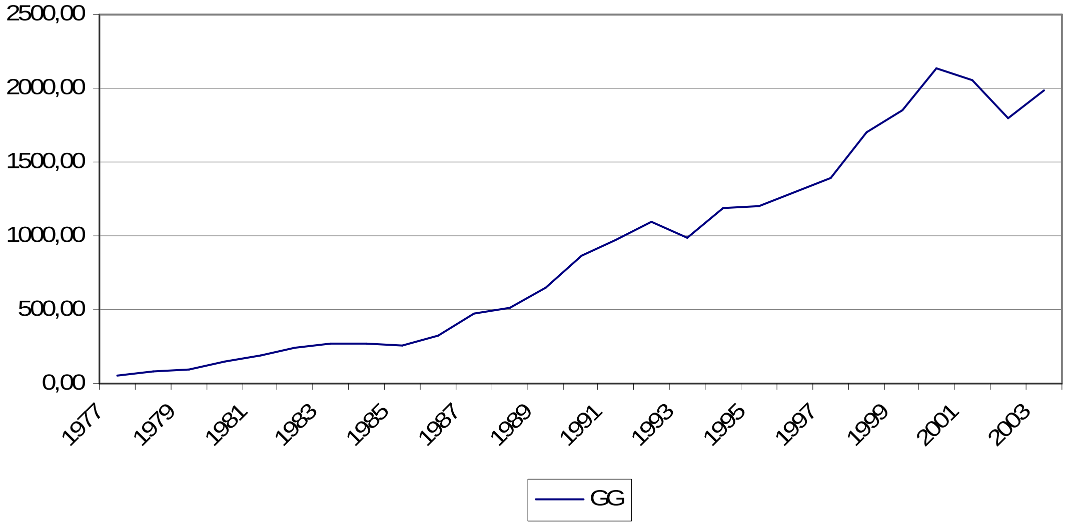

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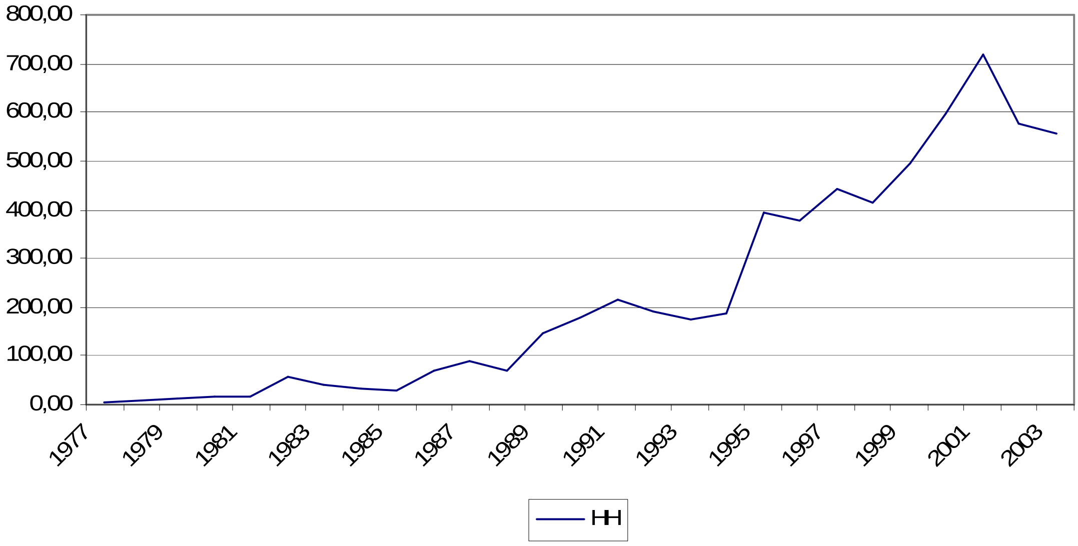

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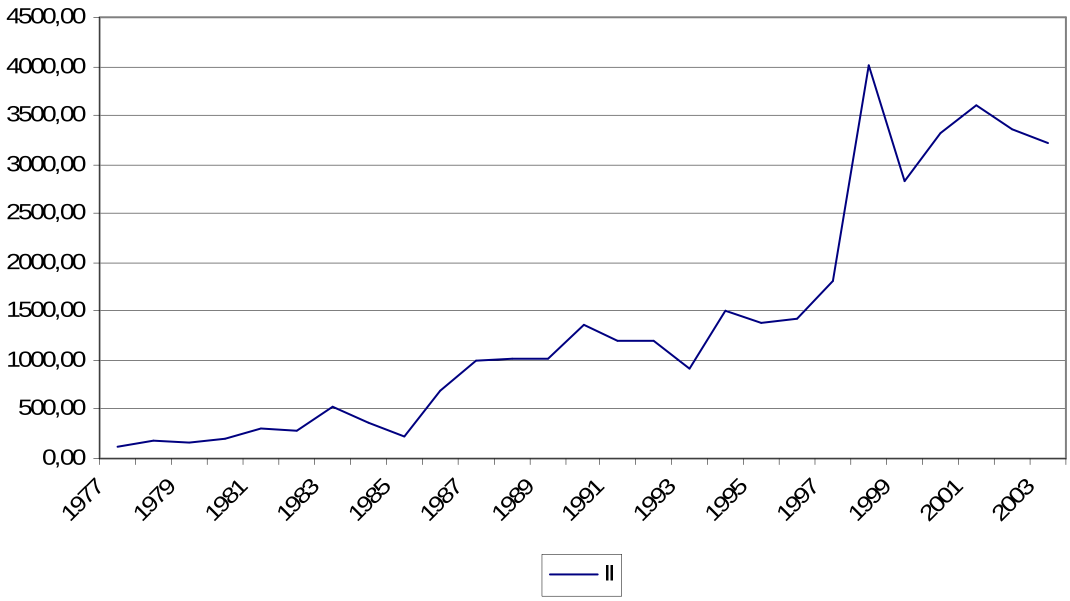

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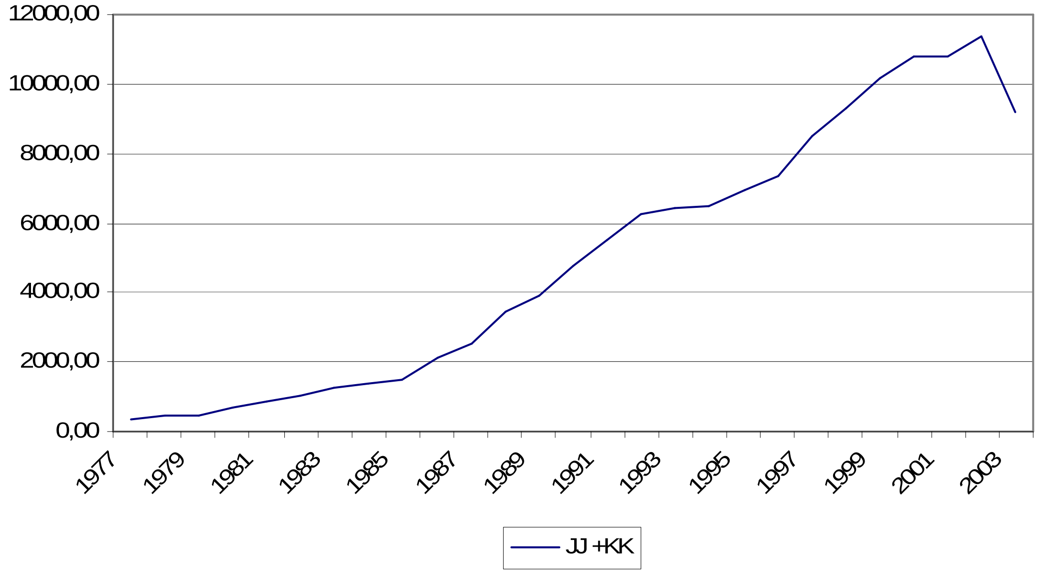


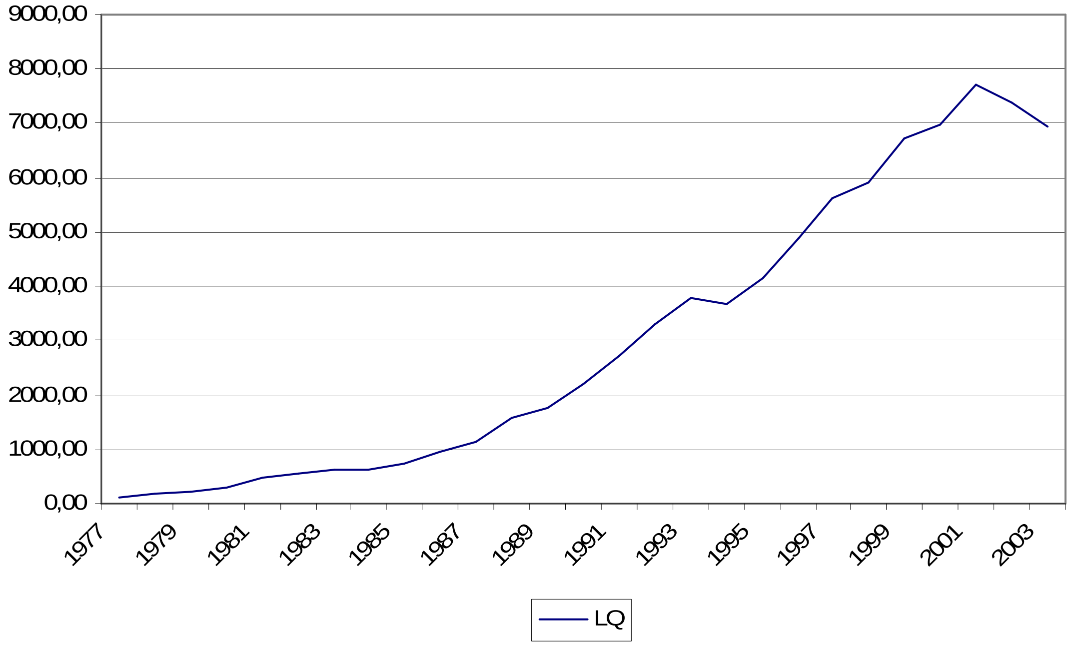
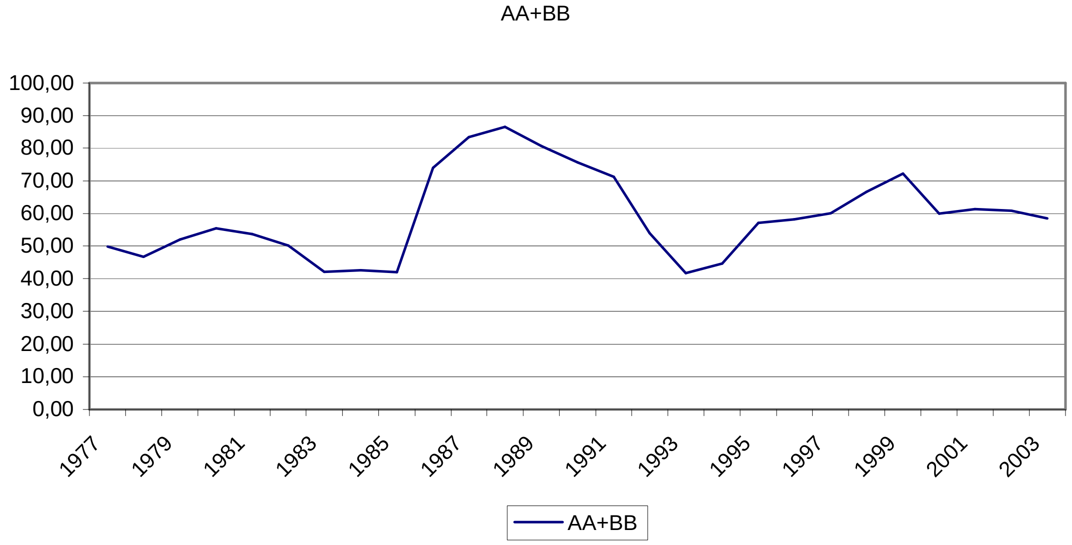
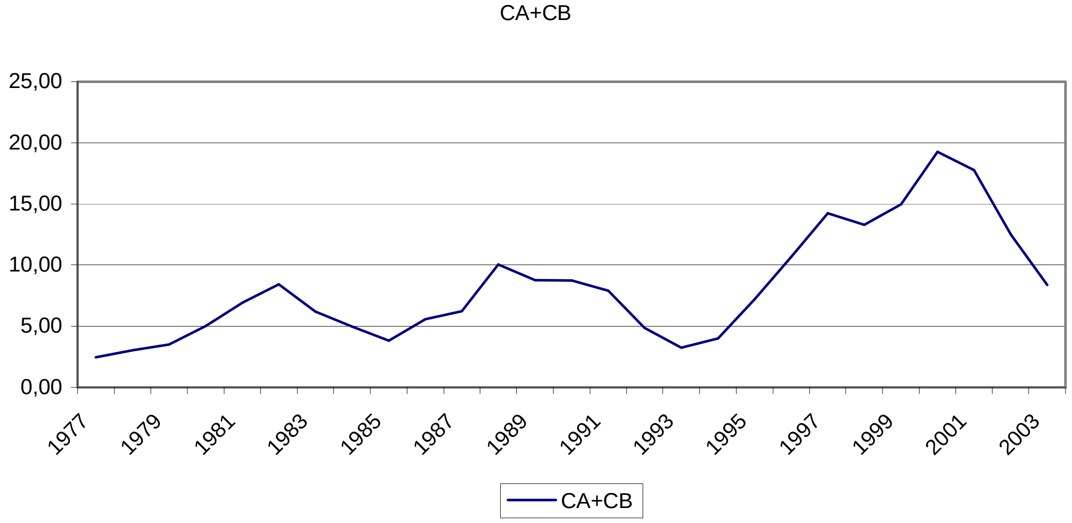


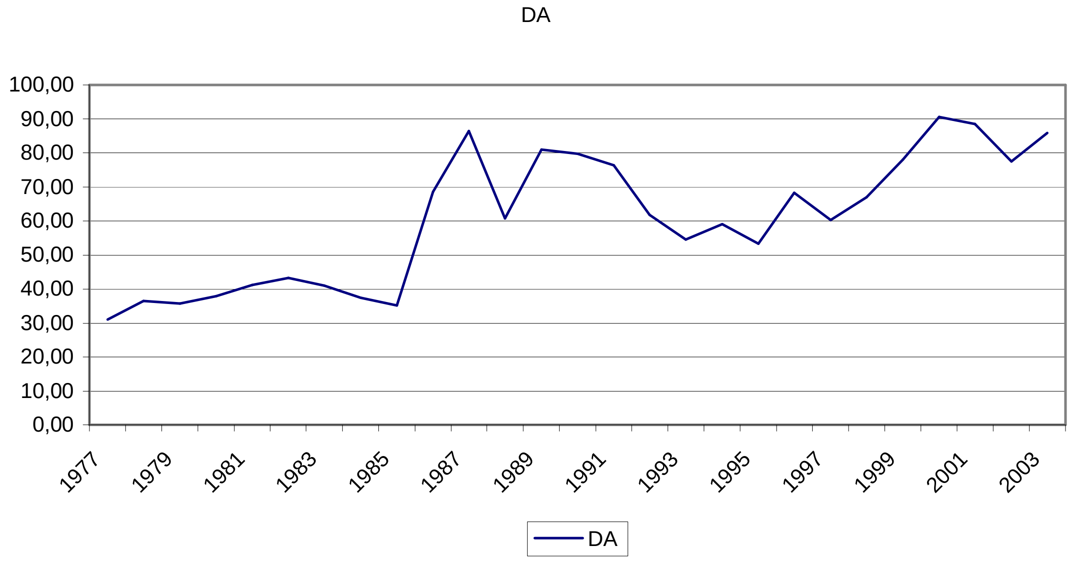
Figure A.1.: GFCF in individual sectors, current prices, 1977-2003

Legend: AA + BB: Agriculture, hunting, forestry and fishing; CA + CB: Mining and quarrying; DA: Manufacture of food products; beverages and tobacco; DB: Manufacture of textiles and textile products; DC: Manufacture of leather and leather products; DD: Manufacture of wood and wood products; DE: Manufacture of pulp, paper and paper products; publishing and printing; DF: Manufacture of coke, refined petroleum products and nuclear fuel; DG: Manufacture of chemicals, chemical products and man-made fibres; DH: Manufacture of rubber and plastic products; DI: Manufacture of other non-metallic mineral products; DJ: Manufacture of basic metals and fabricated metal products; DK: Manufacture of machinery and equipment n.e.c.; DL: Manufacture of electrical and optical equipment; DM: Manufacture of transport equipment; DN: Manufacturing n.e.c.; EE: Electricity, gas and water supply; FF: Construction; GG: Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods; HH: Hotels and restaurants; II: Transport, storage and communication; JJ + KK: Financial intermediation, real estate, renting and business activities; LQ: Social and personal services.

Annex 4: GFCF in individual branches, 1977 prices, 1977-2003







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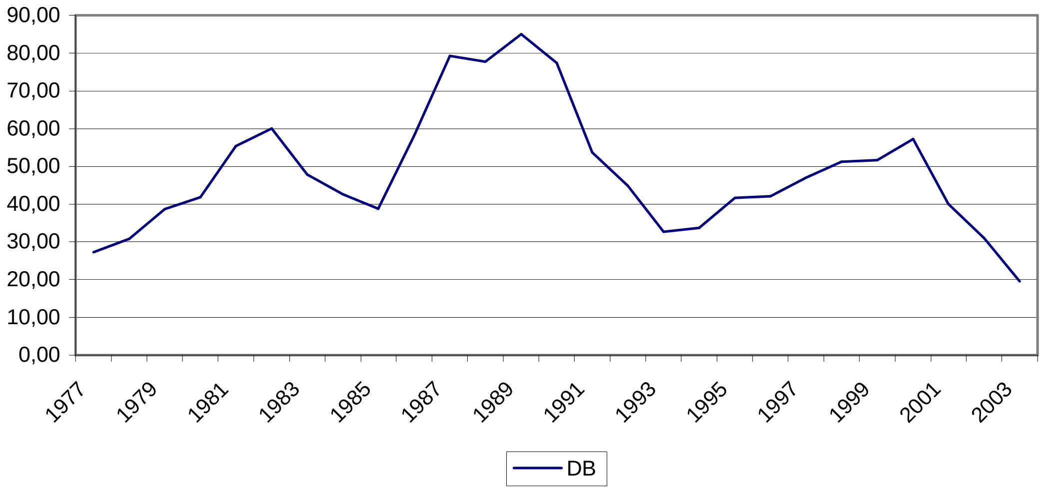

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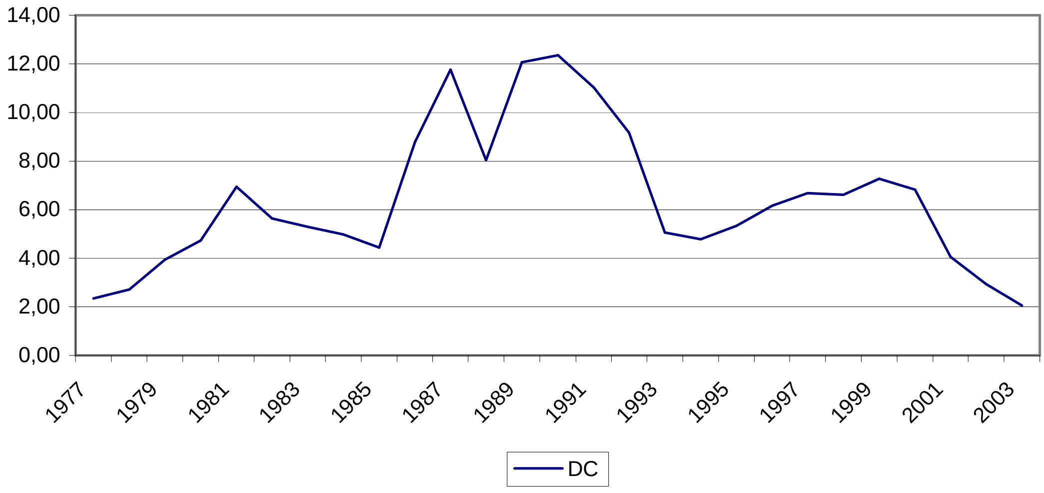

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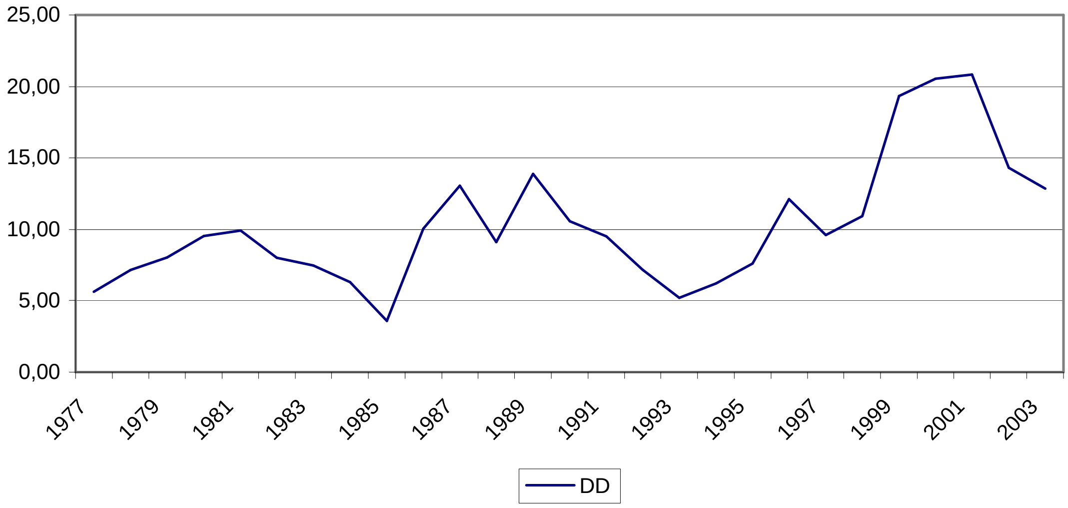

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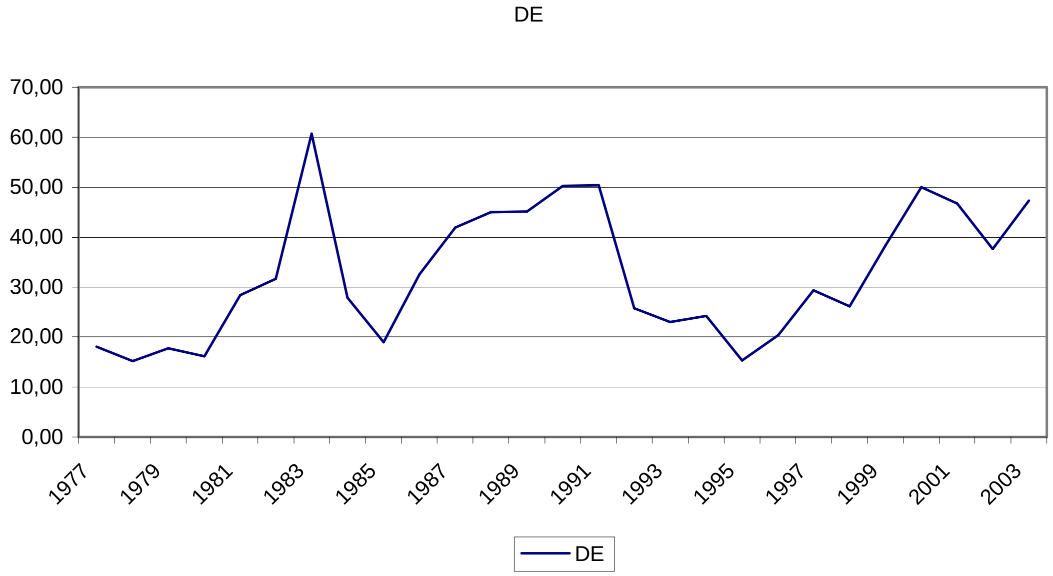
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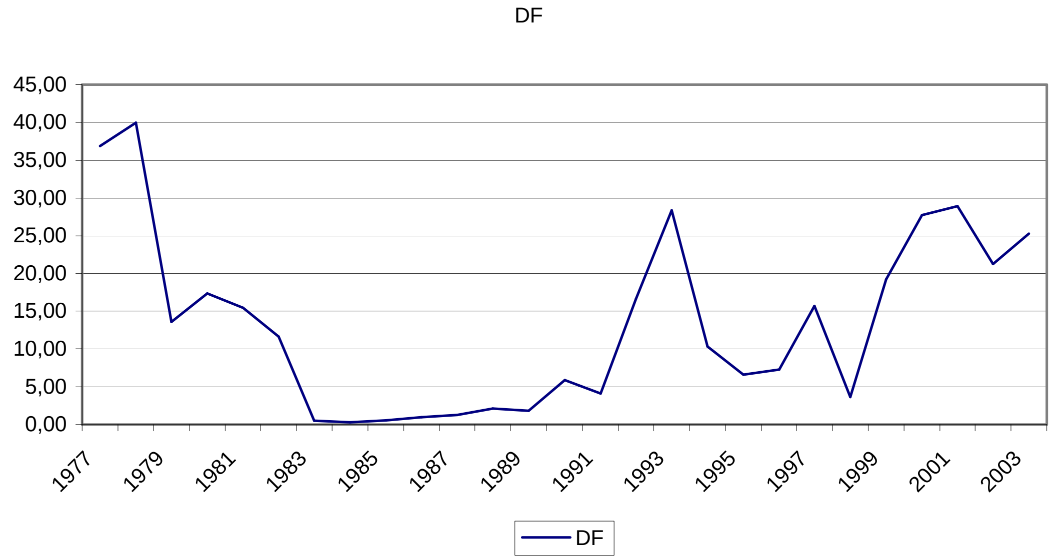
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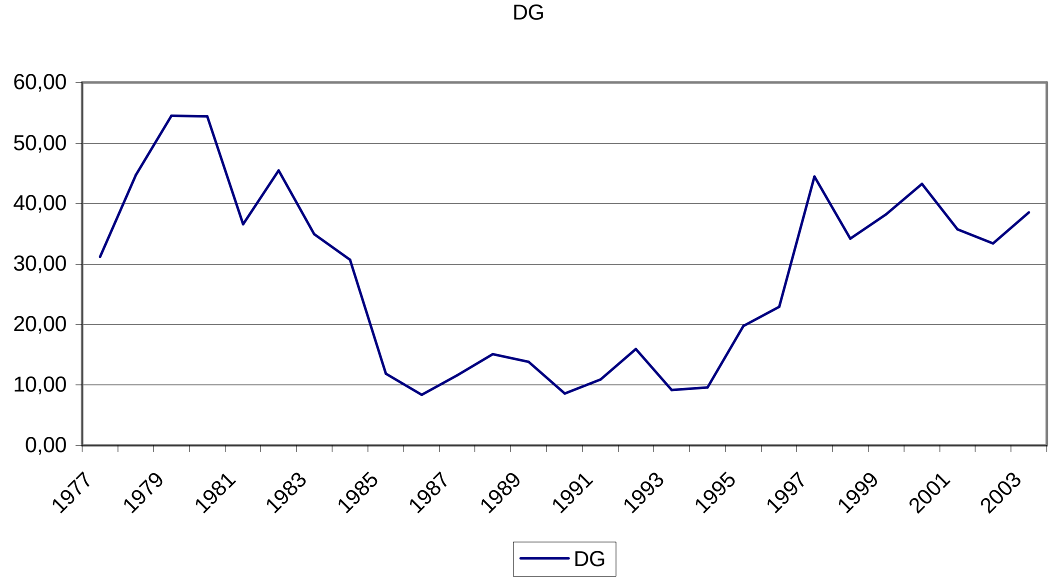
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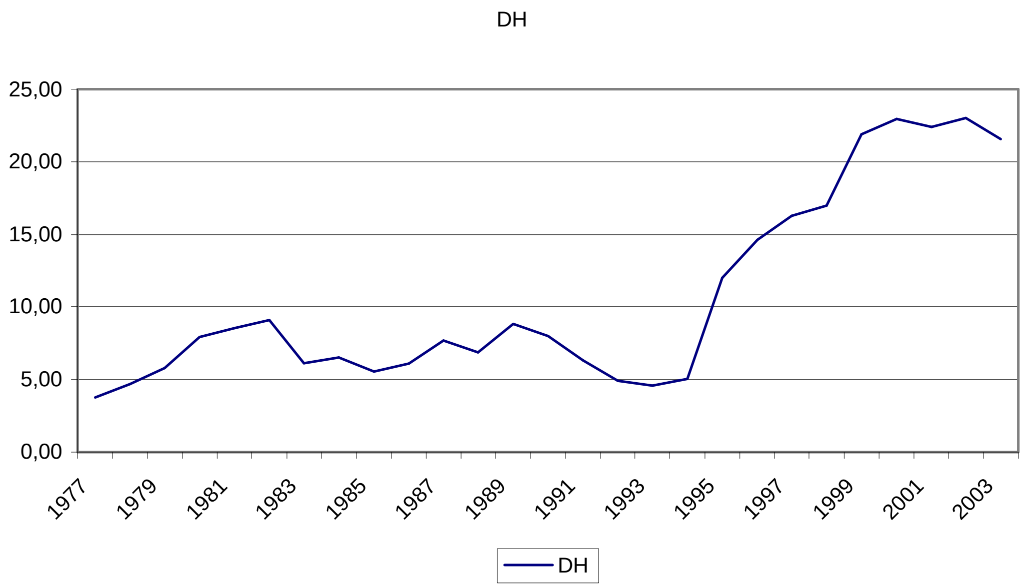
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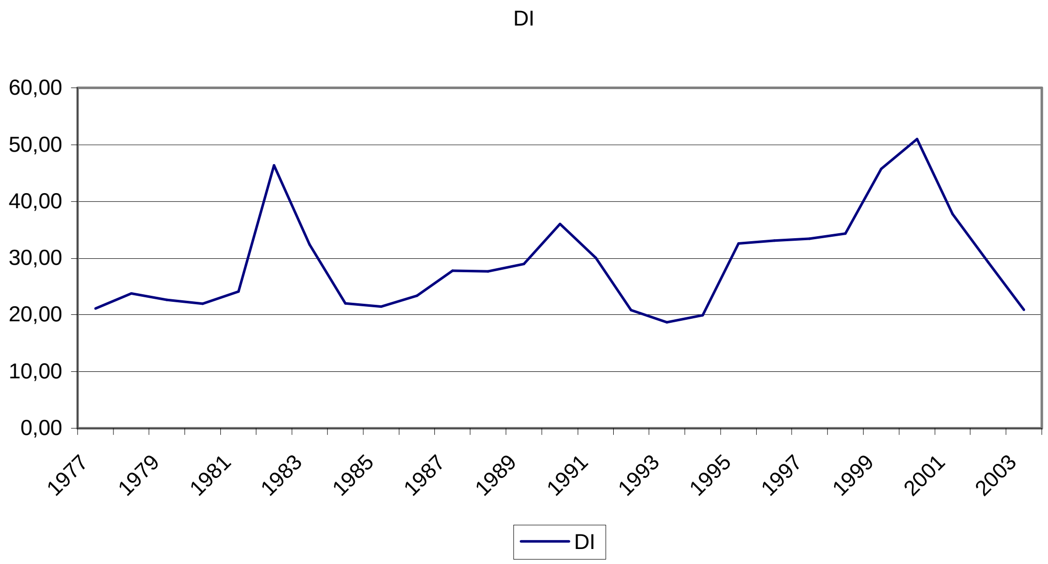
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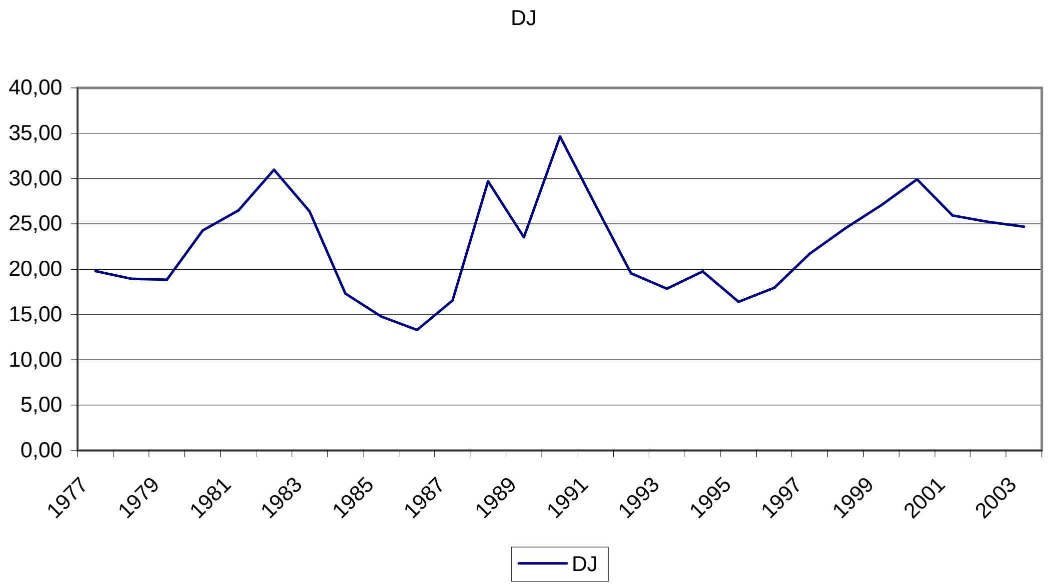
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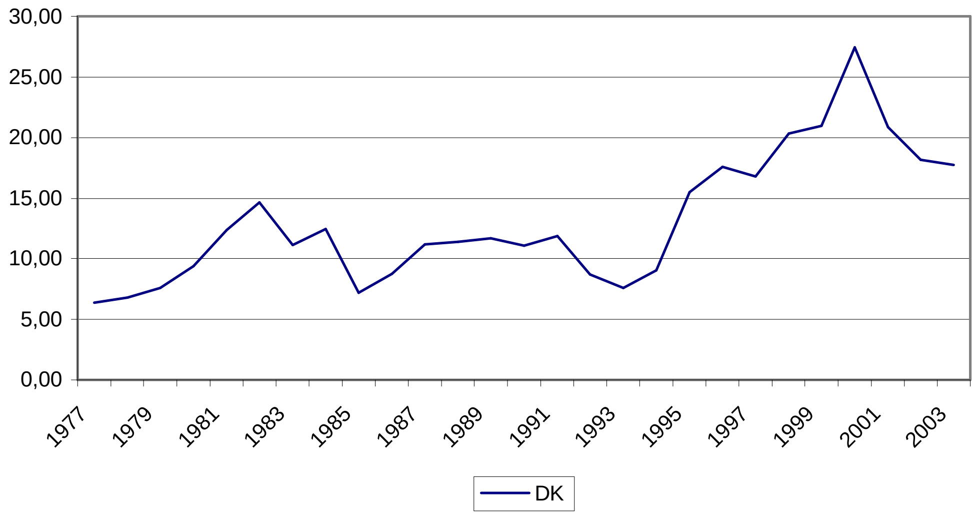

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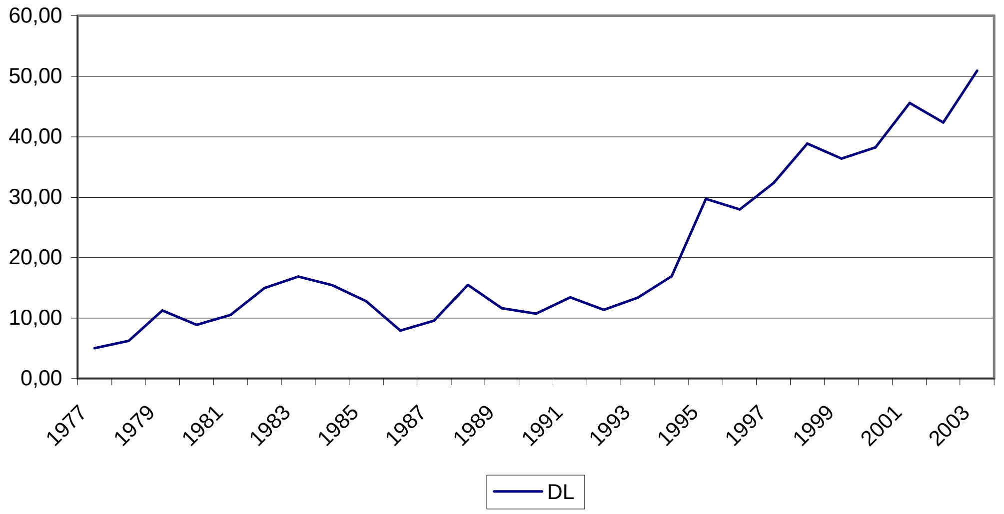

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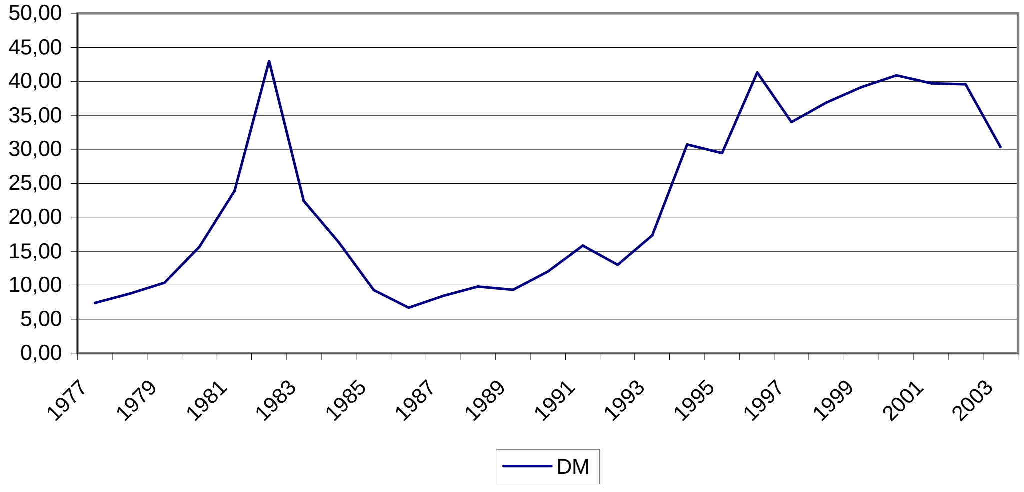

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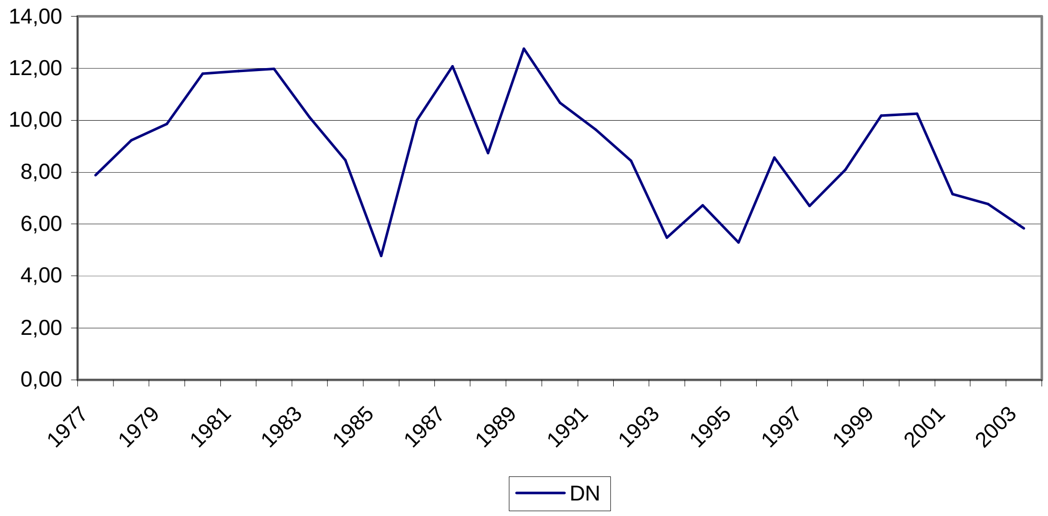
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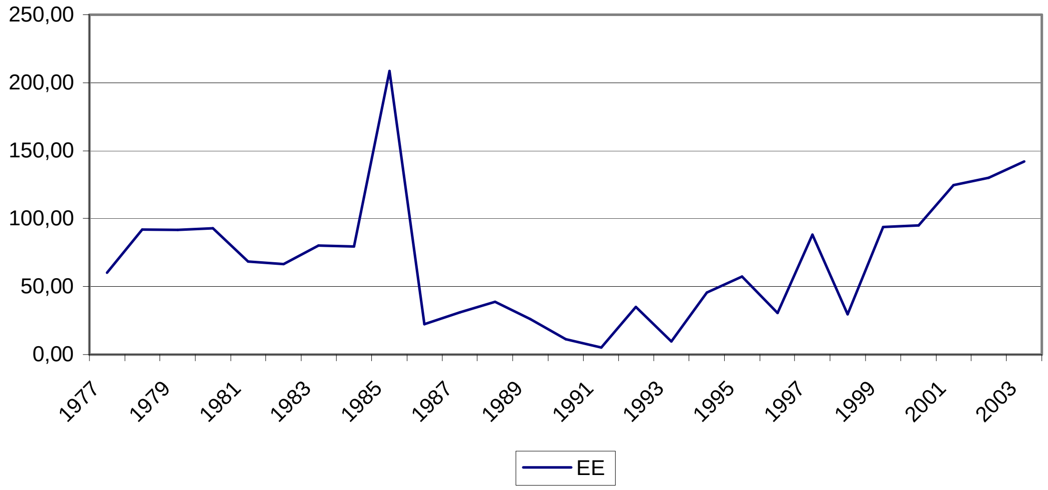
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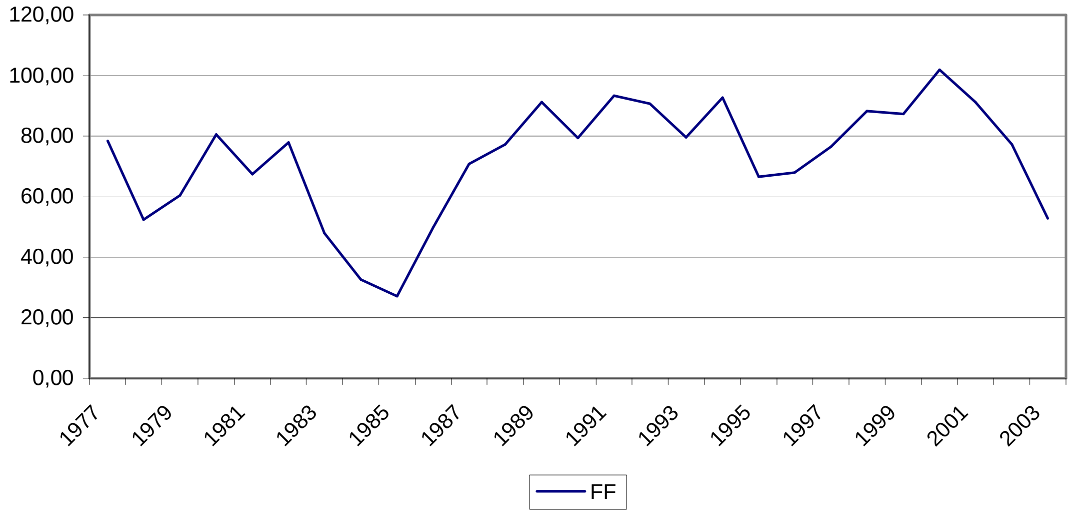
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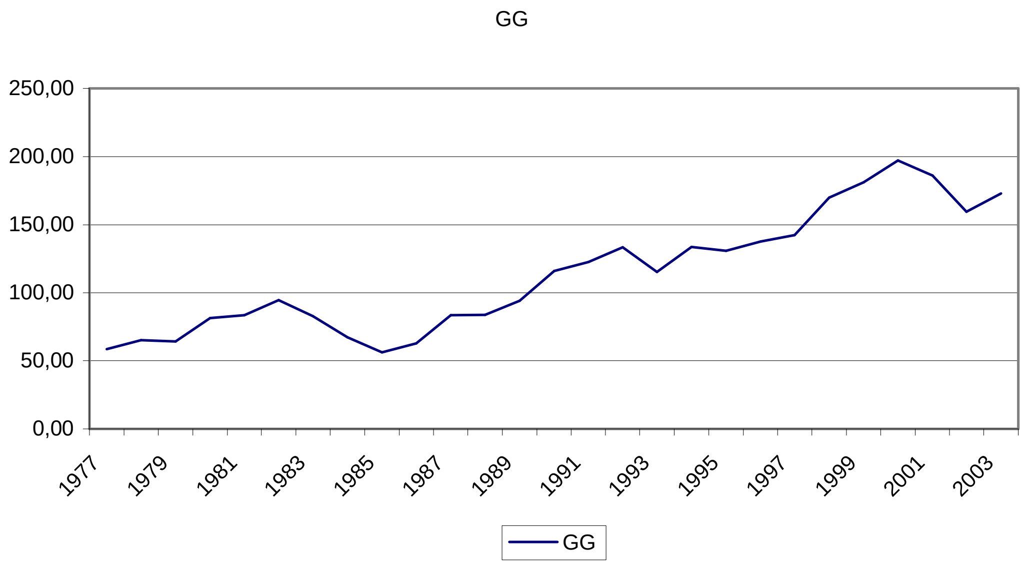
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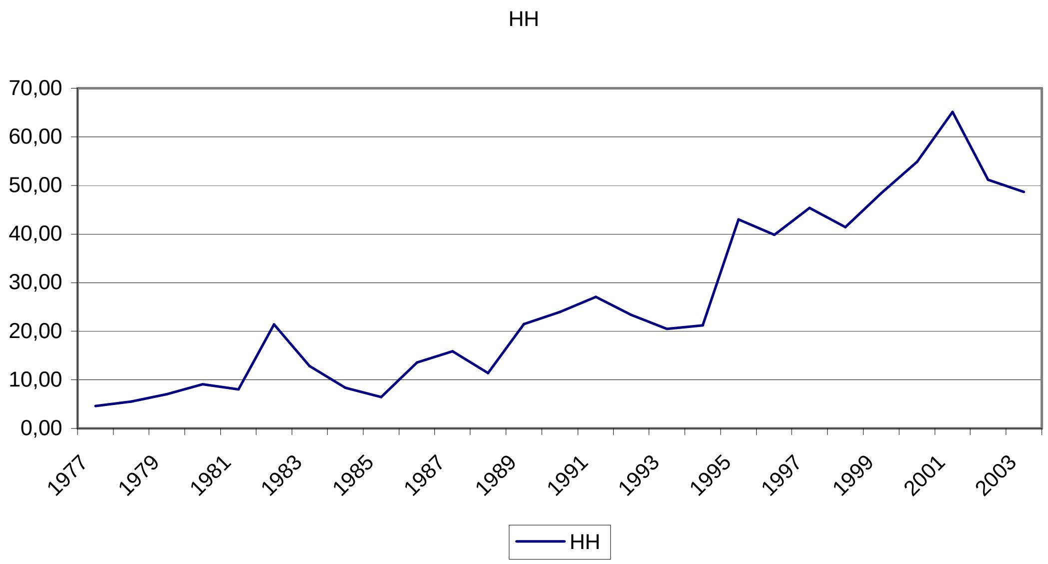
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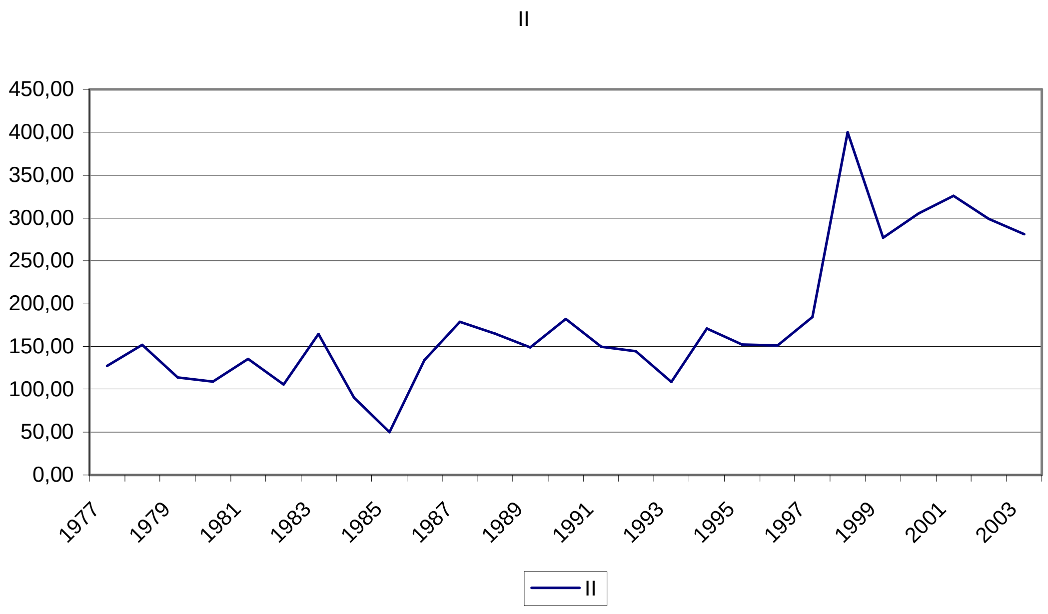
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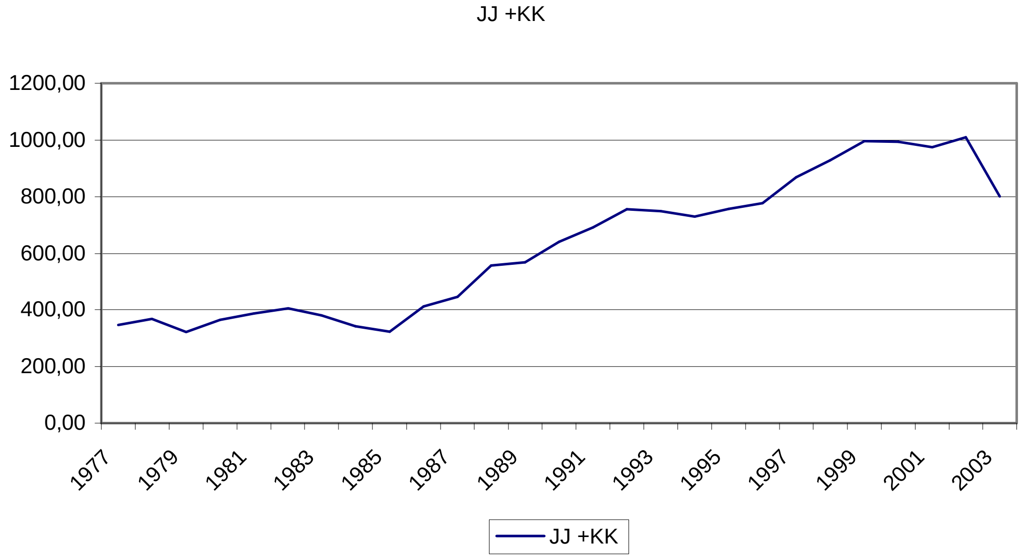


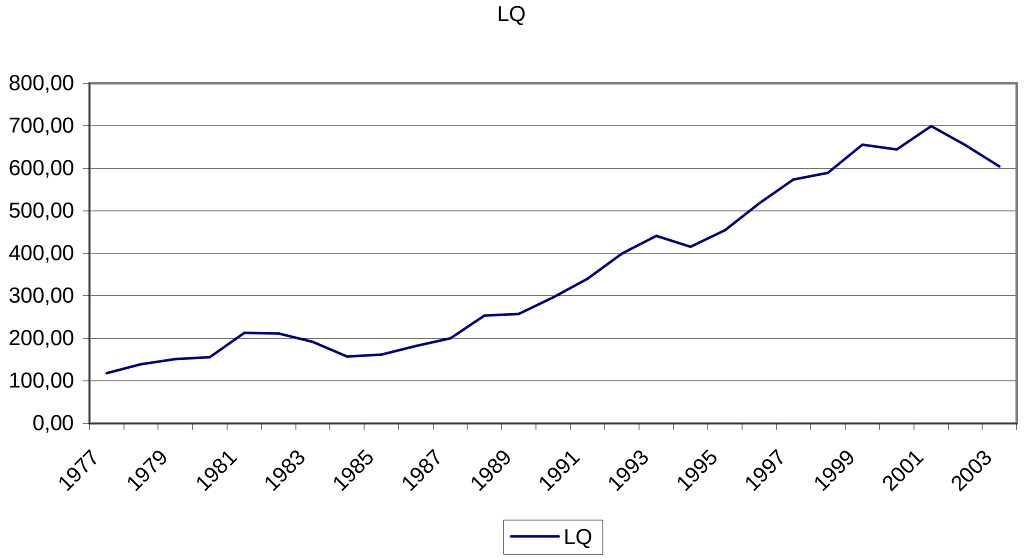


Figure A.2.: GFCF in individual sectors, 1977 prices, 1977-2003

Legend: AA + BB: Agriculture, hunting, forestry and fishing; CA + CB: Mining and quarrying; DA: Manufacture of food products; beverages and tobacco; DB: Manufacture of textiles and textile products; DC: Manufacture of leather and leather products; DD: Manufacture of wood and wood products; DE: Manufacture of pulp, paper and paper products; publishing and printing; DF: Manufacture of coke, refined petroleum products and nuclear fuel; DG: Manufacture of chemicals, chemical products and man-made fibres; DH: Manufacture of rubber and plastic products; DI: Manufacture of other non-metallic mineral products; DJ: Manufacture of basic metals and fabricated metal products; DK: Manufacture of machinery and equipment n.e.c.; DL: Manufacture of electrical and optical equipment; DM: Manufacture of transport equipment; DN: Manufacturing n.e.c.; EE: Electricity, gas and water supply; FF: Construction; GG: Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods; HH: Hotels and restaurants; II: Transport, storage and communication; JJ + KK: Financial intermediation, real estate, renting and business activities; LQ: Social and personal services.

Annex 5: Service lives of assets used by Statistics Netherlands

Table A.3: Service lives of assets used by Statistics Netherlands

Industries	Buildings	Other construction	Transport	Machinery	Computers	Other assets
Agriculture/ forestry	45	35	12	15	5	10
Fishing	50	35	25	15	5	10
Mining and quarrying	40	35	10	20	12	25
Food and beverages	43	35	10	28	13	27
Textile/ leather	47	35	10	28	15	40
Paper/paper products	55	35	10	29	10	36
Petroleum & products	46	35	10	37	10	38
Chemical industry	39	35	10	32	13	38
Basic metal & product	47	35	10	49	16	19
Other manufacturing	47	35	10	32	12	34
Public Utilities	47	35	10	32	12	34
Construction	47	35	10	20	12	34
Trade	60	35	8	15	5	10
Hotel, restaurants	60	35	8	15	5	10
Transport						
Water	60	35	25	15	5	10
Air	60	35	25	15	5	10
Rail	60	35	25	15	5	10
Other	60	35	10	15	5	10
Banking and insurance	60	35	8	15	5	10
Rented dwellings	75	35	8	15	5	10
Rented buildings	60	35	8	15	5	10
Commercial services	60	35	8	15	5	10
Government	60	35	8	15	5	10
Healthcare	60	35	8	15	5	10

Source: OECD (2001b:111)

Annex 6: Service lives of assets used by Czech Republic capital statistics

Table A.4: Service lives of assets used by Czech Republic capital statistics

Industries	Transport Equipment	Other Machinery and Equipment	Of which Computers
Agriculture	13	15	9
Forestry	12	13	6
Mining			
Coal	19	15	9
Other	13	16	8
Food, beverages, tobacco	13	16	7
Textiles and clothing	11	18	10
Wooden products, paper and pulp	15	16	10
Chemicals, rubber and plastic	14	18	9
Metal products, including vehicles, office machinery, etc.	11	18	11
Electricity, gas, water	12	18	11
Construction	11	15	9
Sale and repair of motor vehicles	11	15	9
Wholesale and retail trade	9	12	8
Hotels and restaurants	7	11	7
Air transport	13	14	11
Post and telecommunications	11	16	16
Financial and insurance services	n.a.	9	7
Public administration and defence	13	15	7
Education	13	15	12
Healthcare and welfare services	12	15	8

Source: OECD (2001b:110)

Annex 7: Estimates on the net rate of return of capital (1977-2003)

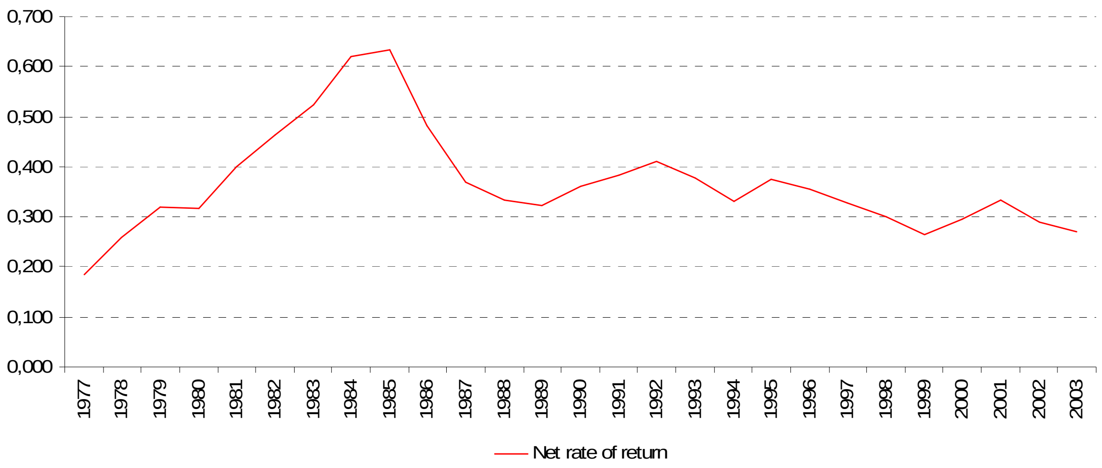


Figure A.3: Net rate of return on capital, 1977-2003.

Note: Author's computations based on data from INE and Banco de Portugal

Annex 8: Volume Index of capital services (all assets) by sectors

Table A.5: Volume index of capital services (all assets) by sectors

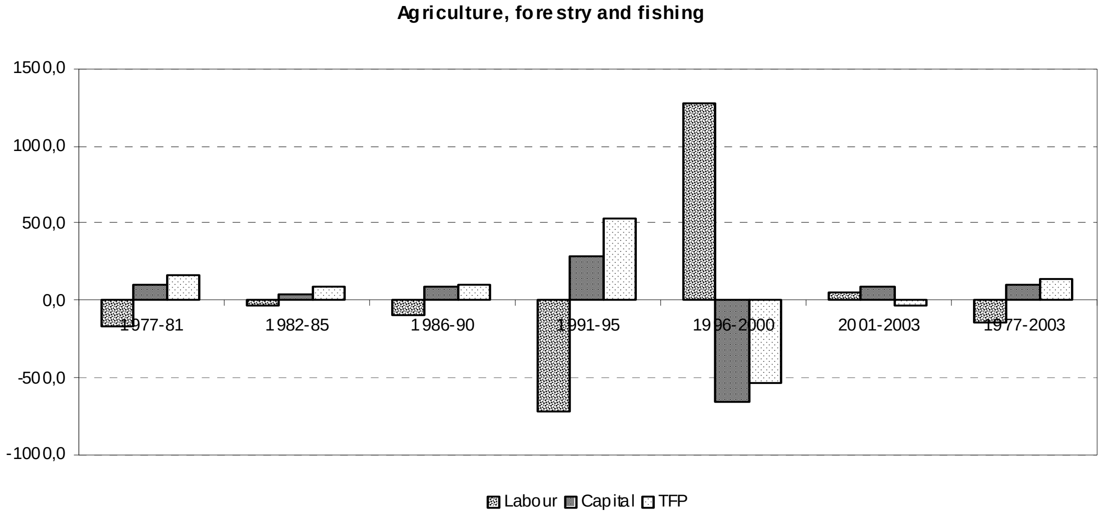
	AAeBB	CAeCB	DA	DB	DC	DD	DE	DF	DG	DH	DI	DJ	DK
1977	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
1978	108,6	109,0	109,7	109,4	146,6	106,3	113,4	109,8	111,5	110,3	108,3	107,1	108,1
1979	120,3	120,3	121,0	121,7	201,3	111,2	129,2	113,0	126,7	122,6	118,7	115,1	118,2
1980	133,1	137,9	131,3	133,6	256,6	123,9	145,5	117,0	142,3	140,4	126,6	124,4	129,1
1981	144,5	161,9	142,6	150,1	333,6	136,8	169,7	123,3	151,6	160,9	135,8	134,6	144,2
1982	156,0	191,5	154,2	166,9	406,8	146,6	195,0	126,2	163,0	181,8	152,8	146,6	161,5
1983	165,4	211,4	165,0	180,0	461,5	155,4	215,3	125,6	171,3	194,4	163,9	156,0	174,0
1984	171,2	225,6	173,8	191,0	509,7	162,2	232,5	124,8	178,0	207,5	170,5	161,2	187,3
1985	174,8	235,7	181,7	200,8	558,0	165,0	247,0	124,1	179,6	218,3	176,9	165,3	194,2
1986	184,2	251,0	196,0	213,5	618,8	174,7	264,7	123,3	179,6	227,4	182,5	167,9	201,2
1987	196,2	244,5	216,5	231,7	709,4	188,0	291,0	122,5	180,5	241,5	190,8	171,9	212,9
1988	209,7	272,6	229,2	250,2	795,6	199,7	319,5	121,7	182,1	253,3	198,4	180,6	223,2
1989	219,5	294,1	246,5	269,5	883,5	215,1	348,5	120,0	182,9	270,9	206,5	186,8	232,8
1990	220,8	319,2	263,9	287,4	965,2	225,6	377,7	119,8	181,5	283,6	216,1	197,3	242,3
1991	226,2	343,2	280,1	298,3	1014,3	235,0	397,4	118,8	180,6	293,0	223,0	204,8	252,6
1992	229,1	353,8	290,7	306,3	1050,5	241,0	409,4	121,4	180,8	299,4	226,8	209,2	259,4
1993	227,8	357,3	297,4	309,5	1058,7	243,3	412,8	127,3	179,0	303,9	228,8	213,0	264,3
1994	227,7	363,1	305,0	311,9	1059,8	246,3	414,5	127,7	176,9	308,2	230,5	217,2	270,2
1995	230,5	387,3	312,2	318,0	1083,2	254,4	421,8	126,8	178,3	339,2	239,8	220,4	287,8
1996	235,0	423,9	322,4	323,0	1100,7	266,8	428,6	126,4	180,1	372,2	248,8	222,7	307,1
1997	239,8	474,8	331,7	329,2	1121,0	274,2	439,7	128,7	187,8	412,9	257,3	226,8	324,7
1998	247,3	526,3	342,3	337,3	1153,6	283,9	451,9	127,2	194,6	456,8	267,0	231,7	347,7
1999	255,6	587,2	356,8	344,1	1176,6	303,5	465,3	129,1	202,7	510,9	280,5	238,3	371,8
2000	259,7	667,8	374,6	352,8	1209,0	328,0	483,3	134,9	212,1	563,0	295,7	245,4	404,2
2001	264,5	742,9	388,8	352,5	1192,0	352,5	489,2	140,8	220,2	612,5	303,8	249,9	425,7
2002	266,9	787,9	397,9	348,4	1161,3	365,6	487,8	145,3	227,4	668,4	308,8	255,6	442,9
2003	270,3	808,5	415,4	340,5	1118,2	373,1	487,7	150,8	237,0	710,7	309,8	261,1	456,6

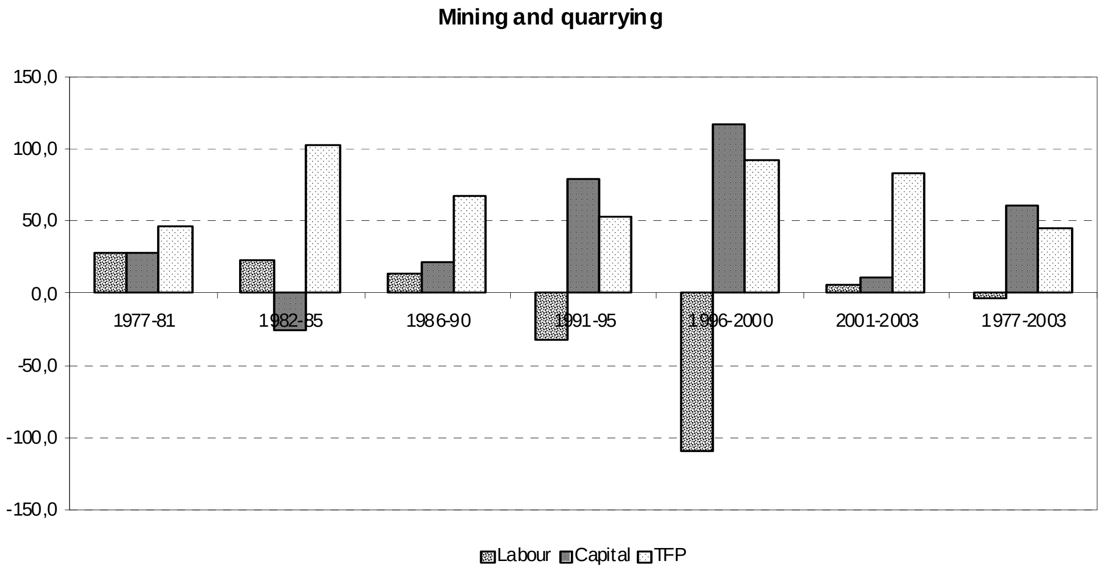
Table A.5 *(cont.)***:** Volume index of capital services (all assets) by sectors

	DL	DM	DN	EE	FF	GG	HH	II	JJeKK	LL	MM	NN	OO	Total Economy
1977	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	**100,0**
1978	110,7	109,0	109,1	108,8	105,0	108,7	108,1	108,2	104,5	108,2	108,4	111,6	108,7	**107,5**
1979	130,0	118,4	120,6	117,0	110,4	116,9	122,8	114,8	109,6	116,1	119,5	123,6	111,4	**114,5**
1980	152,0	131,5	132,7	125,1	117,6	128,3	138,6	120,2	116,5	116,6	131,5	144,5	118,8	**122,3**
1981	171,7	151,2	145,0	130,9	124,4	140,6	151,4	126,7	123,0	126,7	143,7	161,4	127,1	**130,6**
1982	198,5	189,2	157,2	136,4	131,3	153,5	185,1	131,8	129,0	135,5	157,2	174,3	140,1	**138,9**
1983	228,8	207,6	166,9	143,1	135,0	163,8	206,2	139,5	134,2	143,2	170,7	184,5	149,8	**146,2**
1984	254,9	219,7	174,2	149,7	136,9	170,9	217,8	143,2	138,7	149,6	183,8	192,4	156,5	**151,8**
1985	276,4	225,9	177,4	166,1	138,4	176,1	227,3	145,3	142,8	156,4	197,2	201,3	160,8	**157,1**
1986	285,0	228,4	184,1	167,7	141,0	179,9	246,4	151,0	148,8	155,3	208,1	209,1	169,3	**163,2**
1987	295,8	232,3	208,6	170,2	145,2	185,7	268,4	158,7	155,0	165,1	222,7	217,6	177,9	**170,5**
1988	313,3	237,6	215,2	172,9	150,0	193,2	288,8	166,7	162,1	173,6	238,4	227,2	205,8	**178,4**
1989	328,1	241,9	224,8	175,2	156,0	202,4	326,4	173,4	169,2	182,4	257,0	224,6	234,0	**186,6**
1990	340,6	249,1	233,3	175,9	161,7	214,2	365,6	182,3	178,2	192,4	283,0	236,7	268,7	**195,8**
1991	359,1	259,9	242,1	175,8	169,2	228,7	411,1	190,0	187,1	204,3	319,8	256,7	308,9	**204,9**
1992	373,6	268,6	249,8	180,3	176,7	246,5	448,6	197,3	196,6	214,3	356,1	278,5	354,2	**214,2**
1993	393,2	280,5	252,0	180,6	182,9	260,6	478,1	201,9	205,6	223,9	397,1	305,9	410,3	**222,3**
1994	417,7	301,4	255,0	184,1	189,8	275,2	505,5	208,1	214,1	234,0	431,9	331,5	456,7	**230,5**
1995	483,0	330,7	255,3	189,0	194,8	285,3	573,0	214,2	221,0	247,0	462,9	361,0	510,0	**239,0**
1996	539,2	364,0	257,9	191,6	199,6	297,0	637,8	219,8	228,2	265,6	493,5	388,4	551,3	**247,9**
1997	597,5	394,4	259,1	198,0	205,1	309,6	709,3	227,4	236,2	284,7	545,2	423,9	592,7	**258,2**
1998	670,0	428,3	261,4	200,8	212,6	325,4	778,1	244,8	244,8	303,0	613,5	471,6	639,5	**270,2**
1999	739,3	461,4	266,2	208,0	219,9	341,6	870,5	257,8	253,8	323,6	697,9	527,6	683,7	**283,0**
2000	809,2	498,0	272,2	215,1	228,4	359,9	968,1	270,6	262,3	341,4	834,1	585,6	729,1	**296,1**
2001	902,0	535,1	272,7	226,3	235,3	375,2	1088,4	283,8	269,8	360,0	1002,1	646,7	771,7	**308,8**
2002	983,4	575,3	272,1	237,7	240,1	383,1	1170,2	295,5	276,9	375,6	1148,4	704,2	807,8	**319,8**
2003	1095,6	598,1	269,1	251,9	240,1	393,1	1240,1	305,3	280,6	388,9	1272,5	757,8	829,2	**328,9**

Annex 9: Contribution of labour, capital and TFP to average annual growth

Figure A.4: Contribution of labour, capital and TFP to average annual growth (1977-2003; 26 sectors)





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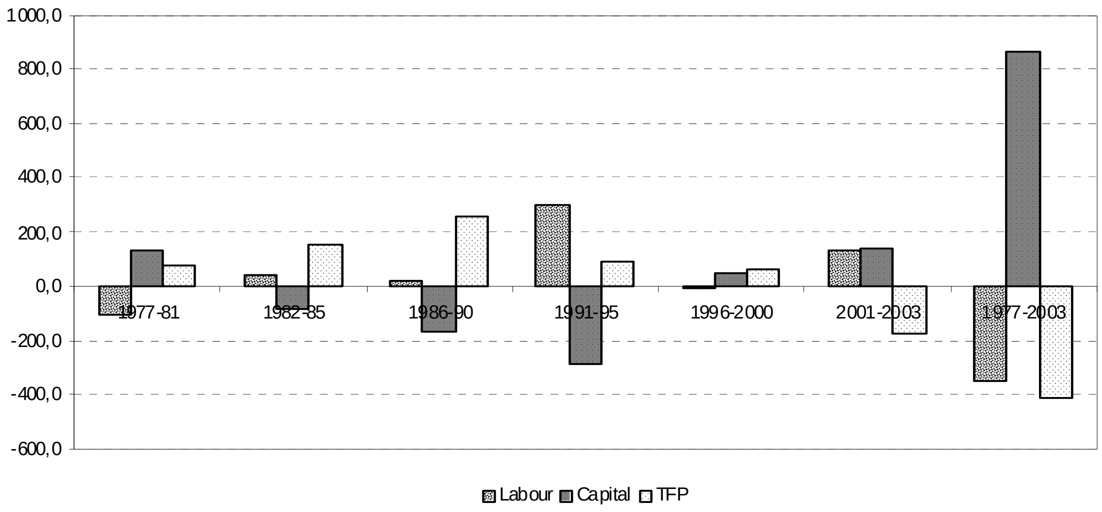

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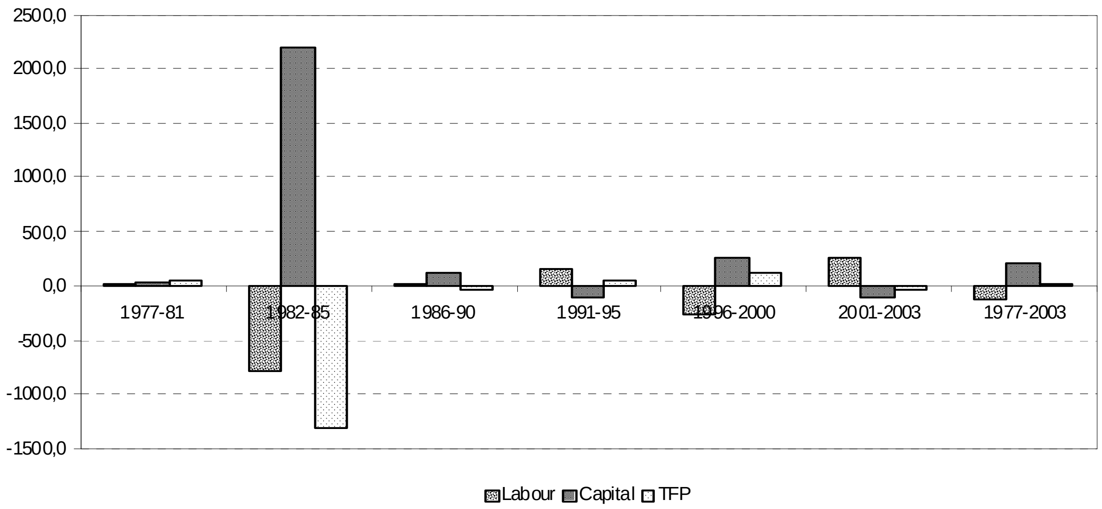

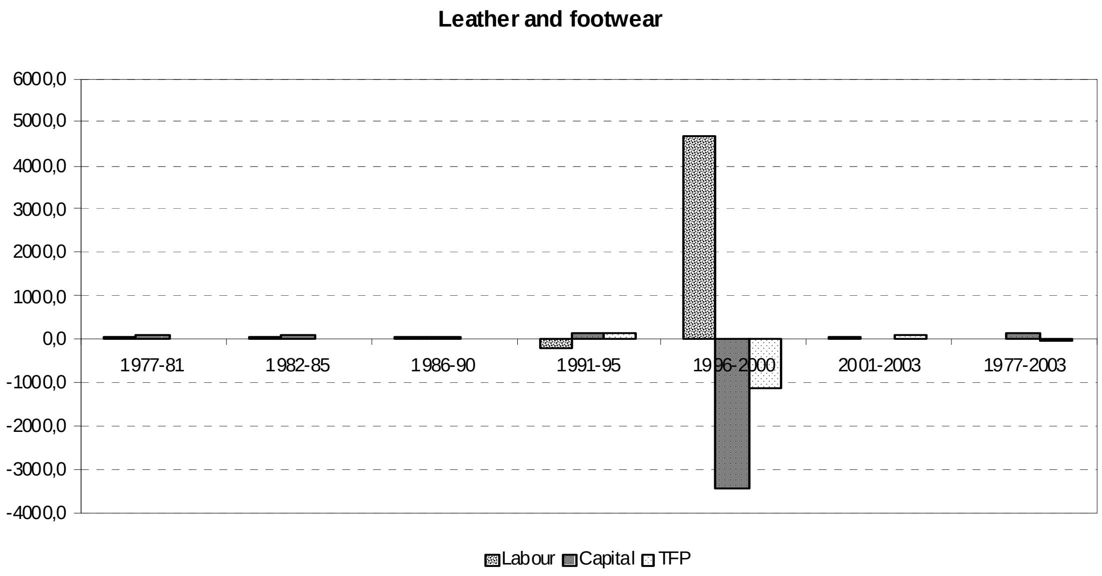
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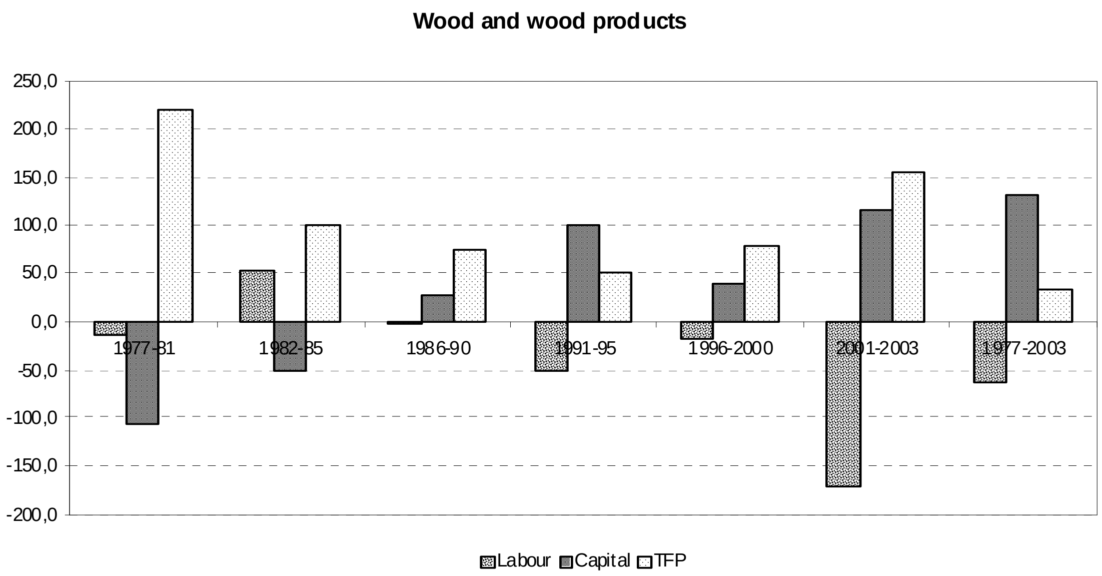
1982-85
1986-90
1991-95
1996-2000
2001-2003
1977-2003
Labour
Capital
TFP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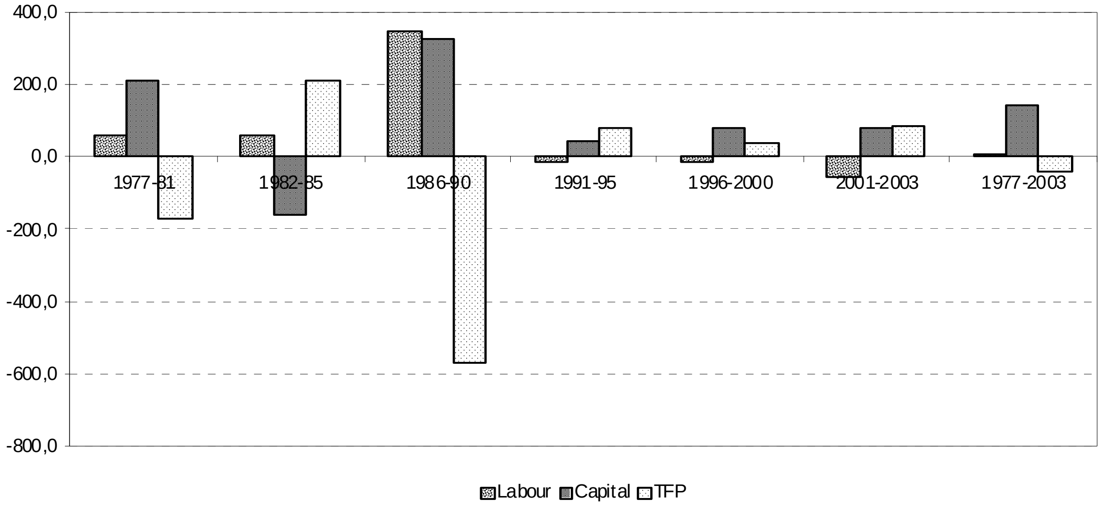
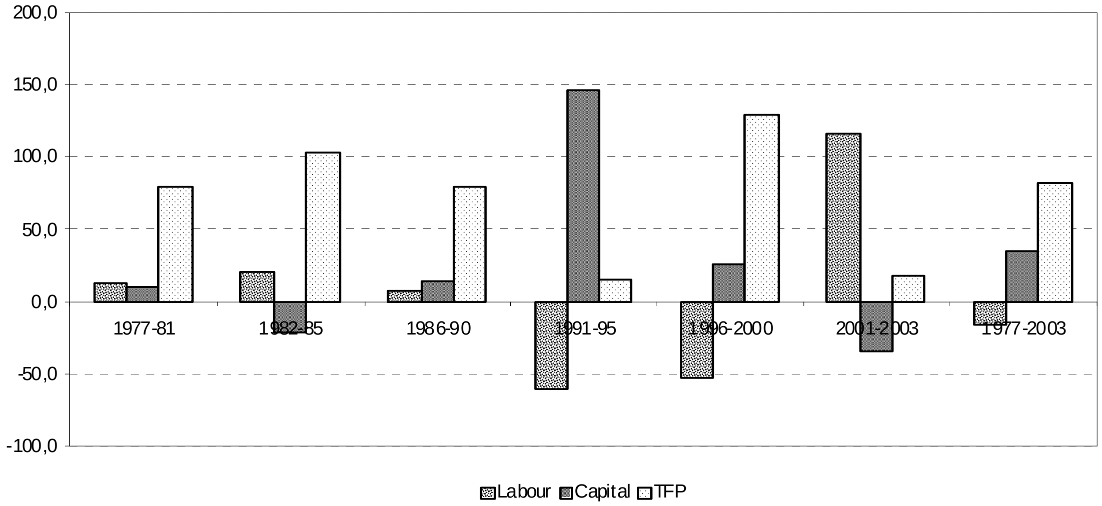
1977-81
1982-85
1986-90
1991-95
1996-2000
2001-2003
1977-2003
Labour
Capital
TFP

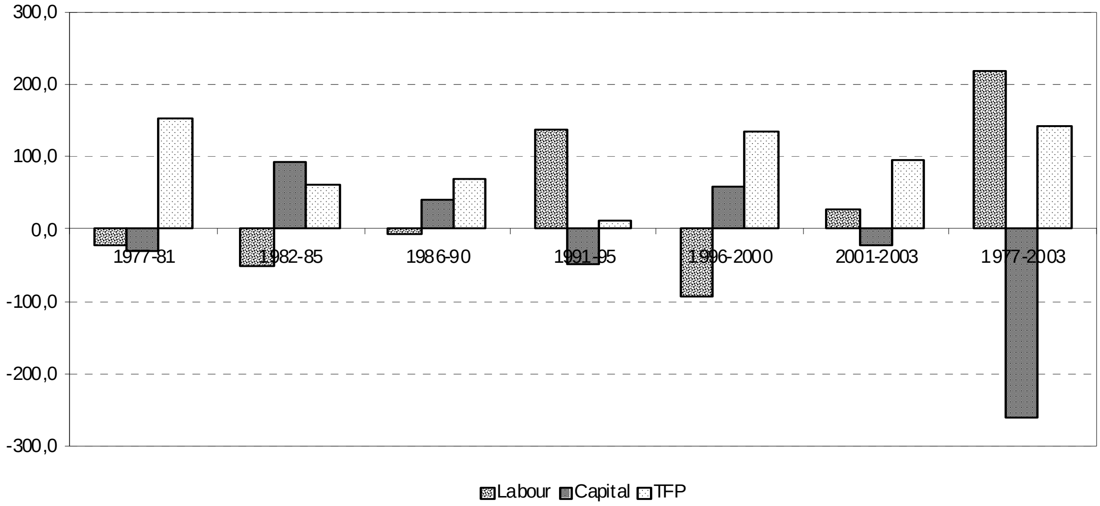
Pulp, paper and paper products, printing and publishing



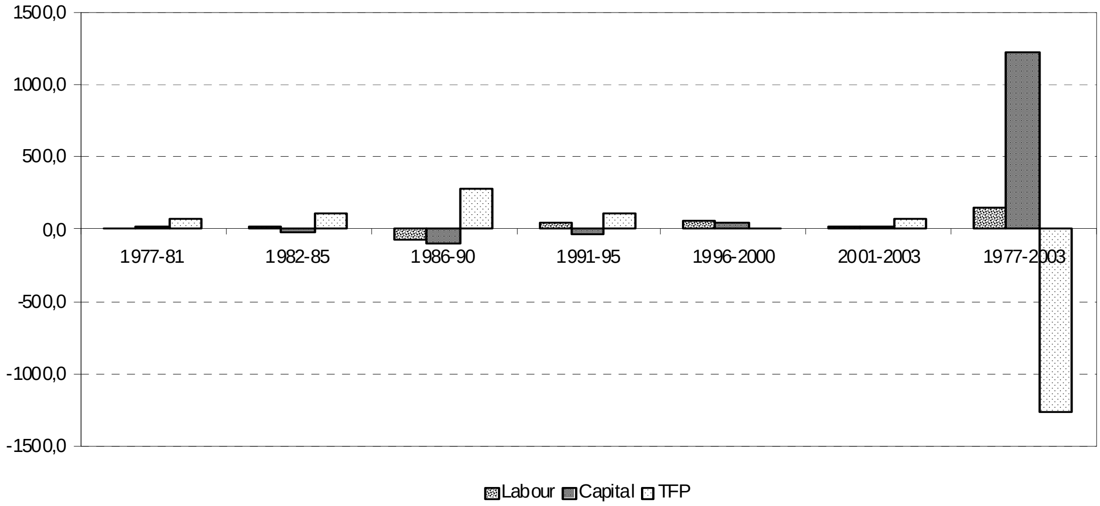
Coke, refined petroleum products and nuclear fuel

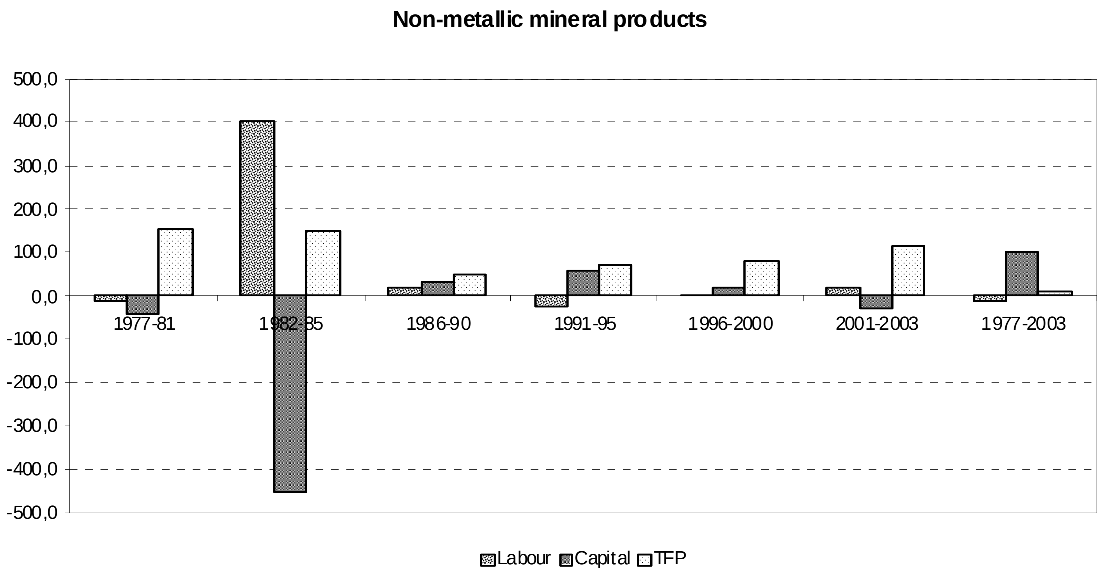


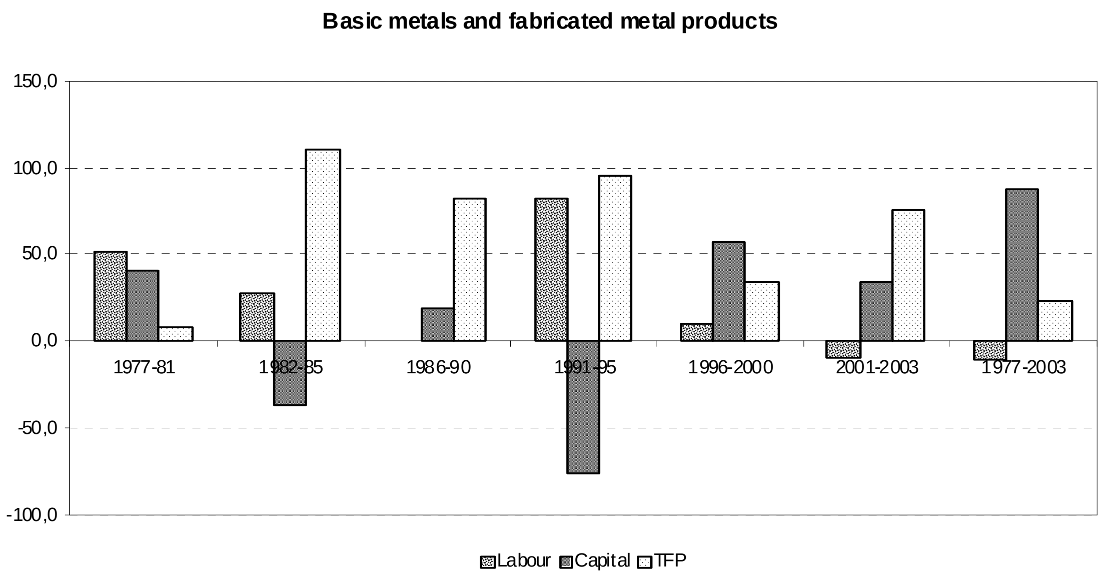
Chemicals and chemical products



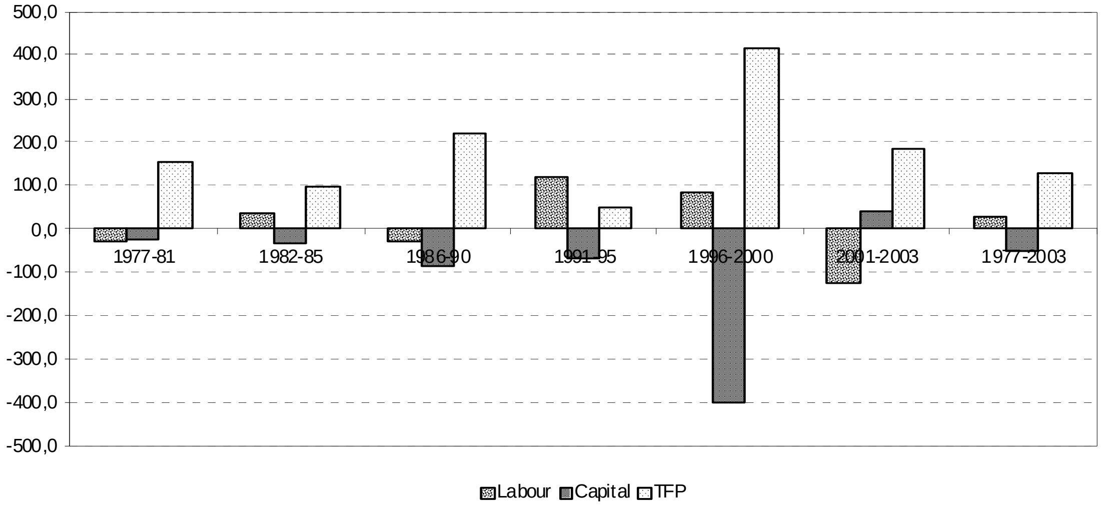
Rubber and plastics



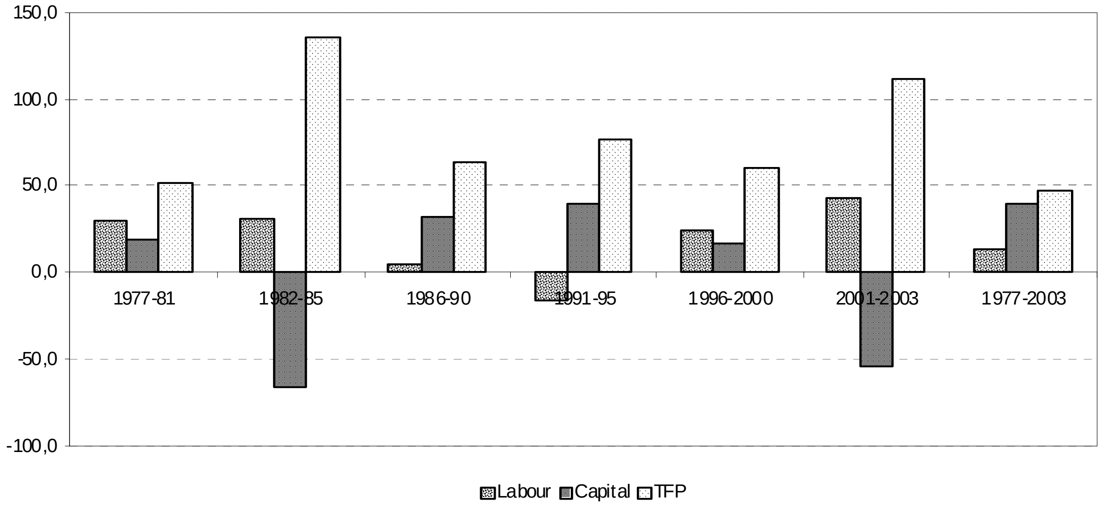

Non-metallic mineral products
500,0
400,0
300,0
200,0
100,0
0,0
-100,0
-200,0
-300,0
-400,0
-500,0
1977-81
1982-85
1986-90
1991-95
1996-2000
2001-2003
1977-2003
Labour
Capital
TFP


Basic metals and fabricated metal products
150,0
100,0
50,0
0,0
-50,0
-100,0
1977-81
1982-85
1986-90
1991-95
1996-2000
2001-2003
1977-2003
Labour
Capital
TFP

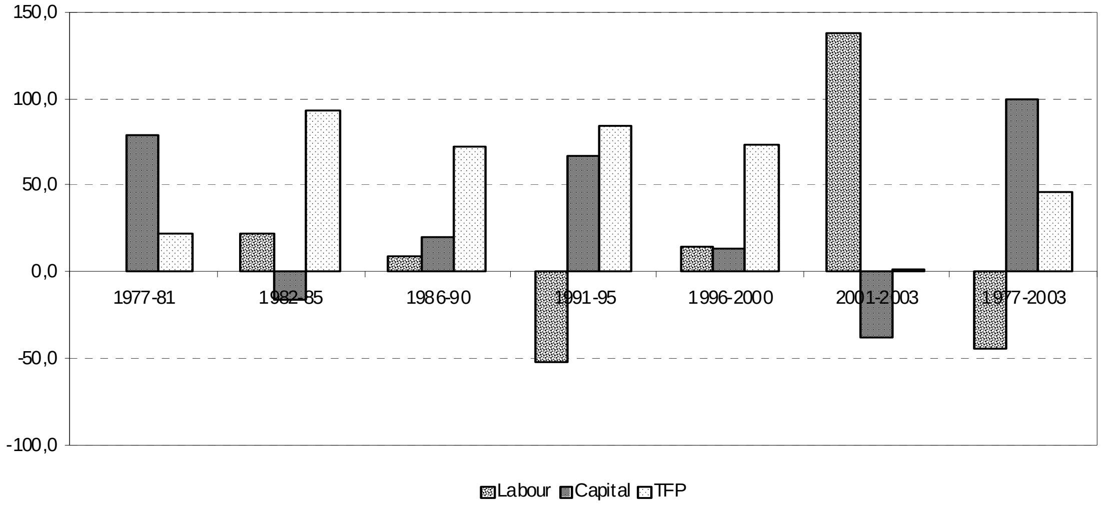
Machinery and equipment n.e.c.



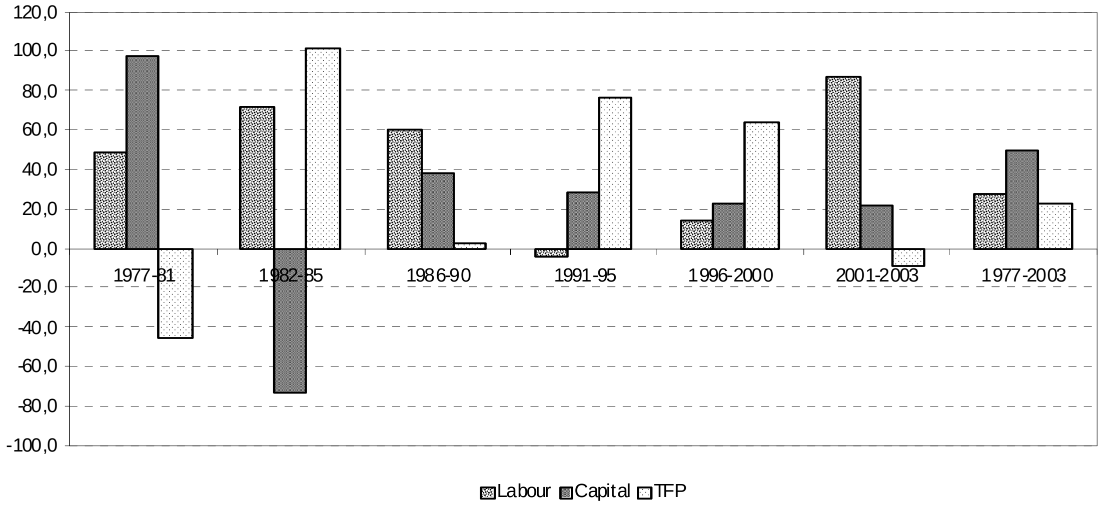
Electrical and optical equipment



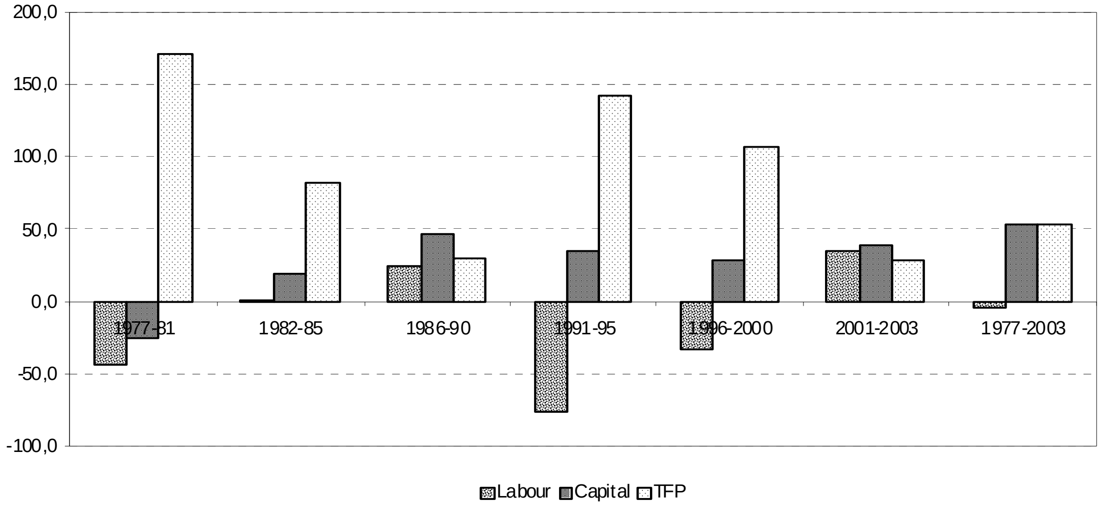
Transport equipment



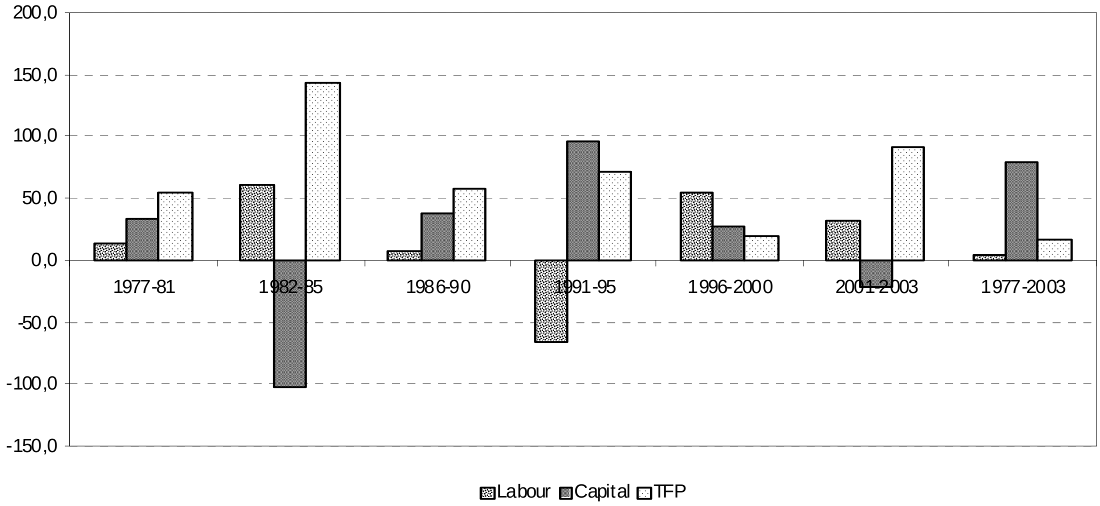
Manufacture n.e.c.



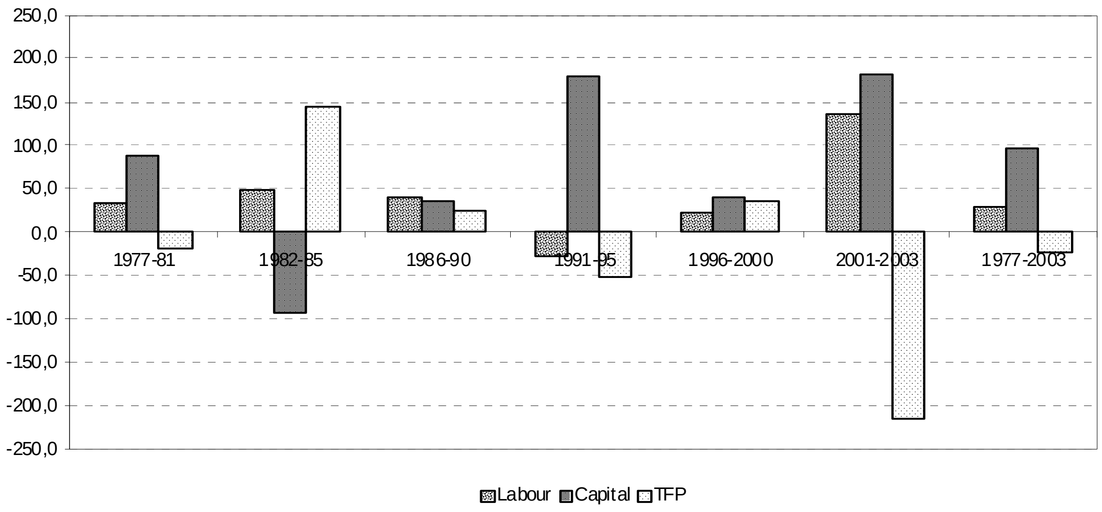
Electricity, gas and water supply



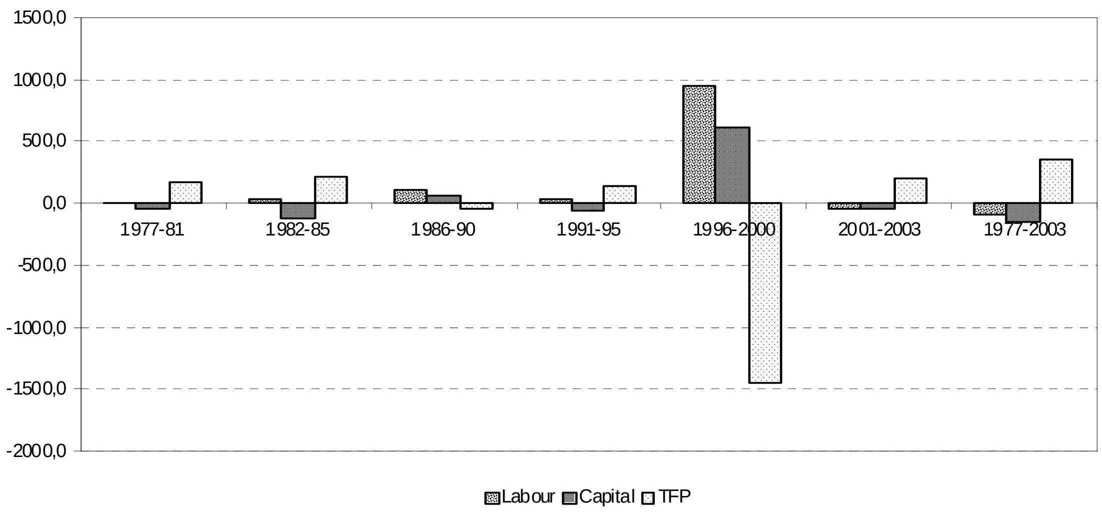
Construction



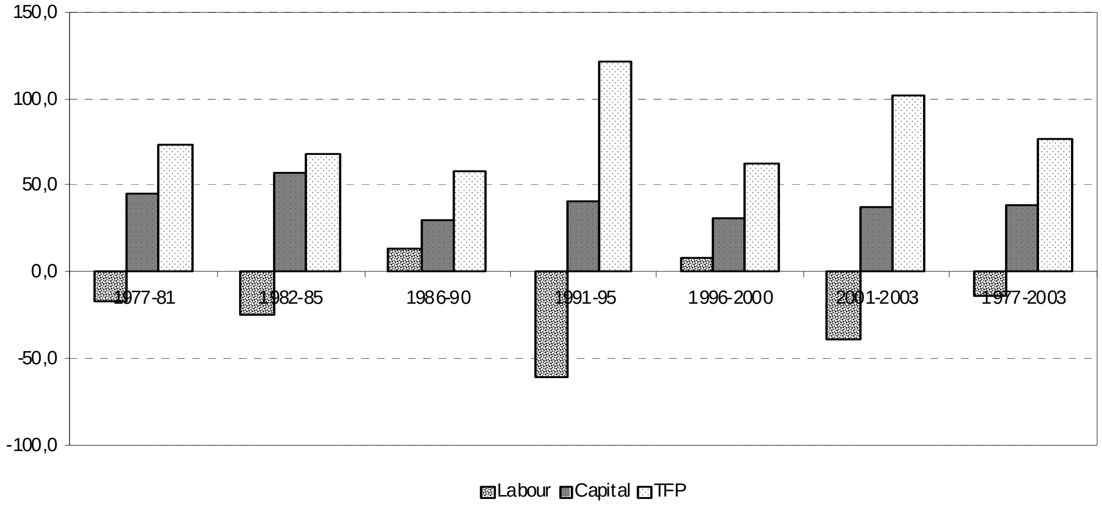
Wholesale and retail trade



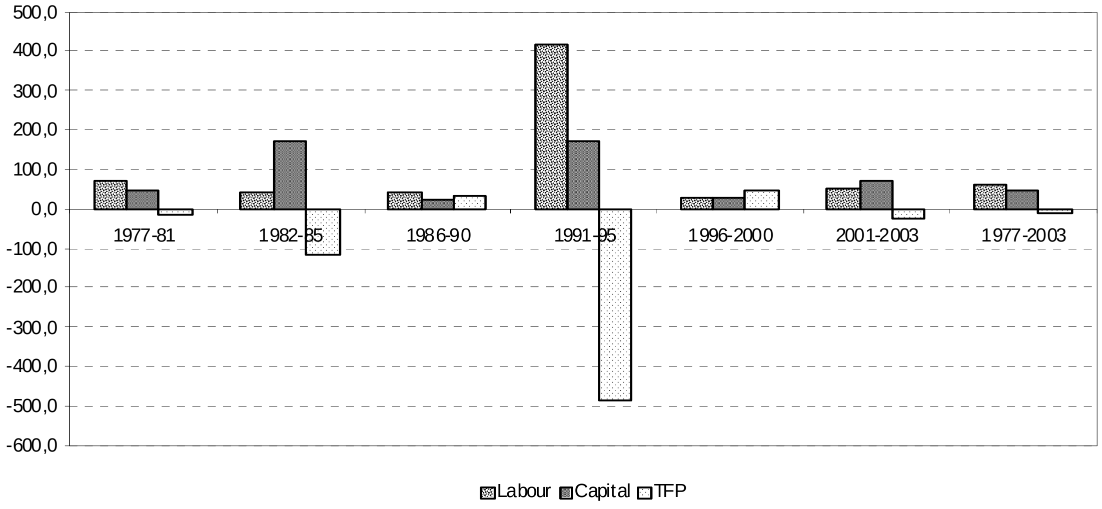
Hotel and restaurant services



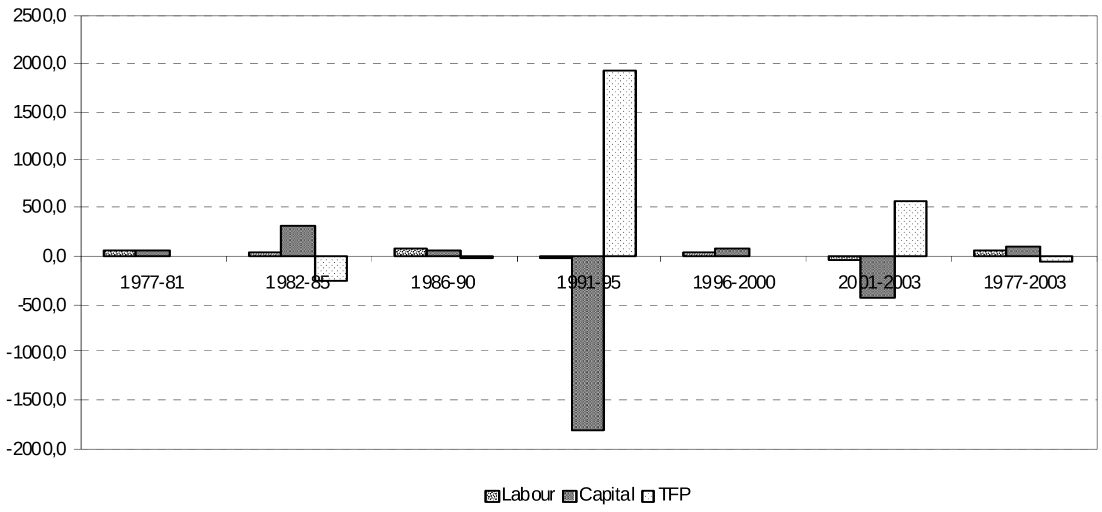
Transport, storage and communication



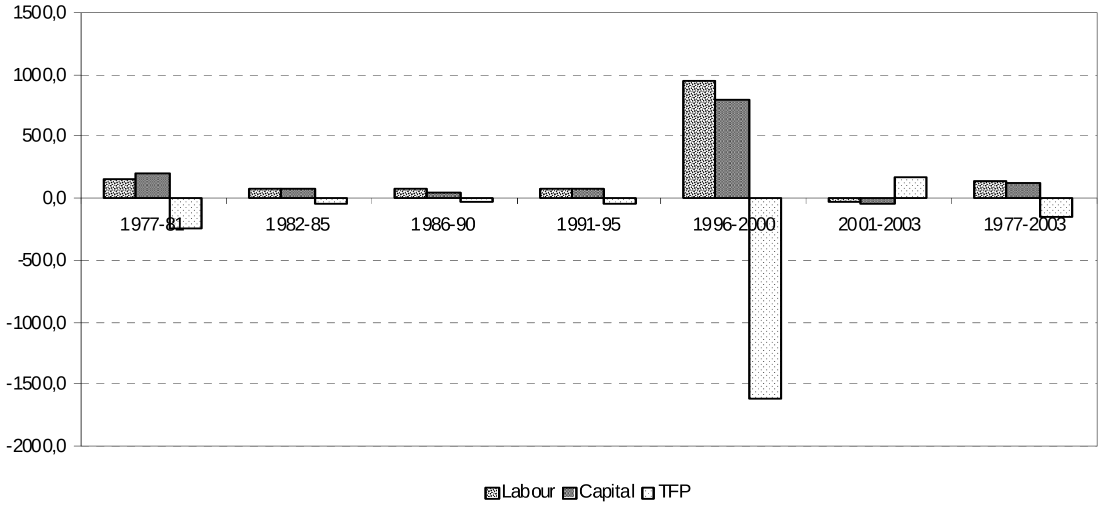
Financial intermediation, real estate, renting and business activities



Public administration and defence; compulsory social security

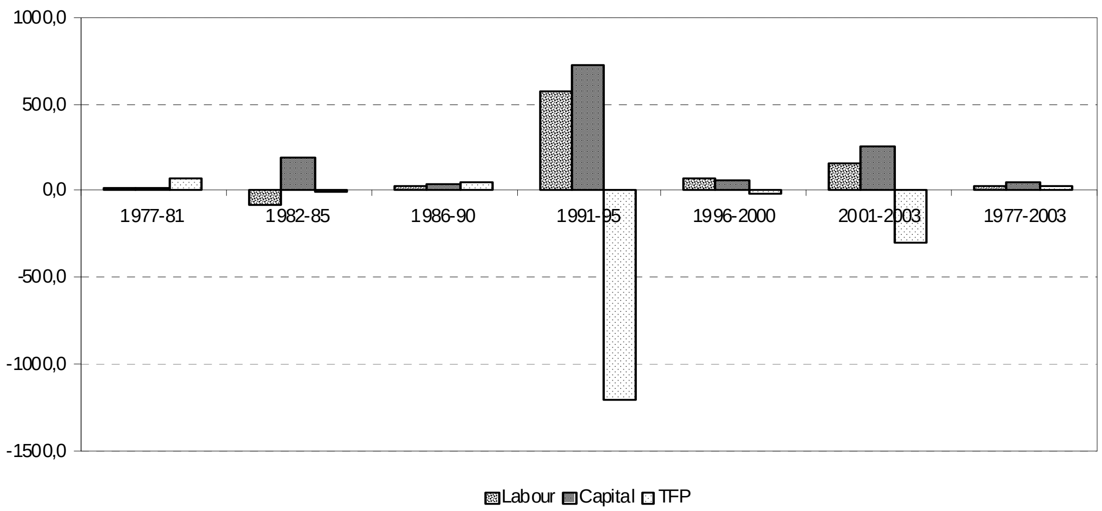


Education



Health and social work

Other community, social and personal services



Annex 10: OECD Classification of manufacturing industries based on technology

Table A.6: OECD Classification of manufacturing industries based on technology

		R&D Intensity (1999)	
	ISIC Rev. 3	R&D divided by production	R&D divided by value added
High-technology industries			
Aircraft and spacecraft	353	10.3	29.1
Pharmaceuticals	2423	10.5	22.3
Office, accounting and computing machinery	30	7.2	25.8
Radio, TV and communications equipment	32	7.4	17.9
Medical, precision and optical instruments	33	9.7	24.6
Medium-high-technology industries			
Electrical machinery and apparatus, n.e.c.	31	3.6	9.1
Motor vehicles, trailers and semi-trailers	34	3.5	13.3
Chemicals excluding pharmaceuticals	24 excl. 2423	2.9	8.3
Railroad equipment and transport equipment, n.e.c.	352+359	3.1	8.7
Machinery and equipment	29	2.2	5.8
Medium-low-technology industries			
Building and repairing of ships and boats	351	1.0	3.1
Rubber and plastics products	25	1.0	2.7
Coke, refined petroleum products and nuclear fuel	23	0.4	1.9
Other non-metallic mineral products	26	0.8	1.9
Basic metals and fabricated metal products	27-28	0.6	1.6
Low-technology industries			
Manufacturing, n.e.c.; Recycling	36-37	0.5	1.3
Wood, pulp, paper, paper products, printing and publishing	20-22	0.4	1.0
Food products, beverages and tobacco	15-16	0.3	1.1
Textiles, textile products	17-19	0.3	0.8
Total manufacturing	15-37	2.6	7.2

Source: OECD (2003), *Science, Technology and Industry Scoreboard 2003 – Towards a Knowledge-Based Economy*, Paris: OECD, Annex 1, p. 220.

Notes: Calculus based on data for 12 OECD countries: United States, Canada, Japan, Denmark, Finland, France, Germany, Ireland, Italy, Spain, Sweden, United Kingdom. Aggregate R&D intensities are calculated after converting countries' R&D expenditures, value added and production using GDP PPPs. The absence of updated ISIC Rev. 3 input-output tables did not allow for the calculus in this period of the R&D intensity indicator considering technology embodied in intermediate and investment goods.

Annex 11: Peneder's (2002) classification of manufacturing industries

Table A.7: Peneder's (2002) classification of manufacturing industries

Taxonomy I	Taxonomy II	NACE Rev. 1
Mainstream manufacturing	**Skill type**	
Finishing of textiles	LS	1730
Knitted and crocheted articles	LS	1770
Other textiles	LS	1750
Knitted and crocheted fabrics	LS	1760
Articles ofpaper , paperboard	MSWC	2120
Paints, coatings	MSWC	2430
Rubber products	LS	2510
Plastic products	LS	2520
Glass and glass products	LS	2610
Concrete, plaster, cement	LS	2660
Other mineral products	LS	2680
Tubes	LS	2720
Other metal products	MSWC	2870
Machinery f. mech. power	HS	2910
Other machinery	HS	2920
Agricultural machinery	HS	2930
Special purpose machinery	HS	2950
Weapons and ammunition	HS	2960
Domestic appliances n. e. c.	MSWC	2970
Electric motors, generators	MSWC	3110
Isolated wire and cable	MSWC	3130
Accumulators, batteries, etc.	MSWC	3140
Lighting equipment, lamps	MSWC	3150
Motorcycles and bicycles	MSWC	3540
Other transport equipment	MSWC	3550
Labour intensive industries		
Textile weaving	LS	1720
Made-up textile articles	LS	1740
Leather clothes	LS	1810
Other wearing apparel	LS	1820
Articles of fur	LS	1830
Saw milling, etc.	MSWC	2010
Panels/boards of wood	MSWC	2020
Carpentry and joinery	MSWC	2030
Wooden containers	MSWC	2040
Products of wood; cork, etc.	MSWC	2050
Ceramic goods	LS	2620
Construction materials	LS	2640
Processing of stone	LS	2670
Structural metal products	MSWC	2810
Steam generators	MSWC	2830
Metal processing	MSWC	2840
Casting of metals	LS	2750

Treatment, coating of metals	MSWC	2850
Machine-tools	HS	2940
Electrical equipment n. e. c.	MSWC	3160
Bodies for motor vehicles	MSWC	3420
Ships and boats	HS	3510
Railway vehicles	MSWC	3520
Furniture	MSWC	3610
Jewellery and related articles	LS	3620
Capital intensive industries		
Textile fibres	LS	1710
Pulp & paper	MSWC	2110
Coke oven products	MSWC	2310
Refined petroleum prod.	MSWC	2320
Basic chemicals	MSWC	2410
Man-made fibres	MSWC	2470
Ceramic tiles and flags	LS	2630
Cement, lime and plaster	LS	2650
Basic iron & steel	LS	2710
Processing of iron & steel	LS	2730
Basic non-ferrous metals	LS	2740
Parts for motor vehicles	MSWC	3430
Marketing driven industries		
Meat products	LS	1510
Fish and fish products	LS	1520
Fruits and vegetables	LS	1530
Oils & fats	LS	1540
Dairy products; ice cream	LS	1550
Grain mill prod., starches	LS	1560
Prepared animal feeds	LS	1570
Other food products	LS	1580
Beverages	LS	1590
Tobacco products	LS	1600
Tanning/dressing of leather	LS	1910
Luggage, handbags, etc.	LS	1920
Footwear	LS	1930
Publishing	MSWC	2210
Printing	MSWC	2220
Recorded media	MSWC	2230
Detergents, clean, perfumes	MSWC	2450
Tanks, reservoirs, radiators	MSWC	2820
Cutlery, tools, gen. hardware	MSWC	2860
Watches and clocks	MSWC	3350
Musical instruments	LS	3630
Sports goods	LS	3640
Games and toys	LS	3650
Miscellaneous manufacturing	LS	3660
Technology driven industries		
Agro-chemical products	MSWC	2420
Pharmaceuticals	HS	2440

Other chemical products	MSWC	2460
Office machinery, computers	HS	3000
Electricity distribution, etc.	MSWC	3120
Electronic components	MSWC	3210
Telecoms equipment	MSWC	3220
Audiovisual apparatus	MSWC	3230
Medical equipment	MSWC	3310
Precision instruments	MSWC	3320
Process control equipment	MSWC	3330
Optical instruments	MSWC	3340
Motor vehicles	MSWC	3410
Aircraft and spacecraft	HS	3530

Notes: LS low-skill; MSBC medium-skilled blue collar; MSWC medium-skilled whitecollar; HS high skilled industries.
Source*:* Peneder (2002).

Annex 12: Marsili's taxonomy of manufacturing industries based on technology regimes

Table A.8: Marsili's taxonomy of manufacturing industries based on technology regimes

	Industries	ISIC Rev.3[1]
Science-based regime	Pharmaceutical products	2423
	Computers and other information processing equipment	30
	Electrical motors, generators and transformers	311
	Electricity distribution and control apparatus	312
	Insulated wire and cable; accumulators, primary cells and primary batteries	313
	Lighting equipment and electric lamps	315
	Electrical equipment n.e.c.	319
	Electronic valves and tubes and other electronic components	321
	Telecommunication equipment	322-323
	Photocopy and photographic equipment	332
Fundamental-process regime	Coke, refined petroleum products and nuclear fuel	23
	Inorganic basic chemicals	2411
	Organic basic chemicals (incl. agricultural chemicals)	2421
	Resins and man made fibres	243
	Paints, varnishes and similar coatings, printing ink and mastics	2422
	Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	2424
	Other chemical products	2429
Complex knowledge system regime	Motor vehicles	341
	Motorcycles and bicycles	3591-3592
	Other transport equipment (incl. aircraft)	3599+353
Product-engineering regime	Rubber and plastics products	25
	Structural metal products	281
	Tanks, reservoirs and containers of metal; central heating radiators; steam generators	282
	Forging, pressing, stamping and roll forming of metal; powder metallurgy	289
	Treatment and coating of metals; general mechanical engineering	289
	Cutlery, tools and general hardware	289
	Other fabricated metal products	289
	Machinery for the production and use of mechanical power, except aircraft, vehicle and cycle engines	291
	Lifting and handling equipment	2915
	Non-domestic cooling and ventilation equipment	2919
	Other general purpose machinery n.e.c.	2919
	Agricultural and forestry machinery	292
	Special purpose machinery	292
	Domestic appliances n.e.c.	293
	Medical and surgical equipment and orthopaedic appliances	331
	Measuring and control instruments; watches and clocks	332+335
	Bodies (coachwork) for motor vehicles, trailers and semi-trailers	342
	Parts and accessories for motor vehicles and their engines	343
	Building and repairing of ships and boats	351
	Miscellaneous manufacturing n.e.c.	369

Continuous process regime	Food products	151-154
	Beverage	155
	Tobacco products	16
	Textiles processes (preparation, spinning, weaving and finishing)	171
	Made-up textile articles, except apparel	1721
	Other textiles	172
	Knitted and crocheted fabrics and articles	173
	Wearing apparel, dressing and dyeing of fur	18
	Leather and leather products	19
	Wood and wood products	20
	Pulp, paper and paperboard	210
	Articles of paper and paperboard	210
	Publishing, reproduction of recorded media	221+223
	Printing and service activities related to printing	222
	Glass and glass products, ceramic products	261
	Bricks, tiles and construction products, in baked clay; cement, lime and plaster; articles of cement, lime and plaster	2693
	Other non-metallic mineral products	269
	Basic ferrous metals	271
	Basic precious and non-ferrous metals	272
	Casting of metals	273
	Furniture	361
	Recycling	37

Note: 1) Our classification according to ISIC Rev.3 code.
Source: Marsili and Verspagen (2002), Appendix.

Annex 13: Average years of education of the working age population, 1979-2003

Table A.9: Average years of education of the working age population, 1979-2003

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Austria	10,3	10,4	10,5	10,6	10,7	10,8	10,9	10,9	11,0	11,1	11,2	11,3	11,3	11,4	11,4	11,4	11,5	11,6	11,7	11,8	11,9	12,1	12,1	12,2	12,2
Finland	9,5	9,6	9,7	9,7	9,8	9,9	10,0	10,1	10,1	10,2	10,3	10,4	10,5	10,6	10,7	10,8	10,9	11,0	11,1	11,2	11,5	11,8	12,1	12,4	12,5
Greece	7,9	7,9	8,0	8,1	8,2	8,2	8,3	8,4	8,5	8,6	8,7	8,8	9,0	9,1	9,2	9,3	9,5	9,6	9,7	9,9	10,2	10,2	10,3	10,4	10,4
Ireland	8,4	8,5	8,6	8,7	8,8	8,9	9,0	9,0	9,1	9,2	9,3	9,4	9,5	9,6	9,7	9,8	10,0	10,1	10,2	10,3	10,5	10,6	10,8	10,9	10,9
Italy	7,3	7,3	7,4	7,5	7,6	7,7	7,8	7,9	8,0	8,1	8,2	8,4	8,5	8,6	8,8	9,0	9,2	9,4	9,6	9,8	10,0	10,1	10,2	10,4	10,4
Japan	10,1	10,2	10,3	10,4	10,5	10,6	10,7	10,8	10,9	11,0	11,1	11,2	11,4	11,5	11,6	11,7	11,9	12,0	12,1	12,3	12,3	12,4	12,5	12,7	12,7
Korea	6,8	6,8	7,0	7,3	7,5	7,8	8,0	8,3	8,5	8,7	9,0	9,3	9,4	9,6	9,7	9,9	10,1	10,2	10,2	10,3	10,4	10,5	10,5	10,6	10,8
Portugal	6,9	6,9	6,9	7,0	7,0	7,0	7,1	7,1	7,1	7,2	7,2	7,2	7,3	7,3	7,4	7,5	7,5	7,6	7,7	7,7	7,8	7,8	7,8	7,8	8,0
Spain	6,3	6,3	6,4	6,5	6,6	6,7	6,8	6,9	7,0	7,1	7,2	7,3	7,5	7,6	7,8	7,9	8,1	8,3	8,5	8,7	9,1	9,3	9,5	9,6	9,7
Taiwan	6,4	6,4	6,5	6,6	6,7	6,8	6,9	7,0	7,1	7,2	7,3	7,4	7,6	7,7	7,8	7,9	8,0	8,1	8,2	8,3	8,4	8,5	8,6	8,7	8,8

Notes: Data for the 1979-1998 period regarding all countries, except Korea and Taiwan, is from Bassanini and Scarpetta (2001). We extend Bassanini and Scarpetta's estimates up to 2003, considering data on educational attainment from OECD *Education at a Glance* (various issues), and using the cumulative years of schooling by educational level considered by the authors.

Data on Korea and Taiwan between 1980 and 2000 is based on Barro and Lee (2001). We interpolate the five-year observations provided by the authors to obtain annual figures for both countries. Education estimates for Korea between 2001 and 2003 were obtained considering data on educational attainment from OECD *Education at a Glance*, and assuming the cumulative years of schooling used by Barro and Lee (2001). Finally, estimates regarding Taiwan for 2001, 2002 and 2003 were obtained assuming that the average years of education of the working age population during this period has grown at an annual rate similar to the one experienced in the previous quinquennium.

Annex 14: **Table A.10:** Industry shares in VAB and employment hours (%), average number of years of formal education and per capita income (2003, various countries)

	Low-skill		Medium-skill		High-skill		Sup. Dominated		Scale intensive		Spec. supplier		Science based		Inf. Intensive		Non-market serv.		Education	PPPpcGDP
	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	VAB	HOURS	YEARS	C. int. dollar
Australia	33,0	42,4	30,8	32,6	36,2	25,0	20,9	29,4	13,7	7,9	8,0	8,5	1,1	0,8	40,8	33,2	15,5	20,1	12,6	30.111,5
Austria	33,4	44,7	35,6	33,7	31,0	21,7	24,3	34,5	11,1	8,1	10,8	9,6	2,0	1,5	35,9	26,7	16,0	19,6	12,2	31.366,3
Belgium	25,1	29,4	36,2	40,2	38,7	30,3	14,9	19,5	10,4	8,3	15,3	9,1	4,1	2,7	34,3	32,5	21,0	27,9	11,3	29.059,8
Canada	31,9	40,1	35,1	35,6	32,9	24,3	18,7	28,0	16,1	8,1	6,8	10,1	1,6	0,9	39,4	34,0	17,4	18,9	13,5	31.808,5
Denmark	25,1	31,1	40,4	42,8	34,5	26,1	18,2	23,0	10,0	6,5	8,8	9,5	2,8	2,1	37,1	29,7	23,1	29,2	11,9	30.302,6
Finland	24,2	36,5	41,9	41,3	33,9	22,2	22,2	29,8	8,7	6,6	13,2	10,5	2,2	1,5	35,2	25,5	18,5	26,1	12,5	27.492,4
France	24,7	33,6	35,8	37,8	39,5	28,5	18,9	25,2	8,3	8,0	10,8	10,1	2,0	1,3	38,5	30,6	21,5	24,9	11,4	28.119,5
Germany	22,3	33,2	38,7	40,5	39,0	26,3	16,7	23,6	11,7	10,3	13,9	11,9	3,9	2,7	36,1	28,2	17,8	23,3	13,5	28.128,9
Greece	42,4	57,7	29,1	26,3	28,5	16,0	31,5	42,9	8,4	7,9	3,1	5,3	0,8	0,6	38,8	27,5	17,3	15,8	10,4	22.380,9
Ireland	28,1	42,7	28,9	33,7	42,9	23,6	21,3	33,9	8,2	6,9	16,8	8,9	14,6	2,3	24,5	27,0	14,6	20,9	10,9	34.300,3
Italy	31,9	40,7	32,3	35,8	35,8	23,4	22,8	34,7	10,2	8,9	11,1	10,7	2,2	1,9	38,1	26,8	15,6	16,8	10,4	26.419,7
Japan	31,1	53,0	34,2	30,6	34,7	16,4	23,5	44,6	10,3	7,1	8,0	8,5	2,7	2,0	44,7	30,3	10,8	7,4	12,7	27.221,9
Korea	33,6	52,0	34,0	29,2	32,4	18,7	24,2	40,6	17,1	7,0	9,5	9,4	3,7	2,4	32,1	30,8	13,3	9,8	10,8	18.607,1
Netherlands	26,7	32,0	39,9	40,3	33,4	27,7	19,0	24,3	10,7	6,1	9,0	9,7	2,7	2,0	37,8	34,0	20,8	24,0	12,3	31.705,6
Norway	38,8	33,4	33,3	41,8	28,0	24,9	15,4	23,8	27,2	9,1	6,5	7,9	1,1	1,0	31,2	29,1	18,6	29,1	12,3	42.761,4
Portugal	34,2	49,8	36,8	33,3	29,1	16,9	24,9	41,8	9,9	7,7	4,6	4,1	1,4	1,4	35,7	24,8	23,5	20,3	8,0	18.739,7
Spain	39,8	47,4	30,3	34,2	29,9	18,5	30,4	37,6	10,5	8,6	7,1	5,9	2,2	1,4	33,5	27,0	16,3	19,4	9,7	24.956,5
Sweden	21,2	28,2	41,1	44,9	37,7	26,9	18,4	24,3	10,6	7,9	11,9	11,0	3,1	1,6	34,0	25,2	21,9	30,0	12,0	29.250,9
Taiwan	26,9	42,6	42,2	39,9	30,9	17,5	15,3	30,9	12,3	8,9	10,7	12,9	3,1	2,9	43,9	31,7	14,7	12,8	8,8	22.392,9
UK	27,0	36,6	33,2	33,6	39,8	29,9	20,3	26,4	9,7	6,5	11,7	9,3	2,1	1,4	39,2	34,6	17,1	21,8	12,1	28.504,4
US	23,5	33,4	38,5	36,0	38,0	30,6	16,1	24,4	9,0	6,2	10,7	9,1	2,2	1,2	40,3	31,9	21,7	27,3	13,1	37.685,0
Average	**29,8**	**40,0**	**35,6**	**36,4**	**34,6**	**23,6**	**20,9**	**30,6**	**11,6**	**7,8**	**9,9**	**9,1**	**2,9**	**1,7**	**36,7**	**29,6**	**18,0**	**21,2**	**11,6**	**28634,1**
Std. Dev.	**6,0**	**8,4**	**4,1**	**4,8**	**4,2**	**4,8**	**4,6**	**7,5**	**4,3**	**1,1**	**3,4**	**2,1**	**2,8**	**0,6**	**4,5**	**3,1**	**3,4**	**6,3**	**1,5**	**5678,3**
Max.	**42,4**	**57,7**	**42,2**	**44,9**	**42,9**	**30,6**	**31,5**	**44,6**	**27,2**	**10,3**	**16,8**	**12,9**	**14,6**	**2,9**	**44,7**	**34,6**	**23,5**	**30,0**	**13,5**	**42761,4**
Min.	**21,2**	**28,2**	**28,9**	**26,3**	**28,0**	**16,0**	**14,9**	**19,5**	**8,2**	**6,1**	**3,1**	**4,1**	**0,8**	**0,6**	**24,5**	**24,8**	**10,8**	**7,4**	**8,0**	**18607,1**

Annex 15: van Ark and Bartelsman (2004) ICT taxonomy of industries

Table A.11: van Ark and Bartelsman (2004) ICT taxonomy of industries

ISIC rev.3	Industries	Classification
01	Agriculture	NICTO
02	Forestry	NICTO
05	Fishing	NICTO
10-14	Mining and quarrying	NICTO
15-16	Food, drink & tobacco	NICTM
17	Textiles	NICTM
18	Clothing	ICTUM
19	Leather and footwear	NICTM
20	Wood & products of wood and cork	NICTM
21	Pulp, paper & paper products	NICTM
22	Printing & publishing	ICTUM
23	Mineral oil refining, coke & nuclear fuel	NICTM
24	Chemicals	NICTM
25	Rubber & plastics	NICTM
26	Non-metallic mineral products	NICTM
27	Basic metals	NICTM
28	Fabricated metal products	NICTM
29	Mechanical engineering	ICTUM
30	Office machinery	ICTPM
313	Insulated wire	ICTPM
31-313	Other electrical machinery and apparatus nec	ICTUM
321	Electronic valves and tubes	ICTPM
322	Telecommunication equipment	ICTPM
323	Radio and television receivers	ICTPM
331	Scientific instruments	ICTPM
33-331	Other instruments	ICTUM
34	Motor vehicles	NICTM
351	Building and repairing of ships and boats	ICTUM
353	Aircraft and spacecraft	ICTUM
352+359	Railroad equipment and transport equipment nec	ICTUM
36-37	Furniture, miscellaneous manufacturing; recycling	ICTUM

40-41	Electricity, gas and water supply	NICTO
45	Construction	NICTO
50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	NICTS
51	Wholesale trade and commission trade, except of motor vehicles and motorcycles	ICTUS
52	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	ICTUS
55	Hotels & catering	NICTS
60	Inland transport	NICTS
61	Water transport	NICTS
62	Air transport	NICTS
63	Supporting and auxiliary transport activities; activities of travel agencies	NICTS
64	Communications	ICTPS
65	Financial intermediation, except insurance and pension funding	ICTUS
66	Insurance and pension funding, except compulsory social security	ICTUS
67	Activities auxiliary to financial intermediation	ICTUS
70	Real estate activities	NICTS
71	Renting of machinery and equipment	ICTUS
72	Computer and related activities	ICTPS
73	Research and development	ICTUS
741-3	Legal, technical and advertising	ICTUS
749	Other business activities, nec	NICTS
75	Public administration and defence; compulsory social security	NICTS
80	Education	NICTS
85	Health and social work	NICTS
90-93	Other community, social and personal services	NICTS
95	Private households with employed persons	NICTS
99	Extra-territorial organizations and bodies	NICTS

Legend: ICTPM- ICT producing manufacturing; ICTPS – ICT producing services; ICTUM – ICT using manufacturing; ICTUS – ICT using services; NICTM –Non-ICT manufacturing; NICTS – Non-ICT services; NICTO – Non-ICT other.