U.PORTO

FEP FACULDADE DE ECONOMIA UNIVERSIDADE DO PORTO

UNCOVERING THE ECONOMIC GROWTH IMPACT OF HUMAN CAPITAL, INTERNATIONAL TRADE AND STRUCTURAL CHANGE: A LONG-TERM PERSPECTIVE (1827-2017) OF THE PORTUGUESE ECONOMY

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Dissertation

Master in Economics

Supervised by

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2019

Biographic note

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After finnishing the first year of the master degree, she started her professional activity at adidas Business Service working, first in the accounts payable department and then moving to the controlling and reporting area. After two years, she decided to change her professional area and she is working at PWC in the assurance department, in the moment of the delivery of this document.

Acknowledgments

This dissertation was only possible due to the support of the following people, therefore I want to acknowledge all the help and support they provided me during this phase.

To Professor Aurora Teixeira, my supervisor, for all her support, incredible motivation, and above all things, for her patience with me through all this time. Her availability and commitment make me realise that I could not have asked for a better supervisor to this dissertation.

To my parents, who have always supported me and my decidions and for making all of my academic choices and in life, possible.

To by brothers, for being my biggest critics but also by biggest admirors. Their love and support made me believe in myself even in the most difficult moments.

To all of my friends, the ones that I have known almost all my life, the ones I have met at the university and also my co-workers, for all the friendship, encouragement and for challenging me every day to be a better professional and a better person.

Abstract

The literature on countries' economic growth is vast, however studies involving analysis of the very long run are scanty. These latter have focused, in isolation, on the direct impact of given determinants of economic growth, such as international trade, technological specialization, overlooking the role of human capital and of the interaction between human capital and other growth determinants.

The present dissertation investigates the direct and indirect (through trade and structural changes) impact of human capital, international trade, and structural change on the Portuguese economic growth in a very long-term perspective. To undertake such endeavor, we resort to co-integration estimation techniques using secondary macroeconomic data on Portugal from 1827 until 2017.

The main results of our study are that, over the last two hundred years, for Portugal: 1) human capital and international trade were important drivers of economic growth; 2) the impact of international trade on economic growth was higher than that of human capital; 3) the improvement in real GDP per capita fostered human capital stock and international trade openness; 4) increases in material life standards reinforced the joint impact of trade openness and human capital on economic growth; 5) albeit important structural change occurred over the period in analysis, with a marked decrease in the weight of the employment in primary sector (and increase in the tertiary sector), structural change do not emerged as a significant growth factor.

Keywords:. Economic growth; Human capital; International trade; Structural Change; Portugal; Co-integration

JEL Codes: N13; N14; O15; O3

Resumo

A literatura que relata o crescimento económico dos países é muito vasta, no entanto estudos que envolvem análises de muito longo prazo, são escassos. Os que existem, focam-se principalmente no impacto direto que determinantes, como o comércio externo ou a especialização tecnológica, têm no crescimento económico, desconsiderando o papel do capital humano e a interação entre o mesmo e outras variáveis de crescimento económico.

A presente dissertação vai investigar o impacto direto do capital humano, comércio externo e mudanças estruturais no crescimento económico de longo prazo da economia Portuguesa, analisando as diferentes fases de desenvolvimento económico e a evolução da economia Portugusesa numa perspectiva de muito longo prazo.

Para tal, vamos recorrer a métodos de estimação de cointegração usando dados macroeconómicos de Portugal desde 1827 a 2017.

Os principais resultados de nosso estudo são que, nos últimos duzentos anos, para Portugal: 1) o capital humano e o comércio internacional foram importantes impulsionadores do crescimento económico; 2) o impacto do comércio internacional no crescimento económico foi maior que o do capital humano; 3) a melhoria do PIB real per capita promoveu o stock de capital humano e a abertura ao comércio; 4) o aumento dos padrões de vida material reforçou o impacto conjunto da abertura ao comércio e do capital humano no crescimento económico; 5) embora importante mudança estrutural tenha ocorrido no período analisado, com uma redução acentuada do peso do emprego no setor primário (e aumento no setor terciário), a mudança estrutural não surge como um fator de crescimento económico significativo.

Palavras-chave: Crescimento Económico; Capital Humano; Comércio Internacional; Mudança Estrutural; Portugal; Cointegração.

Códigos JEL: N13; N14; O15; O33

Index of contents

Biographic note i

Acknowledgments ii

Abstract iii

Resumo iv

List of tables vi

List of figures vii

1. Introduction 1

2. Literature review on the long run determinants of economic growth with a focus on human capital, international trade and structural change 3

2.1. Human capital and long-term economic growth 3
2.1.1. Defining human capital 3
2.1.2. Mechanisms through which human capital impacts economic growth 3
2.1.3. Empirical evidence 4
2.2. International trade and long-term economic growth 7
2.2.1. Defining international trade 7
2.2.2. Mechanisms through which international trade impacts economic growth 8
2.2.3. Empirical evidence 9
2.3. Structural change and long-term economic growth 12
2.3.1. Defining structural change 12
2.3.2. Mechanisms through which structural change impacts economic growth 13
2.3.3. Empirical evidence 14

3. Methodology 17

3.1. Main Hypotheses 17
3.2. Model specification and selection of the estimation technique 17
3.3. Description of the variable proxies and data sources 19
3.3.1. Economic growth 19
3.3.2. Human capital 20
3.3.3. International trade 21
3.3.4. Structural change 22
3.3.5. Interpolation and Maddison's phases 24

4. Empirical results 29

4.1. Unit Root Tests 29
4.2. Cointegration and Granger (non-) causality tests 30

5. Conclusion 36

References 38

Apendix 45

List of tables

Table 1: Studies addressing human capital and economic growth 7
Table 2: Studies addressing international trade and economic growth 12
Table 3: Studies addressing structural change and economic growth 15
Table 4: The impact of human capital, international trade and structural change on countries' economic growth 18
Table 5: The variables: description an source of data 28
Table 6: Non-stationarity tests of the series under study 29
Table 7: Johansen cointegration test 30
Table 8: Long-term relations between GDP per capita and the relevant variables, 1827-2017 31
Table 9: Granger (non-) causality test 33
Table 10: Time series used to compute relevant variables 45

List of figures

Figure 1: Real GDP per capita, Portugal, 1827-2017 19
Figure 2: Human capital, Portugal, 1827-2015 20
Figure 3: International trade, Portugal, 1827-2017 21
Figure 4: Employment in the primary, seconday and tertiary sectors in percentage of total employment, Portugal, 1890-2018 23
Figure 5: Real GDP per capita, Portugal, 1827-2017 24
Figure 6: Human capital stock, Portugal, 1827-2017 25
Figure 7: International trade/ trade openness, Portugal, 1827-2017 26
Figure 8: Employment in the primary, secondary and tertiary sectors in percentage of total employment, Portugal, 1827-2018 27

Figure A 1: Variables in levels and 1st Differences 50

1. Introduction

Economic growth has become central within the study of macroeconomics (Pereira and Lains, 2012; Teixeira and Queirós, 2016). Economists have realized that long-run growth is as important as the short-term fluctuations (Barro, 1996; Acemoglu and Autor, 2012; Mendes, Nunes and Sequeira, 2012). The perspective of long-run economic growth involves the understanding of its sources and causes and the prediction of which policies government should implement to foster long-run growth (Bergheim, 2008). By adopting a long-term perspective, we deal with a story of great changes, remarkable success, incomplete transformation and strong declines (Vasta, 2010).

Although there exists already a voluminous literature on countries' economic growth (see Mendes *et al.*, 2012; Stolz, Baten and Reis, 2013), studies involving analysis of the very long run are scanty. In the literature, there is already some very-long term analysis of countries' economic growth and development for Italy covering almost 150 years (1861- 2009) (Domini, 2016) and 80 years (1861-1939) (Vasta, 2010), Spain from 1861 to 2008 (Felice, Andreu and D'Ippoliti, 2016), from 1500-1850 (De La Escosura, 2007), France since 1901 to 1988 (Piketty, 2001), and the United Kingdom from 1541 to 2001 (Dalko and Wang, 2018), from 1270 to 1870 (Williamson, 2016) and from 1500 to 1800 (Wallis, Colsonand Chilosi, 2018).

These studies have focused on particular determinants of economic growth, namely international trade (Vasta, 2010; Domini, 2016), technological specialization (Domini, 2016), sctructural change (Wallis *et al.*, 2018), life expectancy (Felice *et al.*, 2016), health (Dalko and Wang, 2018), and income inequality (Piketty, 2001; Williamson, 2016). The contribution by Domini (2016) did not address directly the issue of economic growth, focusing instead on the connection between international trade and innovation (technological specialization). In Vasta (2010), the author focuses essentially on the structure of the Italian trade and on the evolution of the capacity of Italy to increase its degree of openness and export goods in a long-term perspective. Thus, none of the very long run analysis considered the joint impact of human capital, international trade and structural change on countries' economic growth either in a panel or country-level/ longitudinal perspectives.

Very long-run and high scientific quality analysis for the Portuguese economy exists, but they do not explicitly address the issue of economic growth. For instance, Neves (1991) analyzed

the Portuguese economic development from 1833 until 1985 through the lens of a poverty balance model, whereas Mata and Valério (1998) analyzed the Portuguese public debt in the period 1830-1914.

The studies which focus on (in isolation or together with other countries) Portuguese economic growth involve, in general, some few decades and analyze a given growth determinant, most notably: human capital (Reis, 2003; Pereira 2005; Teixeira and Fortuna, 2010); international trade (Pereira and Lains, 2012); or structural change (Lains, 2008; Silva and Teixeira, 2011).

The Portuguese long-term economic process over almost two centuries illustrates quite neatly the complex intertwining between three main drivers of economic growth: human capital, international trade and structural change. By estimating the direct impact of these three variables and the indirect impact of human capital through trade and structural change over the whole period and by the main phases of Angus Maddison (1982), we are able to assess the extent to which these variables and their relationship affect long term economic growth and how such impact changes depending on the phases of modern economic growth. For the best of our knowledge, such an analysis has not yet been pursued.

Thus, the main aim of the present dissertation is to assess the very long run determinants of Portugal's economic growth. Specifically, our research question is: What is the direct and indirect impact of human capital, via international trade and structural change, on Portuguese long run economic growth?

To answer this question, we resort to co-integration models and Granger causality tests using data on Portugal ranging from 1827 until 2017.

We therefore seek to contribute to the literature at two main levels. First, at the economic history level in which we will seek to analyze the evolution of the Portuguese economy in a historical perspective from 1827 to 2017. Second, at the level of human capital, international trade and structural change literatures by showing the extent to which the interaction of these variables has been impacting the economy of a country over a very long period.

The present dissertation is organized as follows. Section 2 reviews the relevant literature. The methodology and data are detailed in Section 3. On section 4 the empiric results are discussed. The Conclusions highlight the main contributions and limitation of the present study.

2. Literature review on the long run determinants of economic growth with a focus on human capital, international trade and structural change

2.1. Human capital and long-term economic growth

2.1.1. Defining human capital

Human capital has been identified as a driven force of the economic growth (Solow, 1956; Barro and Lee, 2001, Lains, 2003; Teixeira and Queirós, 2016) and it can be interpreted as the set of intangible resources embedded in the labor factor which improves its productivity (Becker, 1962; Pereira, 2005; Bodman and Le, 2013).

Investment in people can affect the usual measure of the amount of savings and capital formation impacting economic growth, the structure of relative earnings and the distribution of personal income (Becker, 1962; Schultz, 1961). Direct expenditures on education and health are clear examples of such investment which account for the most of the impressive rise in the real earnings per worker and increase in the productivity of an economy (Schultz, 1961; Becker, 1962; Pereira, 2005; Bodman and Le, 2013).

2.1.2. Mechanisms through which human capital impacts economic growth

Many of the authors who study the relation of the human capital and economic growth (e.g., Lucas, 1988; Barro, 1991; Romer 1990) recognize that without an education factor, for example a qualified and skilled labor force, no country would be able to develop in a competitive way.

In their contribution to the (exogenous) theory of economic growth, Mankiw, Rome and Weil (1992) take into consideration Solow's (1956) model and conclude that the higher human capital the higher will be the rate of income. Focusing on the schooling dimension of human capital, Nelson and Phelps (1966) argue that education stimulates the absorption of technology, which would significantly affect productivity growth, helping countries in the international technological catch-up process (Benhabib and Spiegel, 1994; Wang, 2007; Krammer, 2010).

According to Barro (1991; 1996) economies with larger initial stocks of human capital experience a faster rate of new goods introduction, thereby growing faster. In the same line of

reasoning, the study shows that increases in the quantity of human capital per person lead to higher rates of investment in human and physical capital, and hence, to higher per capita growth of the country.

Endogenous economic growth contributions established that economic growth derives from the technological change as an outcome of investment decisions made by profit seeking firms (Romer, 1990). In this theoretical framework, an economy with a higher level of human capital will grow more rapidly (Romer, 1990; Teixeira and Queirós, 2016). Indeed, human capital has a direct effect on economic growth since the increasing of years of school will allow the countries to be more productive and innovative (Romer, 1990). More educated labor force is better at creating, implementing and adopting new technologies, thereby generating growth (Benhabib and Spiegel, 1994).

From the above arguments, we conjecture that:

H1: Human capital positively impacts on country's long-term economic growth.

2.1.3. Empirical evidence

At the empirical level (see Table 1), we can find in the literature studies that emphasize the relation between economic growth and human capital in the long-run using different methodology approaches: cross-section (Barro, 1991 and 1996; Benhabib and Spiegel, 1994; Wang 2007), panel data (Barro, 2001 and 2013; Silva and Teixeira, 2011; Teixeira and Queirós, 2016) or time series using co-integration models (Krammer, 2010). Some studies analyze different groups of countries (Barro, 1991; Benhabib and Spiegel, 1994; Barro 1996 and 2013; Wang, 2007; Bodman and Le, 2013; Teixeira and Queirós, 2016), whereas others analyze only one single economy such as the United States (Acemoglu and Autor, 2012) or the United Kingdom (Dalko and Wang, 2018).

The bulk of earlier empirical studies uses cross section data and have demonstrated that human capital has a direct effect on economic growth as the increasing of years of school will allow the countries to be more productive and innovative (Benhabib and Spiegel, 1994).

Barro and Lee (2001) analyze 142 countries in the period of 1960-2000 showing that the average years of schooling has a positive impact on countries' economic growth. Barro (2001) concludes that economies with larger initial stocks of human capital will grow at a highest

speed and therefore will be able to create new goods faster than economies with low level of human capital.

When we look to panel data analysis, Barro (2013) used school-enrolment rates as proxies for human capital. For a given starting value of per capita GDP, a country's subsequent growth rate is positively related to the measures of initial human capital. In the author's study, a simple variation of human capital explains a variation in per capita growth rates of five percentage points, meaning that increases in human capital are strongly and positively related with subsequent growth. Using dynamic panel data, Teixeira and Queirós (2016) evidenced that when a country is more specialized and technologically advanced the impact of human capital on the economic growth of that country comes amplified.

In cases when the literature analyzes only one country in the very long-run, most of the methodologies are descriptive (Pereira, 2005; De la Escosura, 2007; Acemoglu and Autor, 2012; Dalko and Wang, 2018).

For Acemoglu and Autor (2012) human capital is a central determinant of economic growth, in the case of economic growth in the United States during the 20th century. Dalko and Wang (2018) compares institutional development, public policy, technological advances and scientific discoveries in economic growth with those in health improvement. The authors find the co-existence of slower economic growth and less increasing life expectancy from 1541-1871 and that of faster economic growth and rising life expectancy from 1871-2001. In the case of Portugal, Mata and Valério (1991) compared the level of debt and growth of real GDP per capita for the period of 1830-1985 whereas Pereira (2005) study shows that the years of schooling and labor market ratio have high reliability ratio with the real GDP per capita of the country.

The empirical studies that address the relation between human capital and economic growth focusing on the Portuguese economy involve mainly descriptive analysis (e.g., Mata and Valério, 1998). Mata and Valério (1998) compared the level of debt and the growth of real GDP per capita for the period of 1830-1914 and Pereira (2005) compared years of schooling and labour market ratio with the initial level of real GDP per capita showing that these variables have a high reliability ratio. Pereira (2005) also showed series of human capital for Portugal reeling on more direct sources of date, such as migratory flows, defending that comparing with other series (Teixeira, 2005 and Pina and St Aubyn, 2005), his series of average years of

schooling showed a smother profile of the impact of human capital on the Portuguese economic growth. Also, Lains (2003) compared the economic growth of Portugal with the European core. By examining the period of 1910-1990, the author showed that the investment in human capital was one of the main driving forces (together with physical capital).

In what concerns long-term economic growth perspective, Stolz *et al.* (2013) study reconstructed the height evolution from 1720 until 1980. The authors found that in 1720 Portuguese heights were in line with the average of the European heights, but in 1840 the heights started to diverge, increasing this divergence in a significant way after 1870 and putting Portugal in last place on 1890. Stolz *et al.* (2013) point that a poor investment in human capital, a slow real wage evolution resulting from a late industrialization of the Portuguese economy, and a poor economic growth performance was determinant to the stunted height development in the period analysed.

After the Second World War, the Portuguese economy grew in a level without precedents and was able to shorten the distance from the richest economies of the world (Amaral, 1998). Resorting to the economic convergence hypothesis Amaral (1998) identifies the physical capital, the technology and the human capital as the main drivers for the economic convergence. The author defends that the history of economic growth in the Portuguese economy, after the war, was due to the accumulation of human capital. Amaral (1998) evidence that human capital, measured by the illiteracy rate, is responsible for almost 25% of the growth rate of the Portuguese economy between 1951 and 1973. And if we add the physical capital, the contribution is almost 70%, showing that the history of the Portuguese economic growth in the period after the Second World War, is an history of accumulation of capital.

Studies which analyzed the Portuguese economic growth in a quantitative way, focus the role of human capital and other variables in its distinct dimensions using the co-integration methodology but only in a short period of time, from 1960-2001 (Pina and Aubry, 2005; Teixeira and Fortuna, 2010).

About the above literature we can sum up (see Table 1.) that there exist several studies about human capital. Some are more general and empirical (Acemoglu and Autor, 2012; Dalko and Wang , 2018). Some others rely on cross section analysis to compare the economic performance of a set of different countries (Romer, 1990; Barro, 1991; Benhabib and Spiegel, 1994; Barro 1996 and 2013; Wang, 2007; Bodman and Le, 2013 and Teixeira and Queirós, 2016).

In the Portuguese literature, the descriptive analysis (e.g., Mata and Valério, 1998; Pereira, 2005) is the most used; when the methodology is quantitative (e.g., Pina and Aubry, 2005; Teixeira and Fortuna, 2010), the studies rely on relatively short-term periods. Therefore, no quantitative studies of the impact of human capital on economic growth in the very long run exist for the Portuguese case.

Table 1: Studies addressing human capital and economic growth

	Methodology	Name	Countries	Period	Proxy to EG	Proxy to HC
Several countries						
Long Run	Cross-Section	Benhabib and Spiegel (1994)	42	1974-1977	Real GDP per capita and Total Factor Productivity (TFP)	Years of schooling
		Barro (1991)	98	1960-1985	Real GDP per capita	School enrolment rates
		Barro (1996)	100	1960-1990	Real GDP per capita	Average years of schooling
		Barro (2001)	100	1965-1995	Growth rate of real GDP pc	Average years of schooling and scores on exams
	Panel Data	Teixeira and Queirós (2016)	30	1960-2011	Real GDP per capita	Average years of schooling
		Silva and Teixeira (2011)	21	1979-2003	GDP based on purchasing power-parity (PPP)	Average years of schooling
		Barro (2013)	100	1960-1995	Real GDP per capita	Years of schooling
One country						
Long-run	Co-integration	Teixeira and Fortuna (2010)	Portugal	1960-2001	Total Factor Productivity (TFP)	Average years of schooling
		Pereira and Aubyn (2009)	Portugal	1960-2001	Real GDP per capita	Aerage years of schooling
	Descriptive	Pina and Aubry (2005)	Portugal	1960-2001	Real GDP per capita	Years of schooling
		Pereira (2005)	Portugal	1960-2001	Initial levels of real GDP per capita	Years of scooling and market labout income
		Lains (2003)	Portugal	1910-1990	Real GDP per capita	Years of schooling
Very-long run	Descriptive	Stolz *et al.* (2013)	Portugal	1720-1980	Real wages	Height of recruiters
		Dalko and Wang (2018)	United Kingdom	1541-2001	Real GDP per capita	Life expectancy

Source: Own elaboration.

2.2. International trade and long-term economic growth

2.2.1. Defining international trade

In what concerns the economic internacionalization of a country, there are four different types of transactions between economic agents of different countries (Afonso and Aguiar 2004): international transfers of income (remittances of emigrants, repatriation of profits);

movements of financial assets that support the movement of goods or services (balance of payments); international movements of production factors (FDI, international migrations); international movements of goods and services (international trade).

The phases of economic development where the growth is more accentuated are often related with a raise in exports rates or improvement in the terms of trade (Barro, 1996; Silva and Rebelo, 2017). In the literature, international trade, most notably countries' openness to trade has been emphasized as a driver for the increase of productivity levels (Xu and Chiang, 2005; Teixeira and Fortuna, 2010).

2.2.2. Mechanisms through which international trade impacts economic growth

Trade enhances the channels of communication for transmission of technical information, reduces the duplication of research internally and reinforces the competition through the enlargement of available markets (Grossman and Helpman, 1991; Krammer, 2010).

Focusing on the export capacity of the Italian economy, Vasta (2010) asserted how important is a good specialization in sectors that are gaining importance in the world market. Also, the degree of openness to the imports of capital goods helps the countries to absorb the technology of neighbour countries, which will increase the productivity, reduce costs, and therefore boosts economic growth (Lee, 1995; Krammer, 2010; Teixeira and Fortuna, 2010). If the quantities of goods that are produced within the country do not change, an improvement in terms of trade increases the income but movement in real GDP will only happen if the change in terms of trade stimulates a change in domestic employment and output (Barro, 1996).

In small economies, the main conditions to the economic development are created by the degree of openness to international trade which will induce the technological progress and thus a more efficient use of the resources (Coe, Helpman and Hoffmaister, 2009). Afonso and Aguiar (2004) emphasize the importance of trade to the Portuguese economic growth after 1960 through an analysis of imports and exports, which shows their contribution to the efficiency of the production factors. The degree of trade openness of the Portuguese economy evolved from nearly 11% in the beginning of the century, which was a very low value comparing with the rest of the Europe, to almost 30% at the end of the century (Afonso and

Aguiar, 2004). Reis (1984) evidences that most of the European countries have felt an increase in their economic growth and also in their degree of openness in the nineteenth century, although the results of this expansion were worse for Portugal than for the rest of the Europe. In their study about the economic performance of Portugal, Costa, Palma and Reis (2014), using an estimated dynamic model evidenced that in the long-term intercontinental trade had a substantial and increasingly positive impact on Portugueses economic growth..

The theoretical and empirical literature have acknowledge important interactions between human capital and international trade. As Owen (1999: 63) refers "… when trade alters the payments to skilled and unskilled labor in favor of the relatively abundant factor, incentives to purchase education become more disparate, and the country with the higher initial level of human capital accumulates more human capital, whereas the country with the low initial level of human capital accumulate less". Using a comprehensive panel data set of 79 countries and covering the period 1980–2003, Batten and Vo (2009) demonstrate that international trade (via FDI) has a stronger positive impact on economic growth in countries with a higher level of educational attainment.

From the above arguments, we conjecture that:

H2a: International trade positively impacts country's long-term economic growth.

H2b: The higher the level of trade openness, the higher is the positive impact of human capital on country's long-term economic growth.

2.2.3. Empirical evidence

Trade is an important carrier of technological development through spillovers, vital to less developed countries' growth (Coe *et al.*, 2009; Krammer, 2010). Krammer's (2010) research further suggests that trade brings benefits for all types of countries, stating that less developed, developing and developed countries can all reap large benefits from trade. Related to trade, Foreign Direct Investment (FDI) also boosts economic growth through technological transfer, spillover effects and productivity gains (Wang, 2007). In addition, Wang (2007) stated that FDI can create an international network that promotes the movement of domestic products across borders.

There are also studies that analyze only one country (see Table 2), for example Italy (Vasta 2010). By adopting a long-term perspective, one deals with a story of great changes, remarkable success, incomplete transformation and strong declines (Vasta, 2010). In Vasta's (2010) work, the focus is on the evolution of the capacity of Italian goods to reach international markets. He presented two main conclusions: first, the relevance of the world market share of Italian exports and the capacity to occupy important niches if goods present higher value added; and second, the importance of a good specialization in sectors that are gaining importance in the world market.

In small economies, the main conditions to the economic development are created by the degree of openness to international trade (Aguiar and Figueiredo, 1999), which will induce the technological progress and thus a more efficient use of the resources. The international openness was very important to the growth of the Portuguese economy after 1960 (Afonso and Aguiar, 2004) once it had a positive impact on the efficiency of the production factors. According to the above mentioned authors, the openness degree to the international trade of the Portuguese economy was one of the lowest in the European context, but evolved nearly 20% from the beginning of the century until the end of the century (Afonso and Aguiar, 2004).

International trade had a significant and positive impact on economic growth (Rocha, 1981; Murteira, 1982; Costa *et al.*, 2014). On their study about the economic performance of Portugal, Costa *et al.* (2014) concluded that in the long-term Portugal's empire showed a significant and positive impact on the economic development of the country. The authors also highlight the fact that the smallest economies are the ones that have a higher degree of openness, usually engaging in a trade-growth strategy.

Rocha (1981) affirms that many often the literature points out the entry to the European Free Trade Association as crucial to the increasing of the degree of openness of the Portuguese economy and therefore to the rapid economic growth between 1960-1970. According to Rocha (1981), international trade was already important in the previous years, but it became more relevant between 1970 and 1974. In the mentioned period, the author reports an increase of the contribution of exports from 17% to 26%, confirming the increasing importance of the trade on Portuguese economic growth. Reis (1984) evidences that most of the European countries have felt an increase on their growth and also on their degree of openness in the nineteenth century. Although, according to the author, Portugal also felt this

expansion, in comparative terms, the results were worse than the rest of the Europe. Aguiar and Figueiredo (1999) used imports, exports and real GDP to measure the impact of the international trade on the Portuguese. In their study, we can be observed that in 1860 the degree of openness to the international trade of Portugal was notorious low comparing with other European countries, but in 1985 the Portuguese economy was 20% more open to the international trade than the average of the other seven countries in study (Italy, France, Germany, United Kingdom, Sweden, Denmark and Norway), concluding that the degree of openness to international trade affects positively and significatively the convergence of the Portuguese economy.

In one of his many studies about the Portuguese economic development, Rocha (1997) addresses the role of the colonies to the economic growth of Portugal in 1960-1970, a period of a remarkable economic growth to the Portuguese economy. The author also refers the growing importance of the integration of Portugal in the international economy through the increase of imports and exports in the analyzed period, but also through the absorption of foreign direct investment and technology in the long-term.

Some studies resort to co-integration models. Silva and Rebelo (2017) state that in the case of the Portuguese economy, phases where economic growth is faster are usually accompanied by strong increases in exports. Co-integration econometric results based on the Portuguese experience over four decades (1967-2010) show that increased related variety has led to a significant growth bonus, but only in the case of technologically advanced sectors. The impact of export variety on economic performance seems, therefore, to be conditioned by the technological intensity of the products involved (Silva and Rebelo, 2017).

Existing empirical literature (e.g., Dulleck and Foster, 2008; Banerjee and Roy, 2014) concludes that imports of capital goods have a significant positive impact on countries' economic growth through increases on total factor productivity. Thus, openness to imports of capital goods facilitates the absorption of international frontier technology and is an important vehicle to achieve productivity and economic growth (Lee, 1995; Krammer, 2010; Teixeira and Fortuna, 2010; Banerjee and Roy, 2014; Cuadros and Alguacil, 2014).

Moreover, technological progress affects trade performance since process innovations enhance productivity and reduce production costs, thus increasing a country's competitiveness on international markets (Amiti and Davis, 2012). According to Amiti and Davis (2012),

trade is an important channel of technology diffusion, as the technological content 'embedded' in traded goods flows from the seller to the buyer. Imports of capital goods are an important mean, by which technology flows from advanced countries to less developed ones and exporters benefit from the diffusion of technological knowledge, as they come into contact with a broader set of technologies (Keller, 2004).

Table 2: Studies addressing international trade and economic growth

	Methodology	Name	Countries	Period	Proxy to EG	Proxy to IT
Several countries						
Long run	Cross-Section	Barro (1996)	100 countries	1960-1990	Initial levels of real GDP per capita	Ratio of imports and exports prices
	Panel Data	Krammer (2010)	47 countries	1990-2006	Total Factor Productivity (TFP)	FDI
		Vo and Baten (2009)	79 countries	1980-2003	Real GDP per capita	FDI
One country						
Long run	Co-integration	Domini (2016)	Italy	1861-1939	Technological specialization	Imports and Exports
		Silva and Rebelo (2017)	Portugal	1967-2010	GDP per hour worked	Exports variety
	Descriptive	Aguiar and Figueiredo(1999)	Portugal	1870-1990	Real GDP per capita	Degreee of openess
Very-long run	Time Series	Vasta (2010)	Italy	1861-2009	Real GDP per capita	Imports and Exports

Source: Own elaboration.

2.3. Structural change and long-term economic growth

2.3.1. Defining structural change

The concept of structural change refers to shifts in sectoral composition, in which certain industries gain relative shares of the economy (Montobbio, 2002). According to Silva and Teixeira (2011), the productive structure of an economy and its dynamics are recognized as an important determinant of economic growth. In developing countries, the transformation from agriculture to sectors with higher productivity plays a very important role in the process of economic growth (De la Escosura, 2007).

Structural change is typically seen as representing changes in the number and relative weights of the sectors that compose an economic system, driven either by changes in demand or supply-side factors (Kruger, 2008; Saviotti and Frenken, 2008; Silva and Teixeira, 2011).

2.3.2. Mechanisms through which structural change impacts economic growth

Metcalfe, Foster and Ramlogan (2006) defend that economic growth is the result of structural configurations of the economy and its dynamics: more productive industries gain a greater share in the economies because they have to offer better wages, which will attract more qualified workers. Therefore, direct effects on growth will be created by new ways of production, which will result in a greater earning capacity and will lead to economic growth (Zagler, 2009).

For evolutionist approaches, economic growth depends on the structural change (Metcalfe *et al.*, 2006), more specifically on the capacity for self-transformation of the economy. Meaning that, the higher is the capacity of an economy to create new goods and services or new activity sector, the higher will be the impact on economic growth (Saviotti and Pyka, 2012).

Looking to the Italian economy and using the co-integration method, Domini (2016) evidenced that although Italy's growth was fastest from the end of the Second World War to the early 2000s, the country experienced considerable growth and structural change also in the eight decades due to an overwhelmingly rural country in the aftermath of its unification, had established itself as a producer and an exporter of manufactured goods. Trade played a fundamental role in these achievements, due to the structural openness of Italian economy. The main conclusion of the Domini (2016) study was the emergence of a positive relationship between Italy's patterns of specialization in technology and trade since the late Giolittian era, that is after the country entered its modern economic growth and experienced its first important phase of industrialization.

In what concerns the Portuguese economy, Rocha (1997) defends that in the period 1960-1970 the acceleration of the economic growth is related to highly important structural changes in the Portuguese economy, such as the increasing importance of the industry compared to the agriculture, and also to the degree of openness though the increase of exports and imports and the increase of investment in human capital. According to Teixeira and Queirós (2016) and Saviotti and Pyka (2012), changes in demand that favour more complex products will lead to changes in sectorial composition and in the economic specialization, by boosting technological innovation and creating new products.

Lopes and Amaral (2013) quantified the changes in the structure of the Portuguese economic activity, employment multipliers and human capital in the period 1995-2008. According to the authors, in the period analyzed there was an evolution on the structure of output, value

added and employment, showing a declining in almost all manufacturing activities (e.g. agriculture and mining) and an increase on utilities, construction and services.

Some changes in the demand side focusing in more complex and robust products can lead to structural changes (Saviotti and Pyka, 2012). Therefore, industries using 'high-tech' have higher growth rates of productivity which will impact positively economic growth (Silva and Teixeira, 2011). This impact will tend to be higher when the absorption capacity and innovation, related to high levels of human capital, is higher (Nelson and Phelps, 1996; Teixeira and Fortuna, 2011).

The structural change approach considers human capital as a major determinant of economic growth since this factor enhances structural change, meaning that the productive specialization of economies depends on their endowment factors, whereby technologically more advanced industries will tend to locate in countries with a high stock of human capital (Justman and Teubal, 1991).

Some of the existing empirical literature have to some extent neglected the relevance of human capital through the interaction it can have with the industrialization of a country, neglecting the relevance of the process of structural change (Teixeira and Queirós, 2014). Indeed, human capital can affect economic growth indirectly, via interaction with the structure of the economy (Silva and Teixeira, 2011). More concretely, and according to Silva and Teixeira (2011) and Teixeira and Queirós (2016), when a country is more specialized in knowledge intensive /technologically advanced activities or industries, the impact of human capital on the economic growth comes amplified.

From the above arguments, we conjecture that:

H3a: Structural change positively impacts country's long-term economic growth.

H3b: The higher the intensity of structural change (towards industry and services), the higher is the positive impact of human capital on country's long-term economic growth.

2.3.3. Empirical evidence

Several studies (see Table 3) recognize that the decades that preceded the First World War, the Europe was under an industrial growth and the peripheral economies suffered structural changes without precedents (Reis, 1987).

In what concerns the Portuguese economy, the period of 1960-1970 was the longest of accelerated economic growth in the recent Portuguese economic history and it was associated with structural changes regarding industrialization, diminishing therefore the importance of the agriculture (Rocha, 1984). Lains (2008) compares the evolution of the economic growth in Portugal and in Ireland showing that the structure of these countries changed significantly and in a different way during the period analyzed. The author concluded that the structural changes in the Portuguese economy impacted negatively the growth of the country's labor productivity, whereas in case of Ireland the impact of the structural change was reversed quickly, once 29% of Ireland's labor productivity growth in 1990s was due to the increasing numbers of workers engaged in industries where productivity was increasing rapidly. In the study by Teixeira and Queirós (2014), involving countries of OECD countries, over the period of 1960-2011, the authors concluded that the countries' productive specialization dynamics is a crucial factor for economic growth, showing that the interaction between human capital and structural change towards high-knowledge-intensive industries, impacts on economic growth.

Table 3: Studies addressing structural change and economic growth

	Methodology	Name	Countries	Period	Proxy to EG	Proxy to SC
Several countries						
Long run	Descriptive	Justman and Teubal, 1991	Developing and new industrialized countries	1945-1990	Total factor productivity	Working people in each sector in percentage of the total
	Panel Data	Silva and Teixeira (2011)	21 countries	1979-2003	GDP based on purchasing power-parity (PPP)	Share of 'high-level' industries in total employment
		Teixeira and Queirós (2016)	30 countries	1960-2011	Real GDP per capita	Share of 'high-level' industries in total employment
One country						
Long run	Descriptive	Lains (2008)	Portugal	1960-2004	Real GDP per capita	Working people in each sector in percentage of the total
Very-long run	Co-integration	Domini (2016)	Italy	1861-1939	Real GDP per capita	RSTA (Revealed Symmetrical Technological Advantage)
		De la Escosura (2007)	Spain	1850-2000	Real GDP per capita	Labour force in agriculture as a ratio to total labour force

Source: Own elaboration.

Crafts and Toniolo (1996) evidenced that from 1950 until the mid of 1970, Portugal not only grew in terms of industrialization but also showed some of the highest rates of economic

growth in Western Europe. However, Lains (2008) concluded that the changes observed in the structure of the Portuguese economy (towards low tech, labor intensive industries) impacted negatively the growth of the country's labor productivity.

3. Methodology

3.1. Main Hypotheses

The main goal of this study is to assess the direct and indirect impact of human capital, via international trade and structural change, on the Portuguese economic growth in the very long run, from 1827 to 2017.

Acording to the literature review (Section 2), five main hypothesis are to be tested:

H1: Human capital positively impacts on country's long-term economic growth.

H2a: International trade positively impacts country's long-term economic growth.

H2b: The higher the level of trade openness, the higher is the positive impact of human capital on country's long-term economic growth.

H3a: Structural change positively impacts country's long-term economic growth.

H3b: The higher the intensity of structural change (towards industry and services), the higher is the positive impact of human capital on country's long-term economic growth.

3.2. Model specification and selection of the estimation technique

The relevant studies analyzed on the literature review address different methodologies and estimation techniques. We can distinguish between three types of studies (see Table 4): 1) those that analyze a set of countries in one single period of the time, using the method of (Pooled) Ordinary Least Squares (e.g., Barro, 1991); 2) studies that focused on a group of countries over several periods of the time, using panel data models (e.g., Wang, 2007; Vo and Batten, 2009); and 3) studies that rely on co-integration models to study one country over a period of time (e.g., Teixeira and Fortuna, 2010; Domini, 2016).

Given that our aim is to analyze the very long run determinants of one country's economic growth (Portugal), the adequate methodology is time-series/cointegration. According to Johansen and Juselius (1990), to test the economic development of a single country using time series as a methodology can be very difficult for empirical work. Cointegration models were introduced by Granger (1981) and allow us to study whether there exists a long-term economic relation in unit root (non-stationary) variables (Teixeira and Queirós, 2016). According to Teixeira and Queirós (2016), in a time series analysis if more than one series evolve together, then there exists a co-integration relation within the series and they may become

stable, despite their individual trends. Therefore, even though the variables considered alone are not stationary, when a long-term relationship occurs, the regression of all variables has stationary perturbation terms (Teixeira and Fortuna, 2010).

Table 4: The impact of human capital, international trade and structural change on countries' economic growth

Authors (year)	Countries analyzed	Period	Methodology	Dependent variable	Relevant independent variables	Results
Barro (1991)	98 countries	1960-1985	Cross-Section (OLS)	Real GDP per capita	Human capital	+++
Benhabib and Spiegel (1994)	42 countries	1974-1977	Cross-Section	Real GDP per capital	Human capital	+
Vo and Batten (2009)	79 countries	1980-2003	Panel data	Real GDP per capita	FDI	++
Krammer (2010)	47 countries	1990-2006	Panel unit root and Panel Co-integration	Total Factor Productivity (TFP)	Human capital	+++
					Trade	+++
Wang (2007)	40 countries	1976-1998	Panel data	Real GDP per capita	Human capital	+++
Vasta (2010)	Italy	1861-2009	Time series	Real GDP per capita	Trade	+++
Domini (2016)	Italy	1861-1939	Co-Integration	Technological specialization	Trade	+++
Teixeira and Fortuna (2010)	Portugal	1960-2001	Co-Integration	Total Factor Productivity (TFP)	Human capital	++
					Human capital (through trade)	+++

Notes: +++ (++) (+) Significant at a 1% (5%) (10%) level.

Source: Own elaboration.

Thus, in the present dissertation, we resort to cointegration estimation technique as we are interested in estimating long-term effects between non-stationary series of human capital, international trade, structural change and economic growth.

We resort to co-integration models using data on Portugal ranging from 1827 until 2017.

The above-mentioned relations are specified in the following multiple linear equation:

$$y_t = \beta_1 + \beta_2 HC_t + \beta_3 SC_t + \beta_4 IT_t + \beta_5 (HC * IT)_t + \beta_6 (HC * SC)_t + u_t$$

where:

t represents time.

$\boldsymbol{y}$ – Proxy for economic growth

HC – Proxy for human capital.

SC - Proxy for structural change.

IT – Proxy for international trade.

$\boldsymbol{u_t}$ – Random perturbation term.

3.3. Description of the variable proxies and data sources

3.3.1. Economic growth

In line with most of the studies of the literature we use real GDP per capita to measure the economic growth. To do so we find three differente series (see Figure 1).

The first series is from Valério (2006) and it provides estimations of the real GDP per capita in 1914 escudos of the Portuguese economy. The series covers the period between 1827 and 2003. Before the year of 1865 several years were missing data, respectively between 1828-1841, 1844-1854, 1857-1860 and 1862-1864.

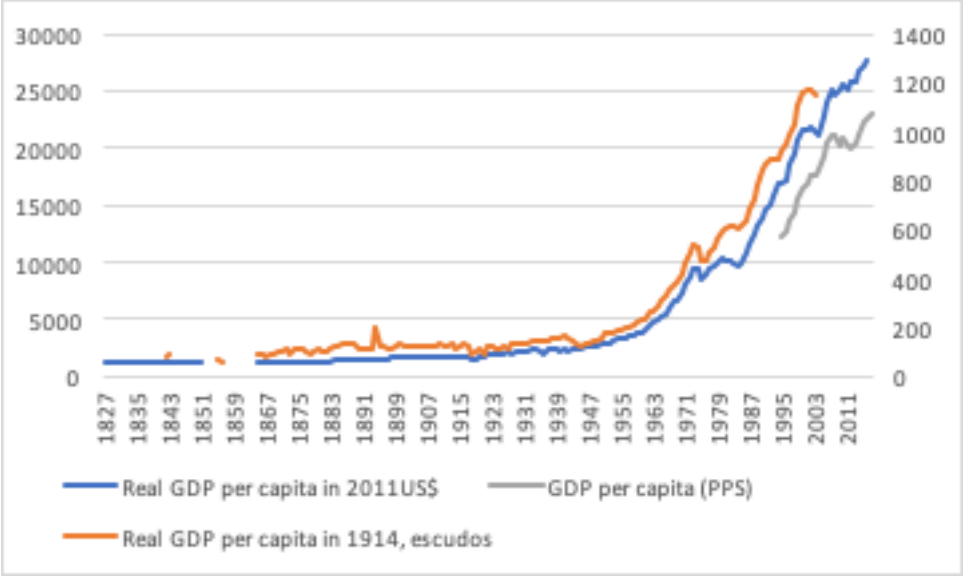


Figure 1: Real GDP per capita, Portugal, 1827-2017
Source: Own elaboration based on data from Maddison Project Database (2018), Valério (2006), and Pordata.

In Pordata, we can find data of real GDP per capita in purchasing power parity between 1995 and 2017, being this the smallest dataset we have analyzed.

The third series analyzed is provided by Maddison Project Database (2018). This data covers the period since 1927 until 2017 and it shows us the real GDP per capita in US dollars of the Portuguese economy. Between 1852-1854, 1856-1860 and 1862-1864 the data is missing on the series.

As we can see in Figure 1 all series follow the same path: The proxy of economic growth has been increasing over the years.

Between the three above mentioned datasets, the one from Pordata is the one covering the shortest period of time and more recent years. The series from Valério (2006) covers a longer period of time but some of the values are still needed to be estimated by interpolation. As the series from Maddison Project Database is the series that covers the longer period and it only has a small amount of values missing, this is the one that will be used in our study.

3.3.2. Human capital

The average years of schooling is the most widely used proxy of human capital (Easterly and Levine,1997; Hall and Jones,1999; Temple and Wößmann, 2006; Moral-Benito, 2012; Bodman and Le, 2013; Teixeira and Queirós, 2016).

We found two different series to compare in what concerns human capital, one from Teixeira and Fortuna (2010) and other from Lee and Lee (2016) – see Figure 2.

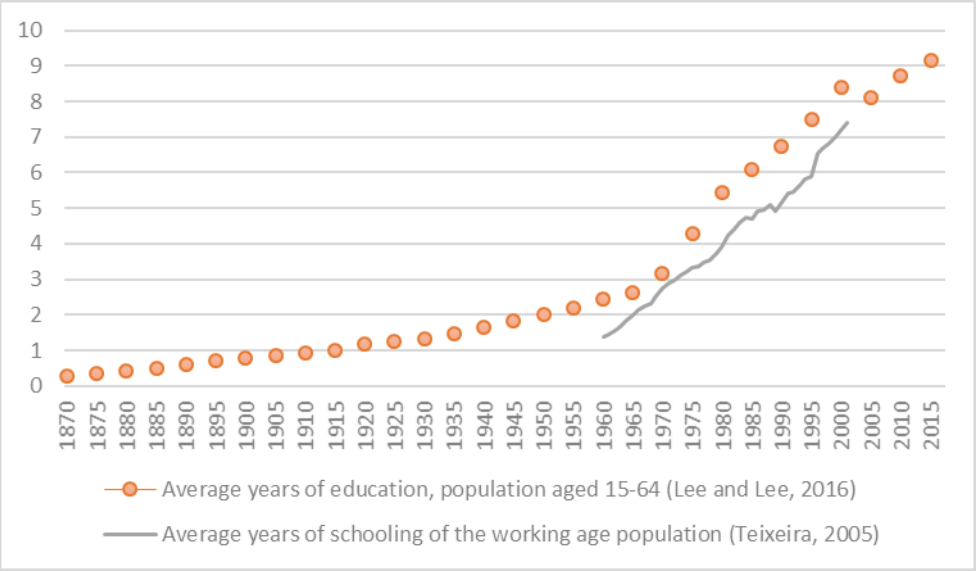


Figure 2: Human capital, Portugal, 1827-2015
Sources: Own elaboration (Data from Lee and Lee (2016), Teixeira (2005)).

Teixeira and Fortuna (2010) use as proxy for human capital the average years of the working age population. On the other hand, Lee and Lee (2016) present us a dataset of the average years of education in population aged between 15 and 64. The series starts at year 1870 and goes up to 2015, providing only values for each 5 years.

As it can be observed in Figure 2, the two time series have a similar trend and levels. Given that the dataset from Lee and Lee (2016) is the one that covers the longest period of time, it will be the series that we will use on our estimation.

3.3.3. International trade

In what concerts the proxy for international trade, Valério (2001) has a dataset of the exports and imports between 1927 and 1998 (with missing values in 1832-1841, 1844-1847, 1849-1850, 1852-1854, 1857-1860 and 1862-1864). In order to compute the trade openness indicador, that is, exports plus imports in percentage of the GDP, we divided the sum of exports and imports by the GDP also available in Valério (2001).

Valério (2006) also provides a series for trade openness indicator, encompassing the period 1827- 2006, with missing values in 1828-1841, 1844-1854, 1857-1860, and 1862-1864 (see Figure 3).

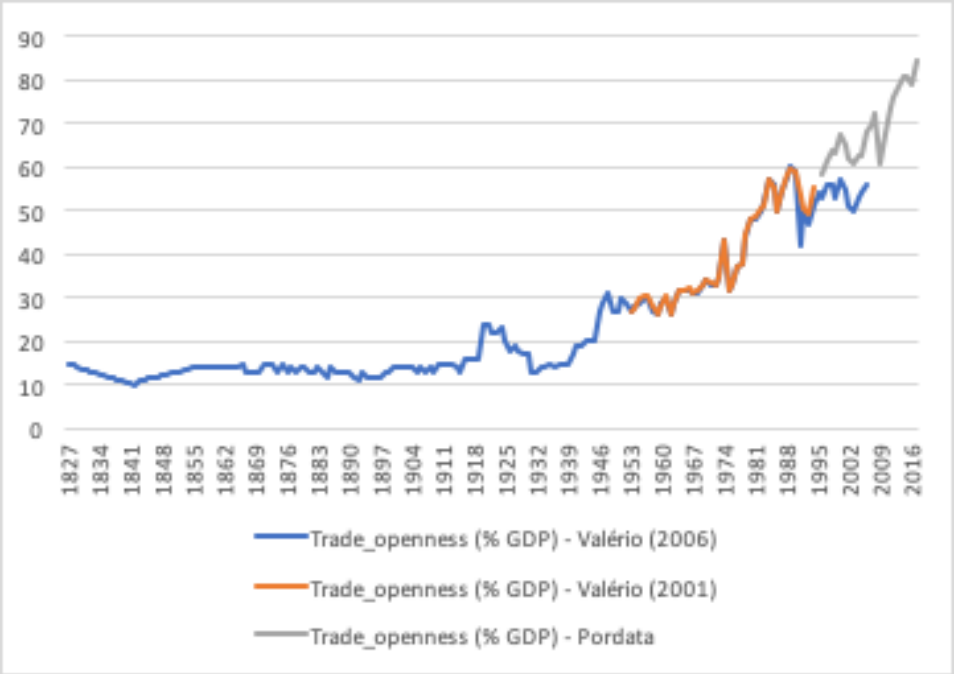


Figure 3: International trade, Portugal, 1827-2017
Source: Own elaboration (Data from Valério (2006), Valério (2001) and Pordata).

From 1996 to 2017 we can also find data from Pordata that is a smaller series (it only covers 22 years), but will be useful for extending the Valério's (2006) time series.

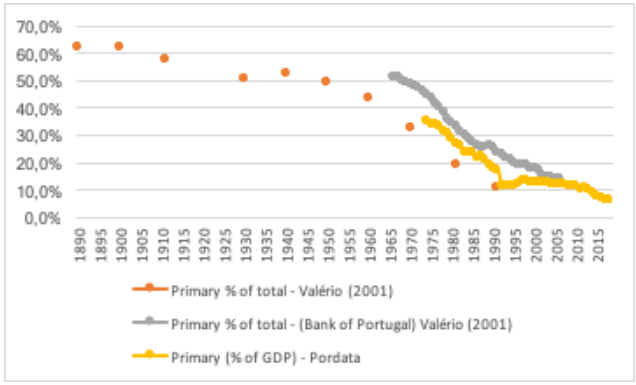
All the series follow a similar path (cf. Figure 3). As that from Valério (2006) is the one that covers the longest period (1827-2006), we will use it in our estimations, extended using the annual growth rates underlying the Pordata's series.

3.3.4. Structural change

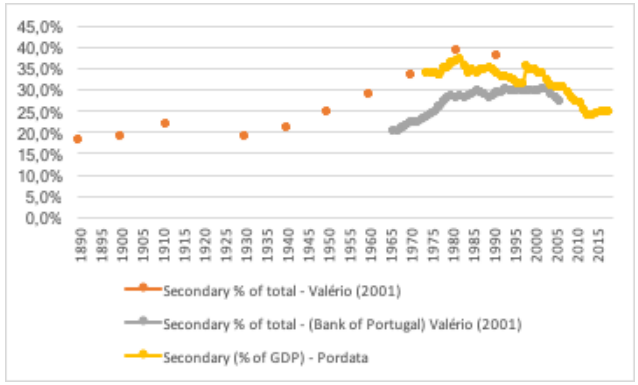
Structural change refers to long-run changes in the weight of sectors of an economy. To measure this changes, the best way is to use employment composition data and its evolution over the period under analysis (Teixeira and Queirós, 2016).

In Valério (2001) we can find the amount of working people in each sector (primary, secondary and teriary) between 1890-1991, but the data is only available in periods of ten or eleven years. Data from Bank of Portugal provides the corresponding values between 1966 and 2006, whereas Pordata covers the period between 1974 and 2018.

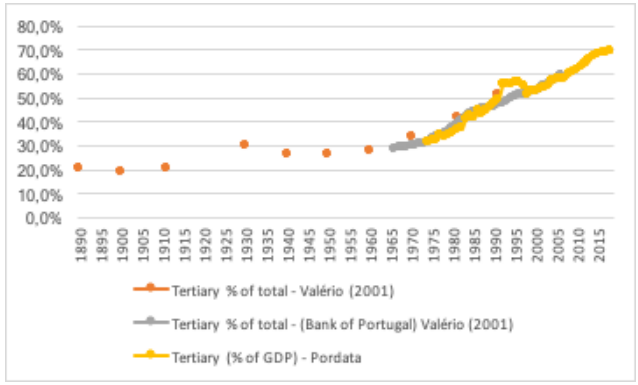
Even though all the series follow the same tendency (cf. Figure 4), evidencing a noticeable decrease in primary sector and a significant increase in the tertiary sector, as the dataset from Valério (2001) is the one covering the longest period, it will be the one we will use in our study, extended with the data from Pordata.



Primary



Secondary



Tertiary

Figure 4: Employment in the primary, seconday and tertiary sectors in percentage of total employment, Portugal, 1890-2018

Sources: Own elaboration (Data from Valério (2001) – Bank of Portugal, Valério (2001) and Pordata).

3.3.5. Interpolation and Maddison's phases

As earlier mentioned, the dataset used to gathered the measure for economic growth is that of Maddison Project Database (2018). For the years 1852-1854, 1856-1860 and 1862-1864 the missing data was calculated by linear interpolation (i.e., we calculated the average annual growth rate between years of available data and interpolated the missing values). To fill the value of 2017 we have calculated the annual growth rate between 2016 and 2017 of the GDP per capita (PPS) provided by Pordata and used the same growth rate to calculate the missing value in the series of the Maddison Project Database.

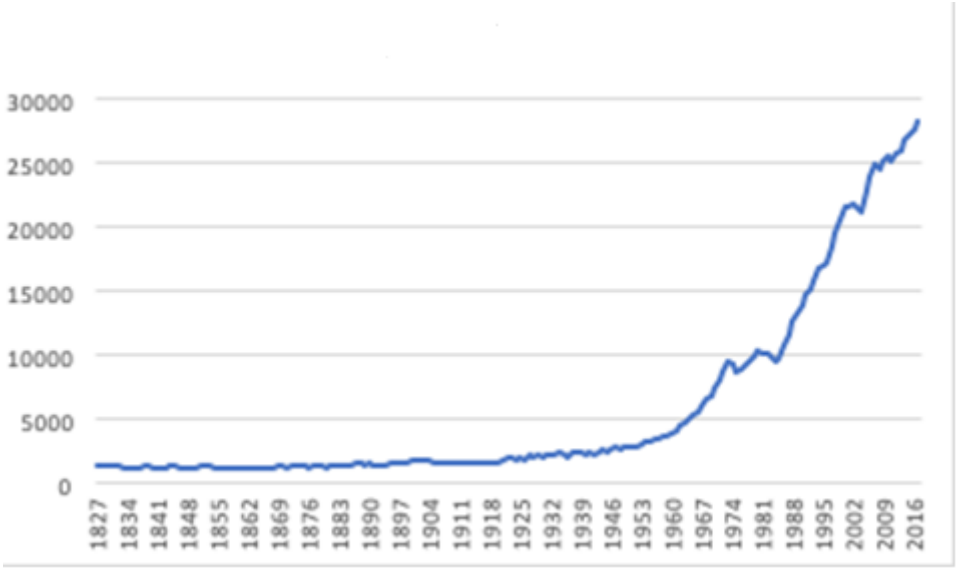


Figure 5: Real GDP per capita, Portugal, 1827-2017
Note: Missing values were calculated using linear interpolation.
Source: Own elaboration based on data from Maddison Project Database (2018).

According to Maddison (2018) the period of 1820-1870 was a period in which some economies started to enroll in a process of economic growth alongside with the industrial revolution. In the case of the Portuguease economy, the growth was steady between those years as the country failed to embark in the industrialization process. The real GDP per capita in US dollars in 1827 was 1300 and in 1870 was 1295. In the next phase of accelerarion of growth, that goes up to the beginning of the First World War in 1913, the real GDP per capita in US dollars grows up to 1660. In the phase of the World Wars and Great Depresion the world economy suffered a decrease in economic growth. As Portugal was not one of the main intervenients in these wars, the real GDP per capita in US dollars decreased to 1558 in 1919 but stated to increase right after achieving 2771 in 1950. In the so called golden years between 1950 and 1973 the real GDP per capita in US dollars increased to 9516. In the next years

(from 1973 to 1978) the growth rate decreases but from 1979 until today the Portuguese economy observed an increase in the GDP per capita. The value of real GDP per capita in 2017 is of 27726 US dollars.

In what concerns human capital we use the data from Lee and Lee (2016) – see Figure 6 – which reflects the number of years of formal education of individuals aged 15-64. Even though this series provides data from 1870 to 2015, the data is only available for each five years. Therefore, in order to complete the series, we use linear interpolation, by calculating the average annual growth rate between the available data periods in order to fill the missing data.

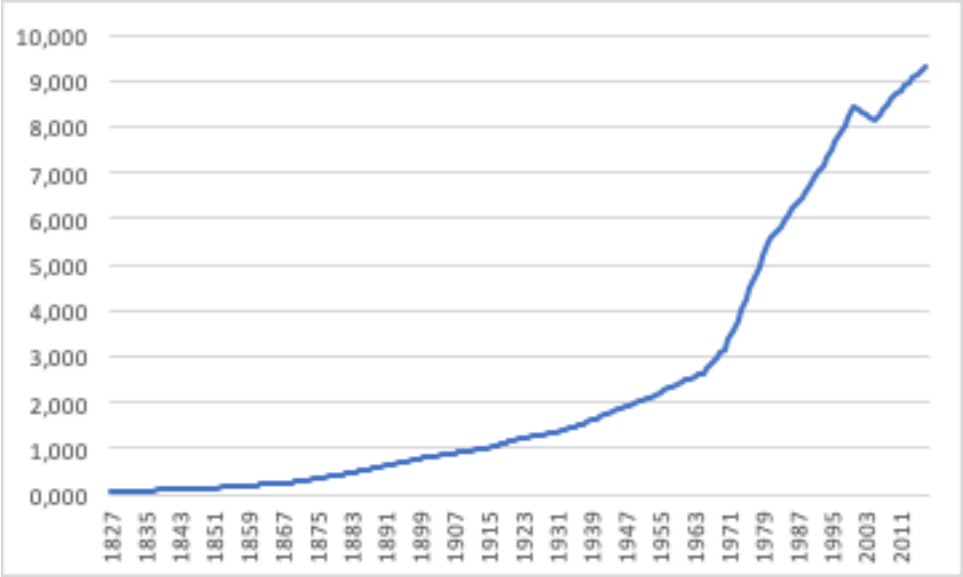


Figure 6: Human capital stock, Portugal, 1827-2017
Note: Missing values were calculated using linear interpolation.
Source: Own elaboration based on data from Lee and Lee (2016)

Alonside with the Maddison's (1982) phases, human capital also presents low and steady values in the first phase (1820-1870): 0.064 years of schooling in 1827 and 0.270 in 1870, meaning that the variation in this variable is not notorious in this phase. In the second phase (1870-1913), the old "liberal order" phase (Maddison, 1982), the years of schooling have a slightly increase up to 0.98 and in the next phase (1913-1950) that is marked by the world wars and the Great Depression and that ends in 1950, the value on the last year of the phase is 2.01 average years of schooling. In the fourth phase (1950-1973), the phase where the economic growth was more accentuated, the years of schooling increased to 3.79. From 1973 onwards, the increase in the average years of schooling is notorious reaching in 2017 the value is 9.31.

For international trade we use the trade openness indicator (exports plus imports in total GDP) from Valério (2006). The series provides data from 1827 to 2006. From 2006 to 2017 we used the data from Pordata in order to calculate the growth rate for each year and then we applied the same growth rate to calculate the missing data on the data from Valério (2006).

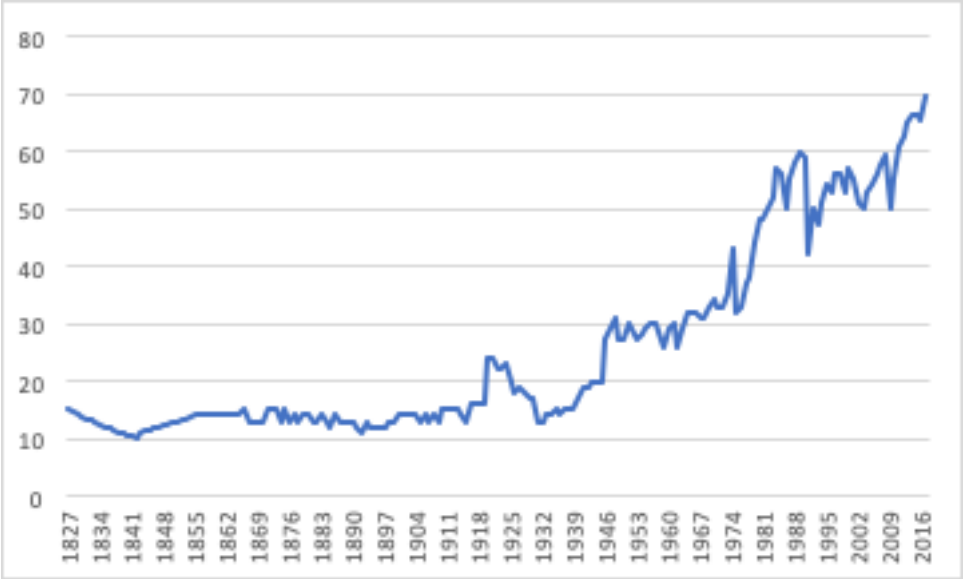


Figure 7: International trade/ trade openness, Portugal, 1827-2017
Note: Missing values were calculated using linear interpolation.
Source: Own elaboration based on data from Valério (2006) and Pordata.

Figure 7 depicts the series of the trade openness indicator, which is more irregular than the previous two series but still denoting an updward tendency. In 1827 the value of the trade openness was 15% and it slighyl decreased to 10% in 1842. However, in the beginning of the following Maddisson's phase, in 1871, the value was again 15%. In the second phase (1970-1913), there are some increases and decreases in trade openness, but the variation is not very significant, and at the end of 1913 the value of the trade openness is once more 15%. After this period we can observe an increase in trade openness, which reaches 23% in 1924. But afterwards it decreases due to the consequences of the Great Depression. In the next years we can see a decrease in values of trade openness in percentage of GDP up to 13% in 1931, between the Great Depression and the beginning of the Second World War. In the end of this phase (1950), the values already start to increase and in the so called "golden age" the trade openness indicator went from 27% in 1950 to 35% in 1973. From 1973 onwards, the increase is more accentuated and in 2017 the value of the trade openness reaches almost 70%.

Finally, regarding the structural change, the series from Valério (2001) only provides data from 1890 to 1991 and in periods of ten or eleven years. To calculate the missing values between those periods, we used also interpolation and we will use the values between 1890 and 1973. From the period between 1827 and 1889 we have used backwards interpolation by calculating the variation growth between 1890 and 1939 (50 years). From 1974 to 2017 we have used the series from Pordata to calculate the growth rate of each year and then we used the same growth rate on the data of Valério (2001).

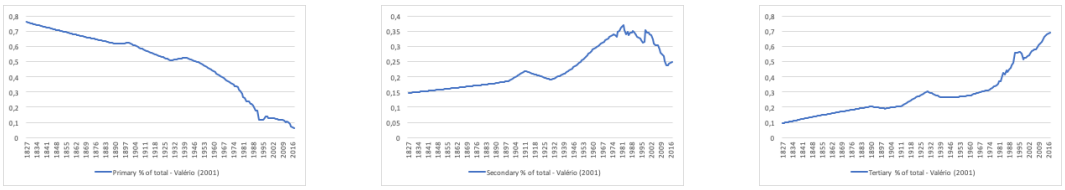


Figure 8: Employment in the primary, secondary and tertiary sectors in percentage of total employment, Portugal, 1827-2018

Note: Missing values were calculated by using linear interpolation
Sources: Own elaboration based on data from Valério (2001) and Pordata.

In the overall, over the Maddison phases, the people employed in the primary sector (in percentage of total employement) has been decreasing. The value in 1827 was 75.9 % and in 1870 was 65.9%. In the next phase (1870-1913) the value decreased to 56.7% but still, as we can see in Figure 8, the primary sector dominated. In the third phase (1913-1950), it is the first time that the people employed in the primary sector is less than 50%, decreasing to 49% in 1950. Between 1950 and 1973 there was a pronounced decrease in the percentage of people employed in the primary sector. The value at the end of the phase, in 1973, is 35.5%. In 2017 the value reached a minimum of 6.4%.

Globally, between 1827 and 2017, Portugal observed an increase in real GDP per capita (Figure 5), human capital/ years of schooling (Figure 6), trade openness (Figure 7), whereas the percentage of employment in the primary sector decreased (Figure 8). The overall descriptive statistics of the relevant series used in the estimation are presented in Table 5.

A final note to clarify the reason why having available the three series reflecting structural change – percentage of employment in primary, secondary and tertiary sectors -, we decided to use only the percentage of employment in primary. Given that the three series add up to 100%, there is a significan degree of collinearity among them. Moreover, the most stricking fact of long term structural change is the marked decline of the relative importance of the

primary sector employment (van Neuss, 2019). Thus, to account for very long run structural change we decided to use only the primary sector weight.

Table 5: The variables: description an source of data

Variable	Description	Source of data	Mean	Min	Max
GDP per capita	Real gross domestic product per capita in 2011 US dolars	Maddison Program Database (2018)	5684.96	1160	28290.13
Human Capital	Average years of education in population aged between 15-64	Lee and Lee (2016)	2.44	0.06	9.31
Trade Openness	(Imports+Exports)/ GDP (%)	Valério (2006) & Pordata	25.53%	10.0%	72.19%
Structural Change	% of total employment in the primary sector	Valério (2001) & Pordata	49.44%	6.40%	75.92%

Source: Own elaboration

4. Empirical results

4.1. Unit Root Tests

As we are using time series as a estimation technique, it is important to check if the relevant variables are stationary or not to avoid misspecification (Engel and Granher, 1987; Teixeira and Lourenço, 2019). To do so, we use the Augmented Dickey Fuller (ADF) and the Phillips-Perron tests. As all the variables in levels have a clear upward or downward trend, (see Figure A1, in Annex) we added a constant and a time trend in the tests (see Table 6).

Table 6: Non-stationarity tests of the series under study

	Augmented Dickey-Fuller test (p-value)	**Phillips-Perron test (p-value)**
Levels		
Real GDP per capita	-1.148 (0.921)	-1.148 (0.921)
Human capital	-0.492 (0.984)	-0.963 (0.949)
Trade Openness	-2.902 (0.162)	-2.665 (0.251)
Employment in primary sector	1.875 (1.000)	1.395 (1.000)
First differences		
Real GDP per capita	-14.360*** (0.000)	-14.345*** (0.000)
Human capital	-2.939 (0.150)	-3.114* (0.096)
Trade Openness	-16.580*** (0.000)	-16-873*** (0.000)
Employment in primary sector	-12.052*** (0.000)	-12.231*** (0.000)

Note: ***(**) (*)statistically significant at 1% (5%)(10%); all variables are in logarithm; the variables in levels include a trend.
Source: Own computation using Stata 14.1.

The overall results are the same in both tests (cf. Table 6). For the levels, results do not reject the non-stationary hypothesis, which indicates that the variables in levels are non-stationary. In differences, all the variables are stationary. Summing up, all the variables are integrated of order 1, that is, have one unit root.

As such, we can conclude that the series can be cointegrated in the long run, meaning that the series can have one or more stationary linear combinations, and therefore they can have a stable long-term relationshop between them.

4.2. Cointegration and Granger (non-) causality tests

Cointegration tests can be used to estimate long-term parameters in a relationship that includes unit root (non-stationary) variables (Teixeira and Lourenço, 2019).

In order to test our hypotheses, we estimated 4 distinct models: Model 1, which included only direct effects / relations between real GDP per capita and human capital, international trade and structural change; Model 2, which includes, besides human capital and structural change, the interaction terms of human capital and international trade; Model 3, which includes, besides human capital and international trade, the interaction term of human capital and structural change; and Model 4, which includes, besides human capital, the two interaction terms of human capital and international trade, and human capital and structural change.

Once findind that the relevant series are all integrated of the same order, that is, they can be cointegrated, we use the Johansen cointegration test (Johansen and Juselius, 1990) to assess whether the series were effectively cointegrated and how many cointegration vectors exist.

For the period in analysis (1827-2017), and for all the relations associated with Models 1-4, the Trace test indicates that there is r=1 cointegrating relation among the variable included in the Models. Because the trace statistic at r=0 of 65.89 (Model 1) exceeds its critical value of 47.21, we reject the null hypothesis of no cointegrating equations. Analogously, as at r=1 the trace statistics is 22.61, below its critical value of 29.68 (Model 1), we accept the null hypothesis of 1 cointegrating equation. Such outcome is valid for all the models (cf. Table 7).

Table 7: Johansen cointegration test

	No interaction terms		With interaction terms					
Number of cointegration vectors	Model 1		Model 2		Model 3		Model 4	
	Trace statistic	5% Critical value	Trace statistic	5% Critical value	Trace statistic	5% Critical value	Trace statistic	5% Critical value
None	65.89	47.21	92.63	62.99	80.01	47.21	103.59	62.99
At least 1	22.61*	29.68	37.90*	42.22	28.80*	29.68	39.25*	42.44

Notes: Trace test is a Johansen cointegration test for the null hypothesis that, among GDP per capita (ln), human capital stock (ln), trade openness (ln), and weight of primary sector in terms of total employment (ln), there are r linearly independent cointegration relations, that is, the 4 variables share 2-r stochastic tendencies; * indicates that this is the value of r selected by Johansen's multiple-trace test procedure.
Source: Own computation using Stata 14.1.

Having found that in all the model there is 1 cointegration vector, or long-run stable relation between the relevant variables, we proceeded by estimating such relations (see Table 8).

According to the Lagrange multiplier test, we cannot reject the null hypothesis that there is no autocorrelation in the residuals for any of the orders tested. Thus this test finds no evidence of model misspecification.

The eigenvalue stability condition indicates that there is a real root at about 0.15. Although there is no distribution theory to measure how close this root is to one, per other discussions in the literature (e.g., Johansen, 1995), we conclude that the root of 0.15 suggests that the predicted cointegrating equation is stationary.

The chi square of the vector error correction model (VECM) for all the models is highly significant, evidencing that all the models present a global good quality of fit.

Table 8: Long-term relations between GDP per capita and the relevant variables, 1827-2017

		No interaction	With interaction terms		
		Model 1	**Model 2**	**Model 3**	**Model 4**
Human capital		0.3412*	1.9243**	0.3959**	1.8466**
		(0.2019)	(0.9168)	(0.1914)	(0.9119)
International Trade (trade openness)		2.8209***		2.2054***	
		(0.7072)		(0.6726)	
Primary sector		0.1041	1.2790		
		(0.5917)	(0.6871)		
HC*IT			1.2702***		1.1593***
			(0.3151)		(0.3206)
HC*Prim				0.2416	0.2836
				(0.2027)	(0.0138)
Lags		2	2	2	
Number of cointegration vectors		1	1	1	1
Vector error-correction model with…		Unrestricted constant	Restricted trend	Unrestricted constant	Restricted trend
Lagrange-multiplier test(1)	**Lag 1**	5.4823	11.7997	5.7568	11.3189
		(0.9928)	(0.7577)	(0.9905)	(0.7894)
	Lag 2	8.8041	11.7266	9.4479	11.0763
		(0.9213)	(0.7626)	(0.8938)	(0.8048)
Eigenvalue stability condition(2)		0.1524	0.1890	0.1653	0.2138
Chi2 of the VECM (p-value)		165.918	74.811	188.753	60.374
		(0.000)	(0.000)	(0.000)	(0.000)

Note: ***(**)[*] statistically significant at 1%(5%)[10%]. All variables are in logarithm; The number of lags was established according to the Akaike information criterion (AIC), Hannan–Quinn information criterion (HQIC), and Schwarz's Bayesian information criterion (SIC); All cointegration vectors include a constant. (1) H0: no autocorrelation at lag order; (2) the cointegrating equations are stationary when the estimated root is not close to 1.
Source: Own computation using Stata 14.1.

Long run elasticities between real GDP per capital and human capital stock are significant and positive ranging from 0.34% (Model 1) to 1.92% (Model 2). Thus, in the long-run, data reveal that high levels of human capital stock are associated with high levels of real GDP per capita. Moreover, when interacted with international trade, the estimate of the long-run elasticity of real GDP per capita and human capital comes leveraged. In other words, increased international trade openness elevates the long-run elasticity of human capital and real GDP per capita. The coefficient of the interaction of human capital with structural change indicator (Models 3 and 4) is not statistically significant, which means that in the long run, the variation in the weight of employment in the primary sector do not change the long run elasticity of human capital and real GDP per capita. Moreover, structural change coefficient per se, both in the restricted model (Model 1) and enlarged model (Model 2) fail to be statistically significant, meaning that in the very long run, in the Portuguese case, structural change does not correlate with economic growth.[1]

The long run elasticities between real GDP per capita and international trade (i.e., trade openness) range between 2.21% (Model 3, with interaction terms) and 2.82% (Model 1, without interaction terms).

These results only indicate correlations, and not causality. Thus, in order to assess, for the significant correlations, in which direction the causality goes, it is necessary to run Granger (non-) causality tests (Ahmad and Harnhirun, 1995; Teixiera and Lourenço, 2019).

According to Granger (1981), when two or more series are cointegrated, then there must exist a Granger causality between them, either one way or both ways.

The results of the Granger (non-) causality test for the significant relations in all the four models are displayed in Table 9.

Results evidence that in the long run, for the Portuguese economy, human capital Granger causes economic growth (the underlying null hypothesis is rejected), but economic growth also Granger causes human capital. In short, in the very long run (1827-2017), the causality between these variable runs both ways (i.e., is bi-directional). The results are similar for the

[1] This same result appear when we consider as proxy for structural change, the weight of employment in the secondary or tertiary sectors.

international trade variable. Indeed, they suggest that international trade, proxied by the degree of trade openness, significantly impact of Portuguese economic growth, and that the latter fosters international trade.

Table 9: Granger (non-) causality test

	No interaction terms	With interaction terms		
Null Hypothesis	**Model 1**	**Model 2**	**Model 3**	**Model 4**
HC *does not* Granger cause GDP per capita	8.115*** (0.004)	1.957 (0.162)	8.416*** (0.004)	3.934** (0.047)
IT *does not* Granger cause GDP per capita	10.160*** (0.001)		9.356*** (0.002)	
HC*IT *does not* Granger cause GDP per capita		0.840 (0.359)		2.299 (0.129)
GDP per capita *does not* Granger cause HC	45.081*** (0.000)	41.928*** (0.000)	65.169*** (0.000)	50.159*** (0.000)
GDP per capita *does not* Granger cause IT	8.011*** (0.005)		7.089*** (0.008)	
GDP per capita *does not* Granger cause HC*IT		14.135*** (0.000)		12.920*** (0.000)

Note: *** (**) [*] statistically significant at 1% (5%) [10%]; All variables are in logarithm; The number of lags *p=2* of the standard VAR was established according to the final prediction error (FPE), Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SIC), and the Hannan and Quinn information criterion (HQIC); Wald test chi-square are displayed with p-values in brackets.
Source: Own computation using Stata 14.1.

The interaction variable, between human capital and international trade, does not Granger cause economic growth (real GDP per capita), but the real GDP per capita Granger causes the interaction variable.

Combing the results from the cointegration test and the Granger causality test, we can conclude that H1 (*Human capital positively impacts on country's long-term economic growth*) and H2a (*International trade positively impacts country's long-term economic growth*) are validated, whereas H2b *(The higher the level of trade openness, the higher is the positive impact of human capital on country's long-term economic growth*), H3a (*Structural change positively impacts country's long-term economic growth*), and H3b (*The higher the intensity of structural change (towards industry and services), the higher is the positive impact of human capital on country's long-term economic growth.*) cannot be validated.

Summing up, in the very long run (1827-2017) for Portugal, 1% variation in human capital stock leads to 0.34% (Model 1, Table 8) – 1.92% (Model 2, Table 8) variation in real GDP per capital. In the case of international trade, the estimates of the elasticities are larger: 1% variation in the degree of trade openess leads to 2.21% (Model 3, Table 8) – 2.82% (Model

1, Table 8) variation in real GDP per capital. In the case of the interaction term (between human capital and international trade), the long run elasticities between this interaction term and the real GDP per capita are statistically significant and positive, but the causality runs from the real GDP per capita to the interaction between human capital and international trade. In other words, increased levels of real GDP per capita leverages the indirect impact of human capital, via international trade, on economic growth.

Lucas (1988), Romer (1990), Barro (1991), Amaral (1998) and Lains (2003), and all recognize that na increase in human capital, proxied by the level of formal education, by generating more qualified and sophisticated labor force will help economies to develop in a more competitive way. Also, we can sum up from the above mentioned results, that international trade has a very strong relationship with the real GDP per capita in the long term.

Teixeira and Fortuna (2010) have used cointegration techniques to estimate the impact of human capital and trade in the Portuguese economy in a shorter period of time (1960-2001), comparing to the period of our analysis (1827-2017). While we have used real GDP per capita as proxy for economic growth and trade openness as proxy for international trade, Teixeira and Fortuna (2010) have used Total Factor Productivity as proxy for economic growth and real imports of machinery and equipment, foreign direct investment and licenses and royalties acquired to foreign as proxies for trade. In what concerns human capital the proxy used on both studies was the same: years of schooling. The results of Teixeira and Fortuna (2010) show that the investment in human capital and local R&D efforts will reinforce the ability of the Portuguese economy to absorb and apply the knowledge that is developed in other countries and trade is also very important in the long-term growth of the total factor productivity. Eventhough we have used different proxies and studying the Portuguese economy, the results of this dissertation show also a positive impact of human capital and international trade in the long-term economic growth of Portugal. Nevertheless, in our work this causality occurs both-ways, meaning that the economic growth has also a strong and positive impact on the human capital and trade openness of the economy.

Batten and Vo (2009) and Costa *et al.* (2014) have shown in their studies the importance of the trade openness on small economies. According to the authors, smaller economies are the ones where the degree of oppeness to the international trade is higher, therefore being this the major cause of the economic growth of those economies. When human capital interacts with the international trade of an economy, the impact in economic growth is even more

accentuated (Owen, 1999; Batten and Vo, 2009). This is in line with our results, that show that an increase on the interaction of human capital with trade oppeness leads to an increase in GDP per capita.

In the literature, we can find studies that analyze the impact of the structural change on the economic growth, using as estimation technique panel data (Silva and Teixeira, 2011;Teixeira and Queirós, 2016) and cointegration (De La Escosura, 2007; Domini, 2016).

Silva and Teixeira's (2011) study focused on 21 less developed countries in the period 1979-2003 and concludes that changes in the economic structure in favor of high-tech and high-skill boots the economic growth. Over the period between 1960 and 2011, the more highly developed OECD counties have been studied by Teixeira and Queirós (2006), using the same proxies as in our dissertation for economic growth and human capital but using as proxy for structural change the share of "high-level" industries in total employment. Their study, despite using distinct samples and methodologies, corroborates the findings in our dissertation that human capital improves the economic growth. However, those studies found that structural change in favour of highly technological intensive industries is a crucial factor for improving the productivity of countries, i.e. the specialization in highly intensive technology sectors tends to accelerate the economic growth. This is not in line with our results, given that we found that long-run elasticities between the structural change proxy and economic growth failed to be statistically significant and Granger (non-)causality tests reinforced that structural change does not (Granger) cause very long run economic growth of the Portuguese economy.

Using the same estimation technique as the present study, De La Escosura (2007) and Domini (2016) also studied the very long run (and, respectively) processes of Spain (1850-2000) and Italy (1861-1939), but focusing on distinct relations. Domini (2016) assessed the long run relation between innovation and trade, having concluded that the Revealed Symmetrical Technological Advantage (RSTA), a proxy for structural change related innovation, and trade mutually cause each other in the case of Italy. In a more comparable study to our own, De la Escosura (2007) used labor force in agriculture as a ratio of total labor force as a proxy to structural change and concluded that structural change have contributed significantly to Spanish economic growth in the very long run. Such result is not therefore in line with the one that was obtained in the present study.

5. Conclusion

Even though in the literature we can find several studies that address the topic of economic growth, studies that analyze a single-country in the very long run are rare. The ones that exist focus on the case of Italy (Vasta, 2010; Domini, 2016), Spain (De La Escosura, 2007; Felice *et al.*, 2016), France (Piketty, 2001), and the United Kingdom (Williamson, 2016, Dalko and Wang, 2018; Wallis *et al.*, 2018) and tend to assess a particular growth factor (e.g., human capital, trade, structural change) in isolation without considering interactions between those growth factors.

The present dissertation is a contribution to fill in this gap by analyzing in the very long run (almost tow hundered years) Portugal, a small and relatively rural economy, which has industrialized and opened to international trade quite later, after the middle twentieh century. Specifically, we have analyzed the very long run impact of human capital stock, international trade (trade openness) and structural change (share of primary sector employment) on Portuguese economic growth, over almost two hundred years (1827-2017), resorting to Johansen cointegration and Granger (non-causality) tests.

The main results of our study are that over the last almost two hundred years, for Portugal: 1) human capital and international trade were important drivers of economic growth; 2) the impact of international trade on economic growth was higher than that of human capital; 3) the improvement in real GDP per capita fostered human capital stock and international trade openness; 4) increases in material life standards reinforced the joint impact of trade openness and human capital on economic growth; 5) albeit important structural change occurred over the period in analysis with a marked decrease in the weight of the employment in primary sector (and increase in the tertiary sector), structural change do not emerged as a significant growth factor.

The results of our study contribute to the scientific literature by reinforcing the fact that for small, technological laggard economies, human capital and specially international trade constitute important levers of long term economic growth. Additionally, it highlights the potential virtuous/ vicious cycle of growth in the sense that higher/ lower economic growth supports/ inhibits further improvements in human capital stock and increased trade openness.

Such results convey important policy implications. First, they suggest that in order to promote economic growth, Portuguese public authorities should contemplate the investment in

human capital through increasing the years of formal schooling of the working population, permiting the development of more advanced and sophisticated skills, which spurt productivity and economic growth. Moreover, public policies towards the diminishing of inequalities in the access to formal education will be highly beneficial for long term growth. Second, implementing public policies that improve regulations and the institutional quality towards a context more prone to international trade (exports and imports) will help to boost Portuguese economic growth.

Even though this dissertation has some contributions to the literature, it presents noticeable limitations. First, in terms of data and the series. For all the variables analyzed, real GDP per capita, human capital stock, international trade and structural change, continuous time series do not exist for the period in analysis. Thus, we had to use linear interpolation to overcome the missing values. Although this is a common procedure in the area (Pereira, 2005; Stolz *et al.*, 2013; Felice *et al.*, 2016; Teixeira and Lourenço, 2019), it can involve some econometric problems such as size distrortion. Meaning that if we estimate this tests and models for a smaller period where interpolation is not required, the results could not be the same. Second, when estimating the cointegration vectors, no time breaks were considered in the series. This could be, nevertheless a pertinent topic for future research.

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Apendix

Table 10: Time series used to compute relevant variables

Years	Real GDP per capita in 2011US$	Trade_openness (% GDP)	Years of schooling	Primary, % total	Secondary, % total	Tertiary, % total
1827	1300	15	0.064	75.92%	14.68%	9.40%
1828	1341	15	0.066	75.67%	14.73%	9.61%
1829	1327	14	0.069	75.42%	14.77%	9.81%
1830	1310	14	0.071	75.17%	14.82%	10.01%
1831	1266	13	0.073	74.93%	14.87%	10.21%
1832	1261	13	0.076	74.68%	14.91%	10.41%
1833	1246	13	0.078	74.44%	14.96%	10.60%
1834	1239	12	0.081	74.20%	15.00%	10.80%
1835	1198	12	0.084	73.95%	15.05%	11.00%
1836	1186	12	0.087	73.71%	15.10%	11.19%
1837	1237	11	0.090	73.47%	15.15%	11.38%
1838	1281	11	0.093	73.23%	15.19%	11.58%
1839	1280	11	0.096	72.99%	15.24%	11.77%
1840	1160	11	0.099	72.75%	15.29%	11.96%
1841	1209	10	0.102	72.51%	15.34%	12.15%
1842	1206	10	0.106	72.28%	15.38%	12.34%
1843	1204	11	0.109	72.04%	15.43%	12.53%
1844	1279	11	0.113	71.80%	15.48%	12.72%
1845	1272	11	0.117	71.57%	15.53%	12.90%
1846	1259	12	0.121	71.34%	15.58%	13.09%
1847	1243	12	0.125	71.10%	15.63%	13.27%
1848	1253	12	0.129	70.87%	15.67%	13.46%
1849	1231	12	0.134	70.64%	15.72%	13.64%
1850	1226	13	0.138	70.41%	15.77%	13.82%
1851	1316	13	0.143	70.18%	15.82%	14.00%
1852	1291	13	0.148	69.95%	15.87%	14.18%
1853	1267	13	0.153	69.72%	15.92%	14.36%
1854	1243	14	0.158	69.49%	15.97%	14.54%
1855	1220	14	0.164	69.26%	16.02%	14.72%
1856	1212	14	0.169	69.04%	16.07%	14.89%
1857	1204	14	0.175	68.81%	16.12%	15.07%
1858	1196	14	0.181	68.59%	16.17%	15.24%
1859	1188	14	0.187	68.36%	16.22%	15.42%
1860	1180	14	0.193	68.14%	16.27%	15.59%
1861	1172	14	0.200	67.92%	16.32%	15.76%
1862	1175	14	0.207	67.69%	16.37%	15.93%
1863	1178	14	0.214	67.47%	16.42%	16.10%
1864	1181	14	0.221	67.25%	16.48%	16.27%
1865	1184	14	0.228	67.03%	16.53%	16.44%
1866	1221	15	0.236	66.81%	16.58%	16.61%
1867	1250	13	0.244	66.60%	16.63%	16.77%

1868	1255	13	0.253	66.38%	16.68%	16.94%
1869	1280	13	0.261	66.16%	16.73%	17.11%
1870	1295	13	0.270	65.94%	16.79%	17.27%
1871	1239	15	0.283	65.73%	16.84%	17.43%
1872	1267	15	0.296	65.51%	16.89%	17.60%
1873	1312	15	0.310	65.30%	16.94%	17.76%
1874	1283	13	0.325	65.09%	17.00%	17.92%
1875	1274	15	0.340	64.87%	17.05%	18.08%
1876	1237	13	0.355	64.66%	17.10%	18.24%
1877	1287	14	0.370	64.45%	17.16%	18.39%
1878	1280	13	0.386	64.24%	17.21%	18.55%
1879	1274	14	0.403	64.03%	17.26%	18.71%
1880	1258	14	0.420	63.82%	17.32%	18.86%
1881	1289	13	0.437	63.61%	17.37%	19.02%
1882	1318	13	0.454	63.40%	17.43%	19.17%
1883	1339	14	0.472	63.20%	17.48%	19.32%
1884	1373	13	0.491	62.99%	17.53%	19.48%
1885	1397	12	0.510	62.78%	17.59%	19.63%
1886	1461	14	0.527	62.58%	17.64%	19.78%
1887	1479	13	0.544	62.37%	17.70%	19.93%
1888	1484	13	0.562	62.17%	17.75%	20.08%
1889	1445	13	0.581	61.97%	17.81%	20.22%
1890	1498	13	0.600	61.76%	17.87%	20.37%
1891	1460	12	0.621	61.81%	17.95%	20.24%
1892	1443	11	0.642	61.86%	18.03%	20.11%
1893	1462	13	0.664	61.90%	18.11%	19.98%
1894	1433	12	0.686	61.95%	18.20%	19.86%
1895	1484	12	0.710	61.99%	18.28%	19.73%
1896	1494	12	0.727	62.04%	18.36%	19.60%
1897	1569	12	0.745	62.09%	18.45%	19.46%
1898	1613	13	0.763	62.13%	18.53%	19.33%
1899	1658	13	0.781	62.18%	18.62%	19.20%
1900	1729	14	0.800	62.23%	18.70%	19.07%
1901	1686	14	0.814	61.78%	18.97%	19.25%
1902	1681	14	0.827	61.33%	19.25%	19.43%
1903	1691	14	0.841	60.88%	19.52%	19.59%
1904	1698	14	0.856	60.44%	19.80%	19.75%
1905	1637	13	0.870	60.00%	20.09%	19.91%
1906	1634	14	0.884	59.57%	20.38%	20.05%
1907	1659	13	0.897	59.14%	20.67%	20.19%
1908	1619	14	0.911	58.71%	20.97%	20.32%
1909	1604	13	0.926	58.28%	21.27%	20.45%
1910	1631	15	0.940	57.86%	21.58%	20.56%
1911	1649	15	0.954	57.44%	21.89%	20.67%
1912	1669	15	0.967	57.07%	21.73%	21.21%
1913	1660	15	0.981	56.69%	21.57%	21.74%
1914	1670	14	0.996	56.32%	21.41%	22.27%
1915	1630	13	1.010	55.95%	21.25%	22.79%

1916	1638	16	1.040	55.59%	21.09%	23.32%
1917	1610	16	1.071	55.23%	20.94%	23.83%
1918	1527	16	1.103	54.87%	20.79%	24.35%
1919	1558	16	1.136	54.51%	20.63%	24.86%
1920	1632	24	1.170	54.15%	20.48%	25.37%
1921	1713	24	1.187	53.80%	20.33%	25.87%
1922	1899	22	1.205	53.45%	20.18%	26.37%
1923	1957	22	1.223	53.10%	20.03%	26.87%
1924	1861	23	1.241	52.75%	19.89%	27.36%
1925	1920	20	1.260	52.41%	19.74%	27.85%
1926	1884	18	1.276	52.06%	19.59%	28.34%
1927	2188	19	1.291	51.72%	19.45%	28.83%
1928	1953	18	1.307	51.39%	19.31%	29.31%
1929	2138	17	1.324	51.05%	19.17%	29.78%
1930	2086	17	1.340	50.72%	19.02%	30.26%
1931	2166	13	1.363	50.91%	19.22%	29.87%
1932	2181	13	1.387	51.09%	19.42%	29.48%
1933	2300	14	1.411	51.28%	19.62%	29.09%
1934	2369	14	1.435	51.47%	19.83%	28.70%
1935	2216	15	1.460	51.66%	20.03%	28.30%
1936	2022	14	1.496	51.86%	20.24%	27.90%
1937	2334	15	1.533	52.05%	20.45%	27.50%
1938	2320	15	1.571	52.24%	20.66%	27.09%
1939	2323	15	1.610	52.44%	20.88%	26.69%
1940	2145	17	1.650	52.63%	21.09%	26.28%
1941	2320	19	1.686	52.27%	21.41%	26.32%
1942	2269	19	1.724	51.90%	21.73%	26.37%
1943	2399	20	1.762	51.54%	22.06%	26.40%
1944	2513	20	1.800	51.18%	22.39%	26.43%
1945	2395	20	1.840	50.83%	22.72%	26.45%
1946	2560	27	1.873	50.48%	23.07%	26.46%
1947	2750	29	1.906	50.13%	23.41%	26.46%
1948	2717	31	1.940	49.78%	23.76%	26.46%
1949	2731	27	1.975	49.43%	24.12%	26.45%
1950	2771	27	2.010	49.09%	24.48%	26.43%
1951	2914	30	2.047	48.51%	24.89%	26.60%
1952	2914	29	2.084	47.94%	25.31%	26.76%
1953	3117	27	2.122	47.37%	25.73%	26.90%
1954	3234	28	2.161	46.81%	26.17%	27.03%
1955	3317	29	2.200	46.25%	26.60%	27.14%
1956	3416	30	2.250	45.71%	27.05%	27.24%
1957	3521	30	2.301	45.17%	27.51%	27.33%
1958	3571	27	2.353	44.63%	27.97%	27.40%
1959	3723	26	2.406	44.10%	28.44%	27.46%
1960	3900	29	2.460	43.58%	28.91%	27.50%
1961	4082	30	2.495	42.90%	29.23%	27.87%
1962	4470	26	2.530	42.23%	29.56%	28.22%
1963	4699	29	2.566	41.56%	29.88%	28.55%

1964	4925	32	2.603	40.91%	30.21%	28.87%
1965	5294	32	2.640	40.27%	30.55%	29.18%
1966	5504	32	2.738	39.64%	30.89%	29.47%
1967	5978	31	2.840	39.02%	31.23%	29.75%
1968	6558	31	2.946	38.41%	31.57%	30.02%
1969	6723	33	3.056	37.81%	31.92%	30.27%
1970	7396	34	3.170	37.21%	32.28%	30.51%
1971	8000	33	3.365	36.63%	32.63%	30.73%
1972	8655	33	3.571	36.06%	33.00%	30.95%
1973	9516	35	3.790	35.49%	33.36%	31.15%
1974	9364	43	4.023	34.94%	33.73%	31.33%
1975	8585	32	4.270	33.93%	33.82%	32.25%
1976	8908	33	4.484	33.90%	33.61%	32.49%
1977	9387	37	4.708	32.94%	33.11%	33.95%
1978	9577	38	4.943	31.27%	34.88%	33.85%
1979	9975	44	5.190	30.56%	34.97%	34.47%
1980	10242	48	5.450	28.56%	36.06%	35.38%
1981	10087	48	5.571	26.69%	36.51%	36.80%
1982	10214	50	5.694	25.88%	37.10%	37.02%
1983	9992	52	5.820	23.54%	35.42%	41.05%
1984	9574	57	5.948	23.76%	33.81%	42.44%
1985	9784	56	6.080	23.79%	34.70%	41.50%
1986	10780	50	6.205	21.93%	33.73%	44.34%
1987	11611	55	6.332	22.16%	34.53%	43.31%
1988	12536	58	6.462	20.88%	34.60%	44.52%
1989	13193	60	6.595	19.00%	34.94%	46.06%
1990	13917	59	6.730	17.92%	34.44%	47.64%
1991	14656	42	6.876	17.46%	33.55%	49.00%
1992	15113	50	7.024	11.50%	33.01%	55.50%
1993	15671	47	7.176	11.57%	32.75%	55.69%
1994	16791	51	7.331	11.76%	32.63%	55.62%
1995	16950	54	7.490	11.52%	32.05%	56.43%
1996	17194	53	7.666	12.28%	31.17%	56.55%
1997	18536	56	7.845	13.62%	31.33%	55.05%
1998	19412	56	8.029	13.61%	35.19%	51.20%
1999	20547	53	8.217	12.83%	34.45%	52.71%
2000	21497	57	8.410	12.80%	34.55%	52.65%
2001	21556	55	8.351	12.86%	33.83%	53.32%
2002	21739	51	8.293	12.51%	33.57%	53.93%
2003	21398	50	8.235	12.68%	32.18%	55.14%
2004	21135	53	8.177	12.28%	30.98%	56.73%
2005	22812	54	8.120	12.05%	30.39%	57.56%
2006	23852	56	8.235	11.91%	30.31%	57.78%
2007	25004	57	8.351	11.84%	30.24%	57.92%
2008	24575	59	8.469	11.44%	28.99%	59.57%
2009	25078	50	8.589	11.45%	27.80%	60.75%
2010	25589	55	8.710	11.20%	27.26%	61.55%
2011	25133	61	8.794	10.21%	26.85%	62.94%

2012	25743	63	8.880	10.81%	25.15%	64.04%
2013	25862	65	8.966	10.23%	23.70%	66.07%
2014	26717	66	9.052	8.65%	23.86%	67.49%
2015	27255	66	9.140	7.53%	24.35%	68.12%
2016	27726	65	9.222	6.91%	24.50%	68.59%
2017	28290	70	9.306	6.40%	24.74%	68.86%

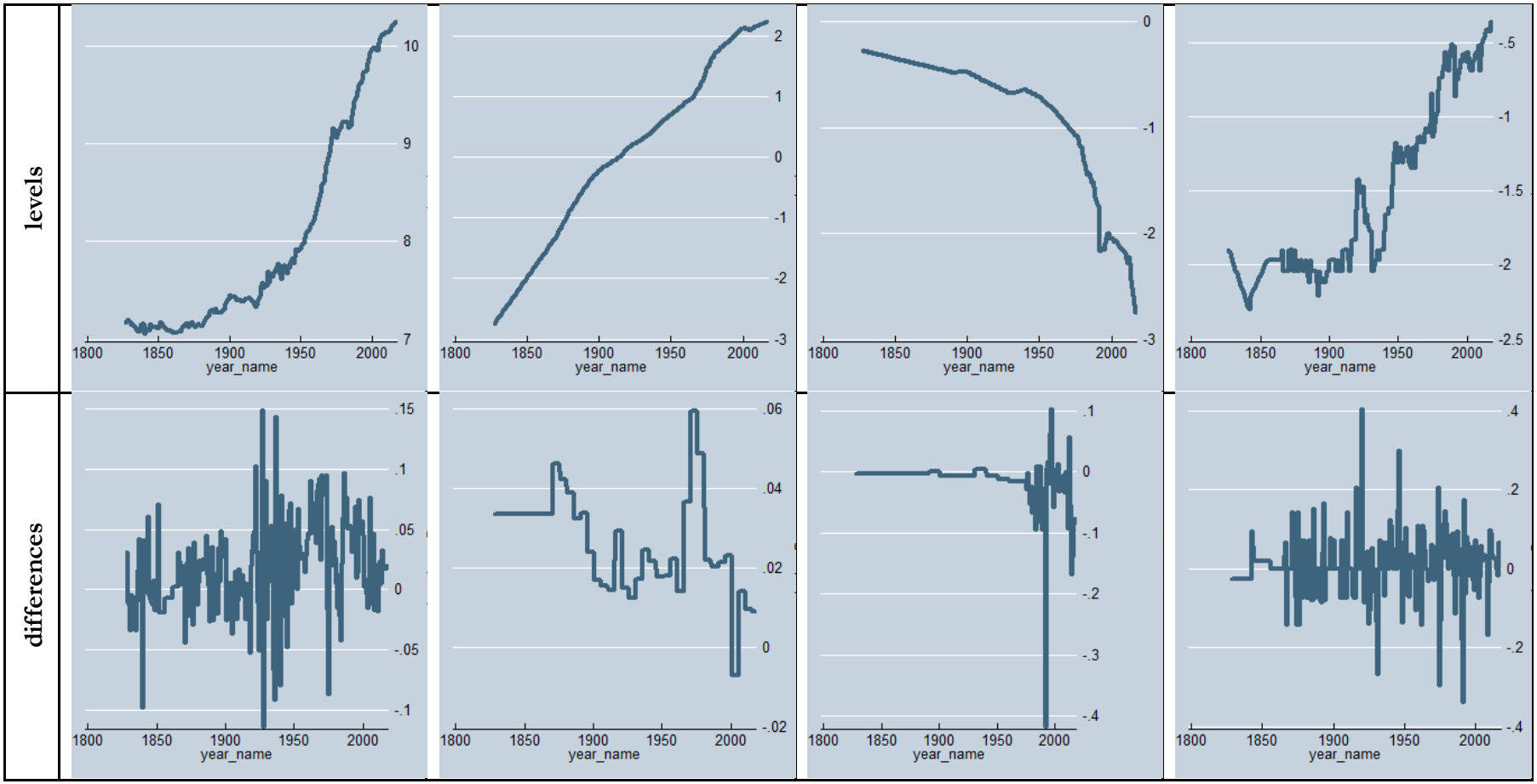

Figure A 1: Variables in levels and 1st Differences