
THE IMPACT OF (DISTINCT TYPES OF) PUBLIC INVESTMENT ON
VERY LONG ECONOMIC GROWTH: PORTUGAL, 1861 – 2020

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To Professor Aurora Teixeira, for being the best supervisor I could ask for.

To my grandparents and to my uncle, for the unconditional love and patience.

To my parents, for being my safe harbor.

In loving memory of my grandfather, Manuel da Silva Oliveira.

Resumo

Estudos que relacionam investimento público com crescimento económico e envolvam análises de muito longo prazo (mais de um século), abrangendo os estágios iniciais dos processos de industrialização dos países, são muito raros e, no caso português, inexistentes.

Com o objetivo de colmatar esta lacuna na literatura, a presente dissertação tem duas principais questões de investigação: 1) Qual é o impacto do investimento público no crescimento económico de um país no muito longo prazo?; e 2) Será que diferentes tipos de investimento público têm um impacto distinto no crescimento económico de muito longo prazo de um país?

Para responder a estas questões de investigação, recorreremos à análise de séries temporais de Portugal, entre 1861 e 2020. Os resultados dos testes de cointegração sugerem que, no muito longo prazo, um aumento de 1 ponto percentual no peso do investimento público no produto interno bruto (intensidade do investimento público) está associado a um aumento estatisticamente significativo de 1,46% do produto real *per capita*. Além disso, com base nos testes de causalidade de Granger, descobrimos que, no muito longo prazo, a causalidade ocorre do produto real *per capita* para a intensidade do investimento público, mas não o contrário. Assim, entre 1861 e 2020, o crescimento económico aumentou a intensidade do investimento público em Portugal, mas não foram encontradas evidências de que este último tenha precedido o primeiro. Os testes de cointegração sugerem ainda que o investimento público em máquinas e equipamentos é o que tem maior correlação no longo prazo com o crescimento económico, seguido do investimento público em construção civil, I&D, infraestruturas, educação e, por fim, saúde. Os resultados dos testes de causalidade mostram que o investimento público em máquinas e equipamentos, construção civil, educação e saúde causam (em termos de Granger) o produto real *per capita*, mas não foi encontrada evidência estatisticamente significativa de que o investimento público em I&D e em infraestruturas precedem o produto real *per capita*. Tal como para o investimento público global, verifica-se que o aumento do nível de vida material promove o aumento de todos os tipos de investimento público.

Códigos JEL: H50; O11; O40

Palavras-chave: Crescimento económico; Muito longo prazo; Investimento público; Tipos de investimento público; Portugal

Abstract

Studies that relate public investment with economic growth involving very long-time analyses (over one century), encompassing the earlier stages of countries' industrialization processes, are very rare and, in the Portuguese case, inexistent.

Aiming at filling this literature gap, the present dissertation has two main research questions: 1) What is the impact that public investment on a country's very long run economic growth?; and 2) Do distinct types of public investment have a different impact on a country's very long run economic growth?. For answering these research questions, we resort to time series analysis of Portugal, between 1861 and 2020.

The results of the cointegration tests suggest that in the very long run an increase in 1 percentage point in the ratio of public investment in gross domestic product (public investment intensity) is associated with a statistically significant increase of 1.46% in real product per capita. Moreover, based on Granger causality tests, we found that in the very long run causality runs from real product per capita to public investment intensity, but not the other way around. Thus, between 1861 and 2020 economic growth has enhanced public investment intensity in Portugal, but no evidence was found that the latter (Granger) preceded the former. Cointegration tests further suggest that by type of public investment as a ratio of real GDP, public investment in machinery and equipment is the one that has the largest long run correlation with economic growth, followed by building construction, R&D, infrastructures, education and health. The results of the causality tests show that public investment in machinery and equipment, building construction, education and health caused (in Granger terms) real product per capita, but no statistically significant evidence was found that public investment in R&D and infrastructures precede real product per capita. As in global public investment intensity, the increase in the material standard of living promotes the increase of all types of public investment.

JEL codes: H50; O11; O40

Keywords: Economic growth; Very long run; Public investment; Types of public investment; Portugal

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1. Introduction

The impact of public investment on economic growth is one of the most important and debated topics at the scientific and policy levels (Afonso & St. Aubyn, 2019).

Public investment is frequently linked to economic growth as productive public investment, i.e., public investment which generates additional output in excess of the servicing cost on the borrowing required to fund it (Makin, 2015), tends to contribute to raise countries' economic activities (Afonso & St. Aubyn, 2019). However, some studies (e.g., Rawat & Khan, 2020) underline that public investment may crowd out private investment by diverting scarce resources from their efficient usage, leading to a potential negative impact on economic growth.

Such a theoretical debate has spurred a considerable number of contributions that tried to figure out the direction and magnitude of the impact of public investment on economic growth. Some of these studies concluded that the impact is positive (e.g., Khanchaoui, Aboudi & Moudden, 2020; Modeste, 2021; Nhlengethwa, Matchaya, Greffiths & Fakudze, 2021), whereas others demonstrated that it is negative (e.g., Ghali, 1998; Makuyana & Odhiambo, 2019). Thus, at the empirical level the debate is far from settled or clear-cut (Ghani & Din, 2006; Aregbeyen & Mohammed, 2016; Qazi & Ammad, 2021), advising further investigation that embraces distinct realities and time spans.

Extant literature that relates public investment with economic growth is relatively abundant and has addressed a multitude of countries and periods resorting to distinct methodological approaches, involving both longitudinal / time series studies of single countries (e.g., Alodadi & Benhin, 2015; Domanska, 2020; Papagni, Lepore, Felice, Baraldi & Alfano, 2021) and panel data samples (e.g., Knight, Loayza & Villanueva, 1993; Museru, Toerien & Gossel, 2014).

Regarding the longitudinal / time series studies of single countries, albeit they have focused a relatively diverse set of countries, with higher incidence on high income economies, the vast majority of the studies has analyzed the period from 1950 onwards (e.g., Nazmi & Ramirez, 1997; Papagni et al., 2021; Qazi & Ammad, 2021), and particular types of public investment, such as public investment in global infrastructure (De Frutos, Gracia-Díez & Pérez 1998), port capital investment (Kawakami & Doi, 2004), and public investment in highway transportation infrastructure (Kustepeli, Gulcan & Akgungor, 2012). Studies in this

topic involving very long-time analyses (over one century), encompassing the earlier stages of countries' industrialization processes, are inexistent or very rare.

The adoption of a long-run perspective on the determinants of economic growth helps to understand the factors that matter the most for that growth, which can by itself be of great usefulness for policy makers (Wallis, Colson, & Chilosi, 2018). Moreover, since the dynamics of countries' earlier industrialization processes depend, to a large extent, on the degree of State intervention, namely through the use of public investment policies (Shafaeddin, 1998), it would be illuminating to quantitatively assess the effective impact of public investment on economic growth since the emergence of the countries' industrialization process. Finally, given the paucity of studies that analyze both the impact of global public and of different types of public investment (Yilmaz, 2018), empirical studies that address this issue would be of scientific value.

Aiming at filling this literature gap, the present dissertation has two main research questions: 1) What is the impact of public investment on a country's very long run economic growth?; and 2) Do distinct types of public investment impact differently on a country's very long run economic growth?

For answering these research questions, we resort to time series analysis of Portugal, more specifically, Johansen cointegration (Johansen, 1988) and Granger causality tests (Granger, 1969), between 1861 and 2020. Albeit several high quality contributions exist that analyzed the Portuguese case (e.g., Pereira & Andraz, 2006; Pereira & Pereira, 2020), these are limited to the last six decades and the impact of distinct types of public investment and economic growth is not yet clear cut, with some studies reporting positive (Pereira & Andraz, 2006; Pereira & Pinho, 2008; Pereira, Pereira & Rodrigues, 2017), and others (e.g., Pereira & Andraz, 2012; Domanska, 2020) negative impacts on economic growth. Thus, additional empirical evidence on the Portuguese case will contribute to assess the importance of public investment over distinct phases of Portugal's industrialization process and uncover which type of public investment has mattered the most for Portuguese very long run economic growth.

This dissertation is structured as follows. In Section 2 we present a comprehensive literature review on the main theories and empirical findings regarding the impact of public investment on economic growth. Section 3 addresses the methodological considerations and data description. Section 4 analyses the long term relation between real GDP per capita and (types

of) public investment in percentage of real GDP between 1861 and 2020 for the Portuguese economy. In Section 5 we summarize the main conclusions, limitations and avenues for further research.

2. Literature review

2.1. Key concepts

2.1.1. Public investment

According to the National Accounts statistics, public investment, excluding the variation of stocks, or public gross fixed capital formation, is composed by fixed tangible or intangible assets, covering machinery and equipment, vehicles, dwellings and other buildings (OECD, 2021). In other words, public investment includes assets whose purpose is the production of other goods and services for a period of more than a year (Valério, 1982).

Public investment is a part of public expenditures, and it leads to increases in public capital stock. Along with private capital, human capital, labor and others, public capital is classified as a production factor; therefore, public investment can be associated with economic growth (Afonso & St. Aubyn, 2019), i.e, increases in material living standards (Khanchaoui et al., 2020; Rawat & Khan, 2020; Modeste, 2021), reflected by the increase in the GDP per capita (Prettner & Werner, 2016).

It is important to highlight that the classification of public investment by types is a complex and often confusing matter in the sense that different studies use a set of very diversified categories, and in some cases the boundaries between public investment and public expenditures are not clearly defined (Ghali, 1998; Khanchaoui et al., 2020). Some authors consider different types of infrastructures - transportation and communication infrastructures (De Frutos et al., 1998), transportation, communication, government, education, health and social service infrastructures (Kalyvitis, 2003), electricity generation distribution and gas distribution infrastructures (Javid, 2019), agricultural water infrastructures (Nhlengethwa et al., 2021), telephone lines infrastructures (Moller & Wacker, 2017) or port capital infrastructures (Kawakami & Doi, 2004) -, whereas other authors refer to the areas of application - health care (Pereira et al., 2017), R&D (Soete, Verspagen & Ziesemer, 2021) or education (Teles & Andrade, 2008).

Besides considering different classifications of public investment, some authors consider some categories of public expenditures (e.g., education, social) as public investment (Ghali, 1998; Khanchaoui et al., 2020). Indeed, a significant part of public investment takes the form of infrastructure spending, however, other types of expenses, such as expenses of a more

current nature, most notably health and education expenses, contribute as well to capital formation, and are therefore considered public investment (United Nations, 2009).

2.1.2. Economic growth

Regarding economic growth, most authors consider that it can be defined as the evolution of material living standards, more concretely, the Gross Domestic Product (GDP) evolution (Khanchaoui et al., 2020; Rawat & Khan, 2020; Modeste, 2021) or the GDP per capita evolution (Prettner & Werner, 2016).

The main difference between the views of the different authors is that some of them use growth rates as the indicator of economic growth (De Frutos et al., 1998; Prettner & Werner, 2016; Al Kharusi & Ada, 2018; Yilmaz, 2018; Makuyana & Odhiambo, 2019), whereas others use the levels (Ghani & Din, 2006; Khanchaoui et al., 2020; Rawat & Khan, 2020; Modeste, 2021; OECD, 2021). According to the latter, when using the GDP or GDP per capita levels as the indicator of economic growth, the evolution of the indicator over time reflects its growth, while if one uses growth rates instead, the evolution of the indicator represents the acceleration or deceleration of economic growth.

2.2. Relation between (types of) public investment and economic growth: Theoretical framework

The impact of public investment on economic growth can be rationalized and explained resorting to three main schools of economic thought (Rawat & Khan, 2020): the Keynesian, the Neoclassical, and the New endogenous growth theories. These perspectives consider different channels through which public investment impacts economic growth.

The Keynesian approach considers that public investment affects economic growth through productivity and aggregate demand mechanisms. Specifically, the productivity mechanism acts through the complementarity between public and private investment and the effect of crowding-in private investment (Anderson, de Renzio & Levy, 2006). Accordingly, public investment impacts economic growth through its effect on the production and on the productivity of private investment. In this vein, public investment creates good conditions for private investment, increasing its productivity and reducing its cost of production

(Xiaoming & Yanyang, 2014). To summarize, public investment crowds-in private investment, contributing to economic growth.

Besides productivity, the Keynesian perspective establishes that public investment impacts on economic growth through the aggregate demand mechanism. Public investment stimulates economic growth through the multiplier effect on output (Bah & Kpognon, 2021). Accordingly, public investment increases aggregate demand, which leads to an expansion of the production, creating jobs (Khanchaoui et al., 2020). Public investment increases aggregate demand because, as public investment is a part of public expenditure (Afonso & St. Aubyn, 2019), an increase in public investment leads to an increase in public expenditures, and the latter boosts consumers' buying power and, thus, consumption (Khanchaoui et al.). In the long run, public investment increases the economic supply potential, which will also increase the production (Abiad, Furceri, & Topalova, 2016; Felice, 2016). According to Abiad et al. (2016), public investment raises the economic supply potential because the rise in the infrastructure capital stock results in productive capacity growth.

In the neoclassical approach, public investment impacts on economic growth through efficiency, aggregate demand, and productivity mechanisms. According to this approach, public investment diverts scarce resources from their efficient usage (Rawat & Khan, 2020), undermining economic growth. Moreover, it is likely to penalize economic growth by crowding-out private investment (Qazi & Ammad, 2021) or by demanding an increase in taxes (Bah & Kpognon, 2021), which ultimately depresses aggregate demand. This happens, according to this perspective, because the increase in public investment tends to entail a rise in the tax collection and/or a rise in the public demand for funds in the capital market, which results in an increase in the interest rate (Aschauer, 1989; Afonso & St. Aubyn, 2008). On the one hand, when public investment is financed by an increase in the tax collection, consumers are affected by a negative wealth effect and consumption decreases, not the least because consumers expect that they will pay higher taxes in the future (Bah & Kpognon, 2021). On the other hand, when governments borrow money to finance public investment and, consequently, there is a rise in the public demand for funds in the capital market, the interest rate increases, leading to a reduction of private investment, which results in a reduction of aggregate demand and, therefore, in a decrease of economic growth (Bah & Kpognon, 2021). Since there is a crowding-out effect of public investment on private

investment, this is likely to undermine labor productivity, and through this channel, economic growth (Qazi & Ammad, 2021).

The endogenous growth perspective establishes that not all public investment matters for economic growth (Barro, 1990; Makuyana & Odhiambo, 2019); only certain types of public investment, namely those in productive infrastructure, health, and education can promote economic growth (Khanchaoui et al., 2020) through the increase of private capital formation and by enhancing efficiency, and stimulating productivity (Beifert, 2016; Bom & Ligthart, 2014; Wang, 2005).

Efficiency reflects the amount of physical infrastructure provided by a given amount of public investment (Miyamoto, Baum, Gueorguiev, Honda & Walker, 2020). The greater the amount of physical infrastructure created for a given level of public investment or the lower the level of public investment for a given amount of physical infrastructure created, the more efficient the public investment is (Mandl, Dierx, & Ilzkovitz, 2008). Additionally, public investment in human capital fosters research and development (R&D) and innovation, which increases economic growth (Khanchaoui et al., 2020), since R&D leads to accumulation of knowledge that is crucial to technological progress and that, consequently, leads to higher productivity (Romer, 1986). Productivity translates in the way the economy is affected by the physical infrastructure created (Miyamoto et al., 2020). In the productivity mechanism there are three possible effects of public investment in economic growth (Anderson et al., 2006): 1) complementarity between public and private capital: as long as public and private capital complement each other, a rise in public investment results in an increase of the economic growth rate, at least to some extent, because there is a rise in the marginal productivity of private capital; 2) crowding-in private investment: public investment crowds in private investment for low levels of public investment; and 3) market integration: public investment contributes to market integration, and consequently to economic growth, since it improves infrastructures related to transportation and communication.

The rationale of the aggregate demand mechanism relates to the impact it has on the level of national income. Due to wage and/or prices rigidity, economies' level of employment is often below the full employment level. When that is the case, a rise in public investment results in an instantaneous increase of the national income (Anderson et al., 2006). Furthermore, another channel related to the aggregate demand mechanism through which public investment impacts economic growth is increased national savings channel. Public

investment can lead to an increase in the rate of national savings. If the government taxes consumption and invests the proceeds, it can increase the saved portion of national income. For such a situation to occur, the private savings rate cannot drop significantly in the case that public investment leads to a reduction in the profitability of private investment (Anderson et al.).

Regarding the different types of public investment namely, public investment in infrastructures, health, R&D and education, the mechanisms through which they impact economic growth are, in general, different.

Infrastructures contribute to the urbanization, industrialization, exports growth and economic development of countries (Rostow, 1960; Kim, 2006). Public investment in infrastructures, namely in transportation and communication infrastructures, contributes to economic growth by facilitating the movement of goods and services, reducing operating time and costs, increasing productivity, and facilitating access to markets (Kustepeli et al., 2012). This means that public investment in infrastructures affects economic growth through the productivity mechanism (public investment in infrastructures increases productivity) and the efficiency mechanism (public investment in infrastructures reduces operating time and costs, while also facilitating access to markets). Besides this, public investment in economic infrastructures contributes positively to private agents' investment plans and makes the private sector more productive (Ntembe, Amin & Tawah, 2018), which ultimately contributes to economic growth. Public investment in infrastructures also affects economic growth also through the aggregate demand mechanism. Indeed, according to Pereira et al. (2017), the construction of health care infrastructures has short-term effects on the demand of the economy, spreading to the rest of the economy. Gradually, those infrastructures need maintenance, which makes the effects on demand last longer. Moreover, over time, the new infrastructures contribute to economic performance, productivity and to better health outcomes, which translates into long-term effects on the supply of the economy. In addition, the construction of these infrastructures contributes to the development of the regions where they are located.

According to Cylus, Permanand and Smith (2018), health care, as an industry, contributes significantly to employment, which means that public investment in health care affects economic growth through the aggregate demand mechanism. A rise in employment leads to an increase in aggregate demand, which contributes to economic growth. Aside from creating

jobs, health systems can affect economic growth through their impact on scientific industries. Furthermore, health systems and, thus, public investment in health care, positively contribute to population health and, consequently, to labor productivity (Cylus et al., 2018). Thereby, public investment in health care influences economic growth also through the productivity mechanism.

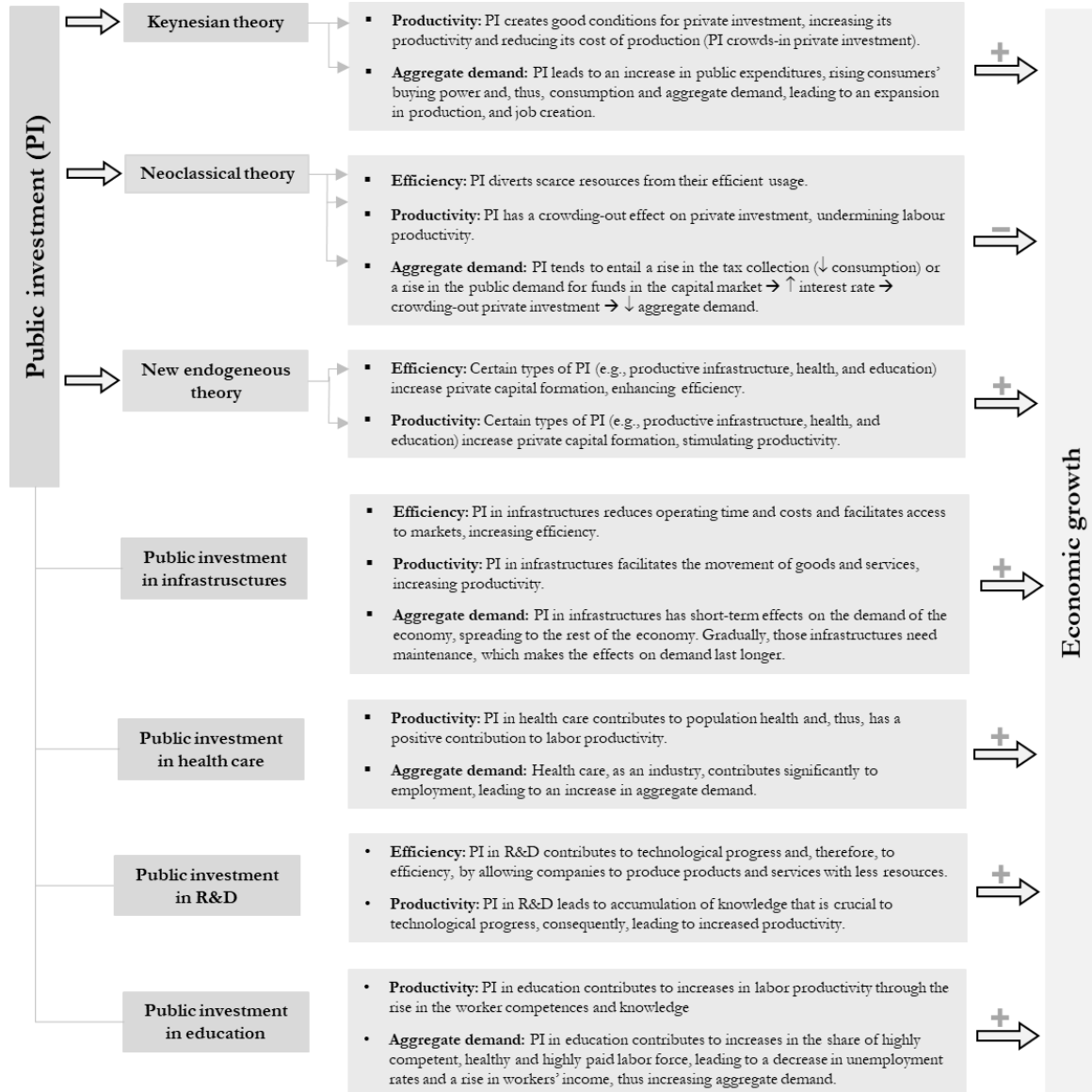


Figure 1: Theoretical framework

Source: Own elaboration.

Economic growth is mainly driven by productivity growth (Kuznets, 1966; Maddison, 2007) and the latter is mainly driven by technological progress (Abramovitz, 1956; Solow, 1957).

This means that R&D can be an important source of economic growth. Public investment in R&D impacts economic growth through the efficiency and productivity mechanisms. This is because R&D leads to accumulation of knowledge that is crucial to technological progress and that, consequently, leads to productivity and economic growth (Romer, 1986). The technological progress contributes to efficiency, namely by allowing companies to produce products and services with fewer resources (Thatcher & Oliver, 2015).

Public investment in education leads to economic growth through the productivity mechanism: education contributes to the increase of labor productivity, through the rise in the worker competences and knowledge (Hien, 2018). Besides the productivity mechanism, economic growth is impacted by public investment in education through the aggregate demand mechanism. Public investment in education fosters the creation of a highly skilled labor force, since education leads to an improvement in the labor force quality, which leads to a rise in the workers' income (Hien, 2018). This rise manifests in an increase in the aggregate demand, which results in economic growth. In addition, public investment in education contributes to the decrease of unemployment rates (Hien, 2018), which also leads to an increase in aggregate demand.

2.3. Relation between (types of) public investment and economic growth: Empirical evidence

Evidence about the impact of public investment on economic growth is mixed (see Table 1). Thus, at the empirical level, the outcome is still ambiguous (Ghani & Din, 2006; Aregbeyen & Mohammed, 2016; Qazi & Ammad, 2021).

Considering public investment as a whole, most of the empirical literature, regardless the methodology used - 2SLS or 3SLS (Nazmi & Ramirez, 1997; Everaert & Heylen, 2004; Aregbeyen & Mohammed, 2016); VAR/VECM techniques (Everaert, 2003; Sial, Hashmi & Anwar, 2010; Alodadi & Benhin, 2015; Cebi & Ozdemir, 2021; Qazi & Ammad, 2021), ARDL (Makuyana & Odhiambo, 2017; Modeste, 2021) or GMM (Zou, 2006) -, the level of development of countries or the period analyzed, found that public investment enhances economic growth, measured by real GDP (e.g., Everaert, 2003; Alodadi & Benhin, 2015) or the growth of real GDP (e.g., Zou, 2006; Cebi & Ozdemir, 2021).

Several explanations are presented for the positive influence of public investment on economic growth. Nazmi and Ramirez (1997), who studied the impact of public investment

on the economic growth of Mexico between 1950 and 1990, pointed out that even though public investment crowds out private investment, indirectly it can stimulate private investment through the output variable and through an accelerator effect. On the other hand, Everaert and Heylen (2004) concluded that a rise in government investment increased the productive capacity of the Belgian economy from 1970 to 1996. Zou (2006), who analyzed both Japan and the USA's case between 1958 and 1997, noticed that in Japan public investment contributed to economic growth in the same way than private investment, while in the USA private investment had a greater importance than public investment, even though public investment also contributed positively to economic growth. The author pointed out that, while in the United States of America the market system seems to have an enormous importance, in Japan it is combined with the role of government, which can explain the stronger impact of the Japanese public investment on its economic growth in comparison to the USA.

The studies that report a negative or null impact of global public investment on economic growth referred, respectively, to lower-middle (Tunisia - Ghali, 1998; Pakistan - Rawat & Khan, 2020) and high-income (Germany - Mitnik & Neumann, 2003; Greece - Angelopoulou & Philippopoulos, 2007) economies. Rawat and Khan (2020) pointed out that a possible justification for the negative impact of public investment on the economic growth of Pakistan from 1973 to 2015 could be the inefficiency of the state in the application of investment, which led to non-productive projects. In addition, the authors referred that many of the developing states have certain issues that result in a negative impact of public investment, such as weak institutions, bad governance and corruption. All these characteristics (inefficient public investment, weak institutions and bad governance) divert the resources from productive use and crowd out private investment, reducing economic growth. Ghali (1998) observed a negative impact of public investment on Tunisian economic growth in the long run between 1963 and 1993, which was associated with a crowding-out effect on private investment. This can be explained by the fact that in Tunisia, public investment is implemented by state-owned enterprises which are inefficient and very dependent from subsidies, reducing the chances for private investment.

Regarding the different types of public investment, most of the empirical literature, regardless the methodology used – OLS/FMOLS (Javid, 2019; Nhlengethwa et al., 2021); VAR/VECM techniques (De Frutos et al., 1998; Pereira & Andraz, 2006; Pereira & Andraz,

2010; Pereira et al., 2017; Kim, Wang, Park & Petalcorin, 2021); ARDL (Ntembe et al., 2018); GMM (Moller and Wacker, 2017); instrumental variables estimation (Kalyvitis, 2003); or a descriptive analysis (Hien, 2018) -, the level of development of countries or the period analyzed, found that the different types of public investment enhance economic growth.

Javid (2019), who concluded that public investment in infrastructures had a positive impact on the economic growth of Pakistan between 1972 and 2015, argued that this type of public investment can have a significant influence on private capital formation through the provision of the needed infrastructure, namely roads, electricity and telecommunications, among others. Accordingly, Kim et al. (2021) pointed out that public investment in infrastructures contributed to the Chinese economic growth in the long run through the rise in productivity of both enterprises and industries. In addition, Kim et al., who found that public investment in R&D had a greater impact on the Chinese output than public investment in infrastructures between 1985 and 2015, mentioned that China should implement a strategy based on productivity and innovation to support its growth.

Focusing on the Portuguese economy, Pereira et al. (2017) found that from 1978 to 2011 public investment in health care had a significantly positive contribution to the Portuguese output, as well as to employment and private investment, which in turn also contributed to economic growth.

Regarding public investment in education, Hien (2018) uncovered that this type of investment stimulates economic growth, since it contributes to a higher-skilled labor force and to better working conditions, through the reduction of poverty and improvements in the intellectual level of the general population.

The studies that report a negative or null impact of specific types of public investment on economic growth referred to fixed capital investment (Makuyana & Odhiambo, 2019; Domanska, 2020), physical capital investment (Ghani & Din, 2006), social security spending (Pereira & Andr  z, 2012) and social security and social protection investment (Pereira & Andr  z, 2014).

Ghani and Din (2006), who concluded that public investment had a negative, but not significant, impact on the economic growth of Pakistan between 1973 and 2004, mentioned that, and in accordance with Devarajan, Swaroop and Zou (1996), public investment can have adverse effects due to misallocation of resources towards unproductive capital expenditures. On the other hand, according to Pereira and Andr  z (2014), the negative

impact of social spending on the economic growth of the United States of America from 1970 to 2007 was the reflection of the negative effect of social spending on unemployment.

The Portuguese case is aligned with the remaining literature in this topic, with most of the empirical literature, regardless the period analyzed, finding that the different types of public investment contribute positively to economic growth (Pina & Aubyn, 2005; Pereira & Andraz, 2006; Pereira & Pinho, 2008; Pereira & Andraz, 2010; Pereira et al., 2017). In accordance to the literature regarding other countries, the studies that report a negative impact of specific types of public investment on the Portuguese economic growth referred to fixed capital investment (Domanska, 2020) and social security spending (Pereira & Andraz, 2012).

Table 1: Synthesis of the relevant empirical literature

Period of analysis	Group of countries*	Authors (Year)	Countries	Period	Public investment type	Economic growth variable and proxy	Relation between PI and EG	Methodology
≤30 years	High-income economies	Everaert & Heylen (2004)	Belgium	1970-1996	Global	Real output	+	Three-stage least squares (3SLS); Simulations
		Mitnik & Neumann (2003)	Germany	1968-1994	Global	Growth rate of GDP per capita	0	Moving window least squares (MWLS)
		Al Kharusi & Ada (2018)	Oman	1990-2015	Fixed capital investment	Growth rate of real GDP	+	Autoregressive Distributed Lag (ARDL) cointegration approach
		Pereira & Andraz (2006)	Portugal	1976-1998	Public investment in transportation infrastructures	Output	+	Vector autoregressive (VAR)/Error Correction Model (ECM)
		Pereira & Pinho (2008)	Portugal	1976-2003	Public investment in durable goods; public investment in construction; public investment in equipment (which includes transportation and other equipment)	Output (measured in millions of euros in 1995 prices)	+	VAR approach
		Pereira & Andraz (2010)	Portugal	1980-1998	Investments in toll-free highways (SCUTS)	GDP	+	VAR approach
		Domanska (2020)	Portugal; Poland	1996-2017	Fixed capital investment	GDP growth	- for Portugal; + for Poland	ARDL models
	Upper-middle income economies	De Frutos, Gracia-Diez & Perez-Amaral (1998)	Spain	1964-1992	Public investment in infrastructure	Growth rate of private gross domestic product (GDP)	+	Vector Autoregressive Moving Average (VARMA) model
		Kim, Wang, Park & Petalcorin (2021)	China	1985-2015	Investment in infrastructure, Investment in manufacturing, Investment in R&D	Gross national income	+ for investment in infrastructure; - for investment in manufacturing; + for investment in R&D	Structural vector autoregression (SVAR) model; VECM
	Lower-middle income economies	Cebi & Ozdemir (2021)	Turkey	1990-2015	Fixed capital investment	Moving average real GDP growth rate	+	Local projection method
		Nhlengethwa, Matchaya, Greffiths & Fakudze (2021)	Kingdom of Eswatini	2000-2017	Agricultural water infrastructure investments	GDP	+	Ordinary Least Squares (OLS)
		Ghali (1998)	Tunisia	1963-1993	Global	Logarithm of real GDP	- in the long run; 0 in the short run	VAR; VECM
		Hien (2018)	Vietnam	2010-2017	Public investment in education and training	GDP growth	+	Descriptive analysis
	Low-income economies	Moller & Wacker (2017)	Ethiopia	1996-2013	Public infrastructure investment	Real PPP GDP per capita	+	System Generalized Method of Moments (GMM)
		Tchereni, Sekhampu & Ndovi (2013)	Malawi	1975-2003	Global	GDP growth rate	+	VECM
30-50 years	High-income economies	Everaert (2003)	Belgium	1953-1996	Global	Real output	+	Cointegrated VAR model; VECM
		Kalyvitis (2003)	Canada	1955-1999	Investment in public (infrastructural) capital	GDP per capita growth rate	+	Instrumental Variables estimation
		Kalaitzidakis & Kalyvitis (2005)	Canada	1956-1993	Capital expenditures	Three-Year Forward Moving Average of GDP per Capita Growth Rate	+ and - (inverse U-shaped relationship)	GMM
		Angelopoulou & Philippopoulos (2007)	Greece	1960-2000	Global	Growth rate of real GDP per capita in constant prices	+ but not significant	Least square regressions

Period of analysis	Group of countries*	Authors (Year)	Countries	Period	Public investment type	Economic growth variable and proxy	Relation between PI and EG	Methodology
		Zou (2006)	Japan; USA	1958-1997	Global	Growth changes in GDP	+ for Japan; + for USA but almost 0	GMM and Ordinary Least squares (OLS)
		Kawakami & Doi (2004)	Japan	1966-1997	Port capital	Logarithm of real GDP	+	Lag-augmented VAR
		Pina & Aubyn (2005)	Portugal	1960-2001	Investment in physical public capital	GDP growth	+	Cointegrated VAR
		Pereira & Andr�az (2012)	Portugal	1970-2007	Social security spending	GDP	-	VAR model
		Pereira, Pereira & Rodrigues (2017)	Portugal	1978-2011	Public health care investments	GDP	+	VAR model
		Alodadi & Benhin (2015)	Saudi Arabia	1970-2011	PI in non-oil sectors	Real GDP	+ in the long term; not significant in the short term	Johansen method for cointegration – VAR; VECM
		Pereira & Andr�az (2014)	United States	1970-2007	Social security and social protection	GDP	-	VAR model
	Upper-middle income economies	Modeste (2021)	Guyana	1980-2017	Global (public capital goods investment)	Real GDP	+	Conditional ARDL framework
		Nazmi & Ramirez (1997)	Mexico	1950-1990	Global PI	GDP growth	+	Two-stage least squares (2SLS)
		Kustepeli, Gulcan & Akgungor (2012)	Turkey	1970-2005	PI in highway transportation	Annual growth in GNP (Gross National Product) for model 1; real GNP for model 2	+ for model 1 a, 2 a and 2 b; - for model 1 b	Granger causality test and Johansen cointegration
		Ntembe, Amin & Tawah (2018)	Cameroon	1977-2015	Social and economic infrastructure investment	Natural logarithm of real gross domestic product (RGDP)	+ in the long run and in the short run	ARDL cointegration estimation
		Khanchaoui, Aboudi & Moudden (2020)	Morocco	1980-2018	Capital investment excluding capital investment in education and health	Real GDP	+	ARDL model
		Aregbeyen & Mohammed (2016)	Nigeria	1970-2010	Global	Real GDP growth	+	2SLS and 3SLS
	Lower-middle income economies	Qazi & Ammad (2021)	Pakistan	1964-2014	PI in all sectors plus general PI; physical investment; social investment; energy investment; infrastructure investment; health investment; education investment	Output	+ for general PI and for all types of PI	VAR/VECM technique
		Javid (2019)	Pakistan	1972-2015	Infrastructure investment	GDP per worker	+	Fully modified ordinary least squares (FMOLS)
		Ghani & Din (2006)	Pakistan	1973-2004	Physical capital investment	GDP	0 (- though insignificant impact)	VAR; ECM model
		Sial, Hashmi & Anwar (2010)	Pakistan	1973-2008	Global	GDP	+ in the long run; 0 in the short run (- though insignificant impact)	VAR; OLS
		Rawat & Khan (2020)	Pakistan	1973-2015	Global	Real GDP	- in the long run; 0 in the short run	ARDL model
		Makuyana & Odhiambo (2017)	Zimbabwe	1970-2014	Global	GDP	+	ARDL-bounds testing approach
		Makuyana & Odhiambo (2019)	Malawi	1970-2014	Gross fixed capital investment	Annual growth rate of real gross domestic product	- in the short run; 0 in the long run	ARDL-bounds testing approach
≥50 years	High-income economies	Papagni, Lepore, Felice, Baraldi & Alfano (2021)	Italy (South)	1951-2011	Global	Real GDP per unit of labor	+ in the whole period, but there are different impacts of public investment on growth over time	VECM; FMOLS; Dynamic OLS (DOLS)

Note: + / - : positive/ negative; 0 – no statistical significance. *See WB classification (see <https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups>): High-income economies; Upper-middle-income economies; Lower-middle-income economies; Low-income economies. Grey cells identify the studies that focused on global public investment.

Source: Own elaboration

3. Methodology

3.1. Research question and econometric specification

The main objective of the present dissertation is to assess the extent to which it is possible to find, in the very long run, from 1861 to 2020, a stable relation between (distinct types of) public investment and Portuguese economic growth, and whether the eventual causality runs from public investment to economic growth or the other way around. Bearing in mind that the underlying research question involves the assessment of the impact of a given variable on another, a quantitative research is the appropriate methodology to follow (Shields & Twycross, 2003; Yin, 2018). This decision can be explained by the fact that the quantitative methodology should be used when something needs to be measured, while the qualitative methodology should be used when the objective is to describe a certain situation and investigate it in depth (Shields & Twycross, 2003).

The relevant empirical literature involving longitudinal analyses resorts to several methods (see Table 1): ordinary least squares (OLS) (Sial et al., 2010; Nhlengethwa et al., 2021), two stage least squares (2SLS) (Nazmi & Ramirez, 1997; Aregbeyen & Mohammed, 2016), three stage least squares (3SLS) (Everaert & Heylen, 2004; Aregbeyen & Mohammed, 2016), Generalized Methods of Moments (GMM) (Zou, 2006; Moller & Wacker, 2017), and time series, most notably Autoregressive Distributed Lag (ARDL) (Domanska, 2020; Khanchaoui et al., 2020), and Vector autoregressive (VAR)/Error Correction Model (VECM) (Ghali, 1998; Pina & Aubyn, 2005; Pereira et al., 2017; Tchereni et al., 2013).

Since the relevant variables in the analysis are often non-stationary, the use of conventional estimation methods (e.g., OLS) would lead to incorrect statistical inference (Shrestha & Bhatta, 2018). Thus, we will resort to time series methods, in which case two alternatives are adequate: cointegration methods, specifically the Johansen's (1988) cointegration technique, in case all variables are integrated of order one (that is, they are stationary in differences), or ARDL, if variables are integrated of different order. To check the order of integration, we resort to graphical analyses of the variables in levels and in their first differences, complemented by the Augmented Dickey-Fuller (ADF) (Dickey & Fuller, 1981) and Phillips Perron (PP) (Phillips & Perron, 1988) tests. In the event that one or more time-series are cointegrated, a Granger causality may exist between them, either one-way or in both directions (Granger, 1969).

The data on public investment and the distinct types of public investment (in percentage of the real GDP) is gathered from combining several data sources, namely those of Mata (1985), Valério (1982), PORDATA, and Banco de Portugal. For the real GDP per capita data is gathered from the Maddison Project Database, version 2020 (Bolt & van Zanden, 2020) and PORDATA.

3.2. *Proxies for the relevant variables*

3.2.1. Economic growth

Economic growth can be operationalized in levels or in growth rates. When using the real GDP or real GDP per capita levels as the indicator of economic growth, the evolution of the indicator over time reflects its growth, while if one uses growth rates instead, the evolution of the indicator represents the acceleration or deceleration of economic growth. In accordance, as proxy for economic growth, we use the real GDP per capita level. Out of the 41 empirical studies summarized in Table 1, 25 (61%) used the real GDP/GNP (or GDP/GNP per capita) in levels (e.g., Javid, 2019; Papagni et al., 2021) instead of growth rates (e.g., Kalaitzidakis & Kalyvitis, 2005; Cebi & Ozdemir, 2021).

The real GDP per capita data is gathered from the Maddison Project Database, version 2020 (Bolt & van Zanden, 2020) and PORDATA.¹ The Maddison Project Database 2020 provides data of the Portuguese real GDP per capita for the period up to 2018, in 2011US\$. This time series has missing data in the period between 1862 and 1864. PORDATA offers a series of the Portuguese real GDP per capita from 1960 to 2020 in euros, in constant (2016) prices. This data is gathered from “INE – Contas Nacionais Anuais” and “INE – Estimativas Anuais da População Residente”. We interpolate the missing values in the period from 1862 to 1864 using the annual average growth rate between years of available data. Regarding the period from 2018 to 2020, we used linear interpolation based on the annual growth rate implicit in PORDATA's series.

Figure 2 depicts the evolution of the real GDP per capita for the Portuguese economy over the period in analysis.

¹ In [https://www.pordata.pt/Portugal/PIB+per+capita+\(base+2016\)-2297](https://www.pordata.pt/Portugal/PIB+per+capita+(base+2016)-2297), last accessed February 2022.

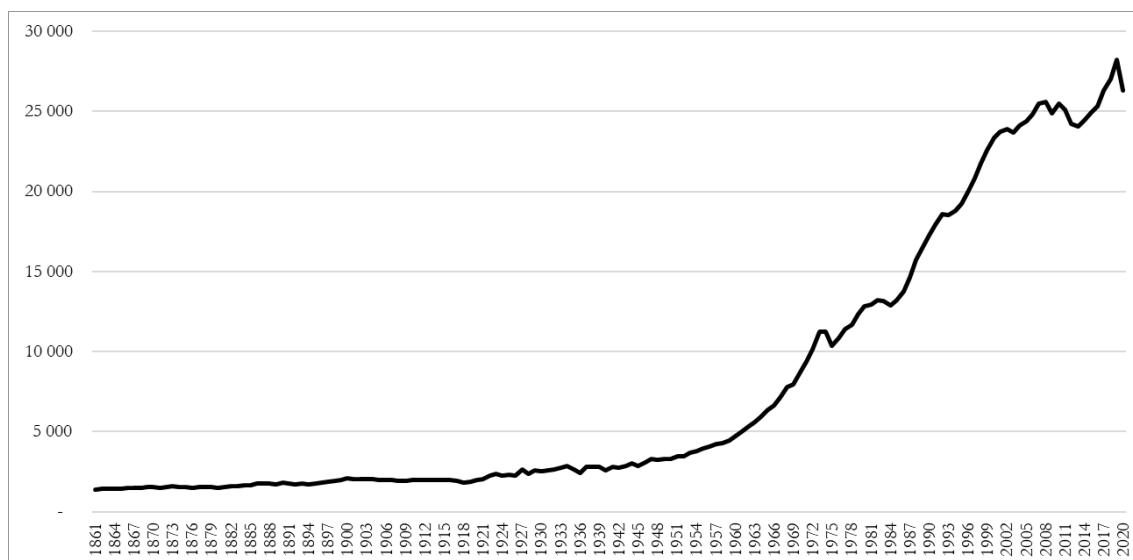


Figure 2: Real GDP per capita in 2011US\$, Portugal, 1861-2020

Note: Missing values were calculated using linear interpolation.

Source: Own elaboration based on data from Bolt & van Zanden (2020) and PORDATA.

3.2.2. Global public investment

A series for global public investment was constructed based on data from Mata (1985) for the period from 1862 to 1914, Valério (1982) for the years between 1915 and 1947, Banco de Portugal (2000) for the interval 1948-1995, and PORDATA² for the period from 1996 to 2020. These series have missing data for the years 1863-1864, 1869, 1871, 1873-1874, 1878, 1880-1881 and 1898-1907. For those years, we used the annual average growth rate between years of available data and interpolated the missing values.

The data from Mata (1985) consists in public investment in *contos*, that is, one thousand of *escudos*, whereas Valério's (1982) series consists in public investment in thousands of *contos*. Banco de Portugal's data comprises gross fixed capital formation of public administrations in million *escudos* and data from PORDATA comprises gross fixed capital formation of public administrations in million euros.

Since we will use the ratio between public investment and the real GDP, i.e., public investment as a percentage of real GDP, we use the real GDP data in the same currency and monetary units as the ones of global public investment data. Therefore, we gathered real

² In

[https://www.pordata.pt/Portugal/Investimento+Forma%20a7%20a3o+bruta+de+capital+fixo+por+sector+institucional+\(base+2016\)-2324](https://www.pordata.pt/Portugal/Investimento+Forma%20a7%20a3o+bruta+de+capital+fixo+por+sector+institucional+(base+2016)-2324), last accessed February 2022.

GDP data from INE (2001) for the period between 1861 and 1952, Banco de Portugal (2000) for the years between 1953 and 1995 and PORDATA³ for the interval 1996-2020.

Real GDP data from INE (2001) is in thousands of *contos*. Thus, we divided the data from Mata (1985) by 1,000 for the period from 1861 to 1914 to express it in *contos*, in accordance with data from INE (2001). Since public investment data from Valério (1982) is in thousands of *contos*, it is directly comparable to real GDP data from INE (2001). Real GDP data from Banco de Portugal from 1953 to 1995 is in million *escudos* just like the public investment data used in that period. Lastly, real GDP data from PORDATA is in million euros, in accordance with the data for public investment used in the period from 1996 to 2020.

The series of global public investment as a percentage of real GDP is shown in Figure 3.

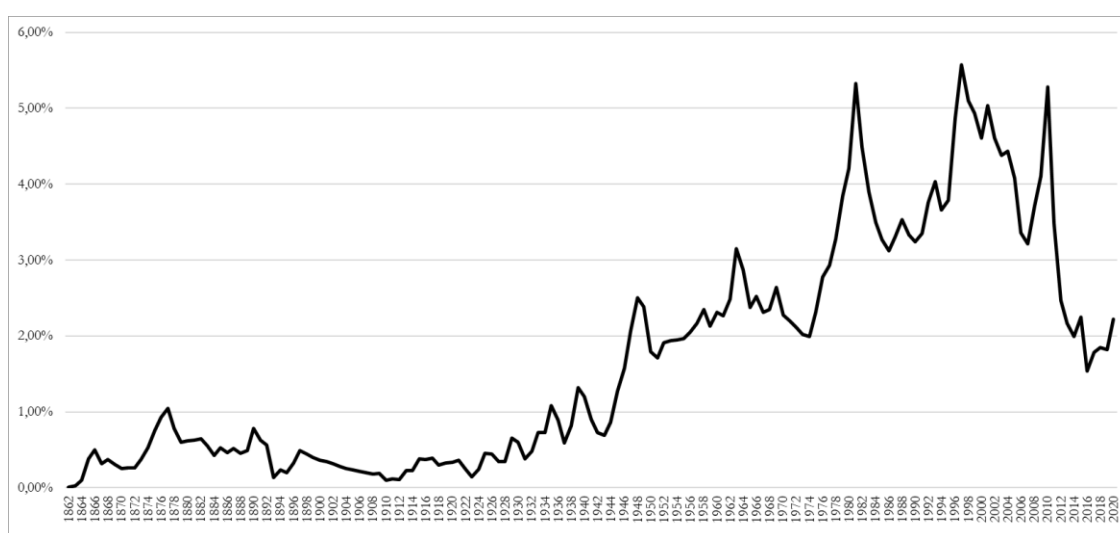


Figure 3: Public investment in percentage of real GDP, Portugal, 1861-2020

Note: Missing values were calculated using linear interpolation.

Source: Own elaboration based on data from Mata (1985), Valério (1982), Banco de Portugal (2000), PORDATA and INE (2001).

3.2.3. Public investment in infrastructures

Regarding public investment in infrastructures, we constructed a series based on data from Mata (1985) for the years from 1861 to 1914 that is in *contos*, from Banco de Portugal (2000) for the period between 1948 and 1977 and Pereira and Pereira (2015) for the years from 1978 and 2011, which is in thousands of euros. The data from Banco de Portugal (2000) for the period between 1948 and 1977 consists in the sum of public investment in machinery and equipment and public investment in building construction, both in million *escudos*. We used

³ In [https://www.pordata.pt/Portugal/PIB+\(base+2016\)-130](https://www.pordata.pt/Portugal/PIB+(base+2016)-130), last accessed February 2022.

the annual average growth rate between years of available data and interpolated the values for the period between 1915 and 1947. For the years from 2012 to 2020, we extended the values of Pereira and Pereira (2015), assuming an identical growth rate in each of these years to the global public investment growth rate.

Real GDP data is from INE (2001) for the years from 1861 to 1914 and from 1948 to 1977 and is from Pereira and Pereira (2015) for the period between 1978 and 2011.⁴

The series of public investment in infrastructures as a percentage of real GDP is illustrated in Figure 6.

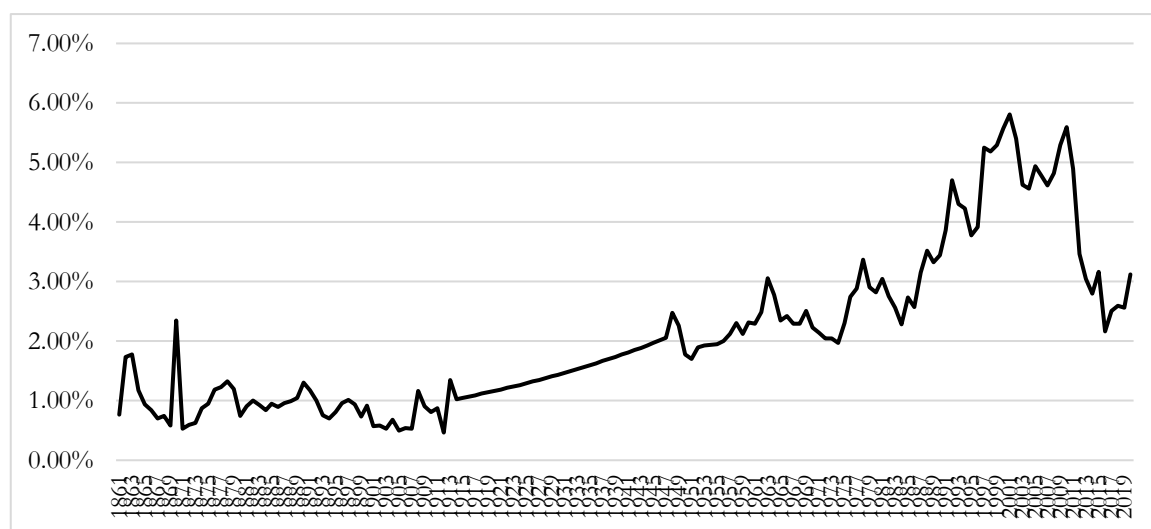


Figure 4: Public investment in infrastructures (as % of the real GDP), Portugal, 1861-2020

Note: Missing values were calculated using linear interpolation.

Source: Own elaboration based on data from Mata (1985), Banco de Portugal (2000) and Pereira and Pereira (2015).

3.2.3.1. Public investment in machinery and equipment

Regarding public investment in machinery and equipment, we constructed a series based on data from Banco de Portugal (2000) for the period between 1947 and 1995. This data consists of the sum of gross fixed capital formation in transportation material and gross fixed capital formation in diverse material, both in million *escudos*.

⁴ As the data comes from several sources, and even in the original sources sometimes there are inconsistencies between the value of global investment and the value of distinct types of investment, in some years the values of public investment in infrastructures as percentage of the real GDP emerged superior (although slightly) than the global public investment in real GDP. The bulk of the public investment for the period in analysis refers to public investment in infrastructures.

Real GDP data is from INE (2001) for the years from 1947 to 1952 and from Banco de Portugal (2000) for the period between 1953 and 1995. INE (2001) data is in thousands of *contos*, that is the same as million *escudos*, and Banco de Portugal data is also in million *escudos*.

The series of public investment in machinery and equipment as a percentage of real GDP is illustrated in Figure 4.

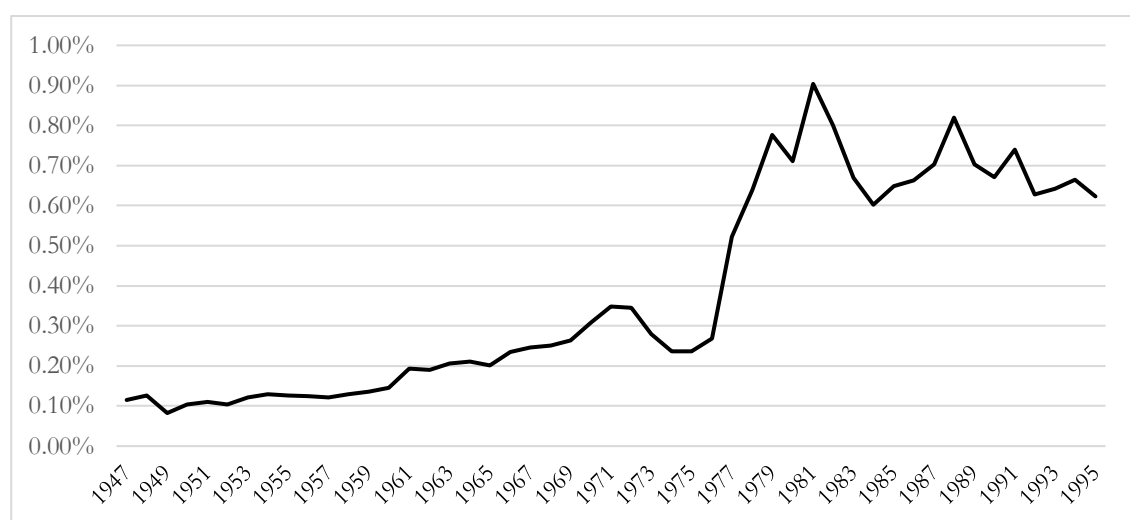


Figure 5: Public investment in machinery and equipment (as % of the real GDP), Portugal, 1947-1995

Source: Own elaboration based on data from INE (2001) and Banco de Portugal (2000).

3.2.3.2. Public investment in building construction

A series for public investment in building construction was built based on data from Banco de Portugal (2000) from 1947 to 1995. Like the series for public investment in machinery and equipment, this data comprises the sum of gross fixed capital formation in housing and other buildings and gross fixed capital formation in other constructions, both in million *escudos*.

The data used for real GDP is the same used for the series of public investment in machinery and equipment as a percentage of real GDP.

The resultant series of public investment in building construction as a percentage of real GDP is shown in Figure 5.

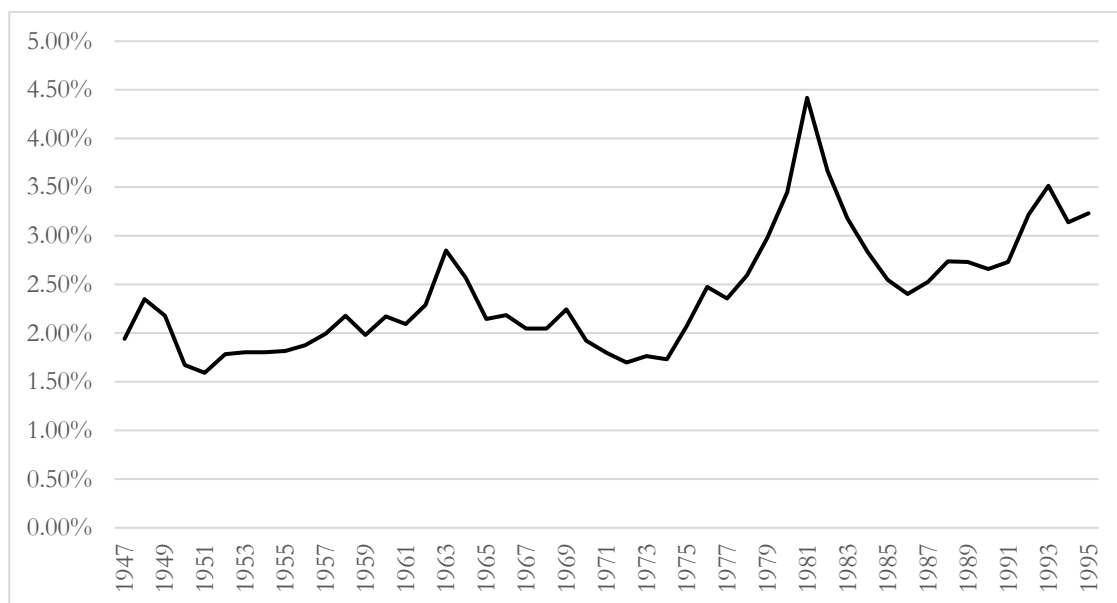


Figure 6: Public investment in building construction (as % of the real GDP), Portugal, 1947-1995

Source: Own elaboration based on data from INE (2001) and Banco de Portugal (2000)

3.2.4. Public investment in health

The series for public investment in health (as a percentage of real GDP) was built from Mata (1985), Valério (1982), INE and PORDATA data.

In Mata (1985), we can find data for public health expenditures from 1862 to 1914 in *contos* de reis, i.e., the same as *escudos*. This series has missing data for the years 1861, 1863-1864, 1869, 1871, 1873-1874, 1878, 1880-1881 and 1898-1907. For those years, we used the annual average growth rate between years of available data and interpolated the missing values. Valério (1982) provides data on those expenditures between 1914 and 1947 in thousands of *contos*. We completed these series with data from INE in million *escudos* until 1971: we used INE (1951) for the years 1948 and 1949, INE (1961) for the period between 1950 and 1959, INE (1962) for the year 1960, INE (1971) from 1961 to 1968 and INE (1973) between 1969 and 1971. For the remaining period between 1972 and 2020, we used data for public health expenditures as percentage of real GDP in terms of budget execution from PORDATA.⁵

Because our series is expressed as a percentage of real GDP, we gathered real GDP data from INE (2001) for the period between 1861 and 1953 and from Banco de Portugal (2000)

⁵ In <https://www.pordata.pt/Portugal/Despesas+do+Estado+em+sa%C3%BAd+e+execu%C3%A7%C3%A3o+or%C3%A7amental+em+percentagem+do+PIB-855>, last accessed February 2022.

from 1954 to 1971. The final series of public investment in health as a percentage of real GDP is illustrated in Figure 7.

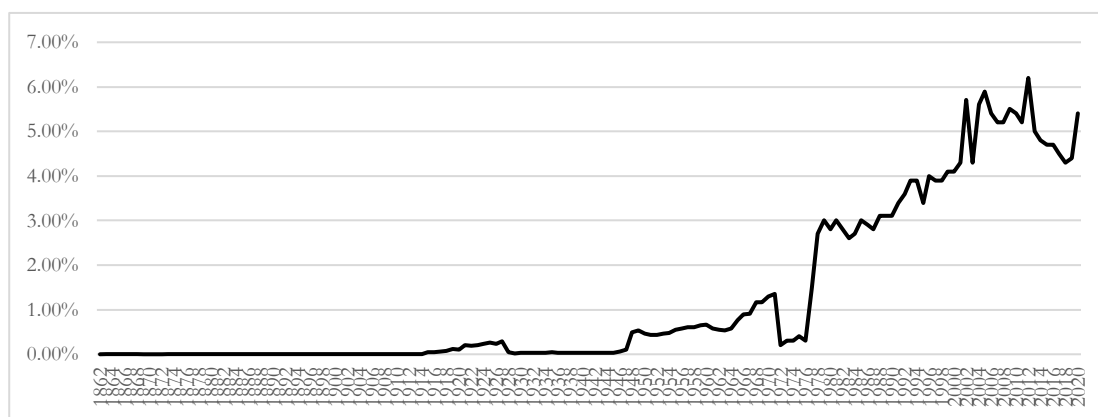


Figure 7: Public investment in health (as % of the real GDP), Portugal, 1861-2020

Note: Missing values were calculated using linear interpolation.

Source: Own elaboration based on data from Mata (1985), Valério (1982), INE, PORDATA, INE (2001) and Banco de Portugal.

3.2.5. Public investment in education

The data used to construct the series of public investment in education as a percentage of real GDP is from the same sources from the series of public investment in health as a percentage of real GDP.

As the series of Mata (1985) for health expenditures, the one for education expenditures has missing data for the years 1861, 1863-1864, 1869, 1871, 1873-1874, 1878, 1880-1881 and 1898-1907. Thus, we used the annual average growth rate between years of available data and interpolated the missing values. The series of public investment in education as a percentage of real GDP is shown in Figure 8.

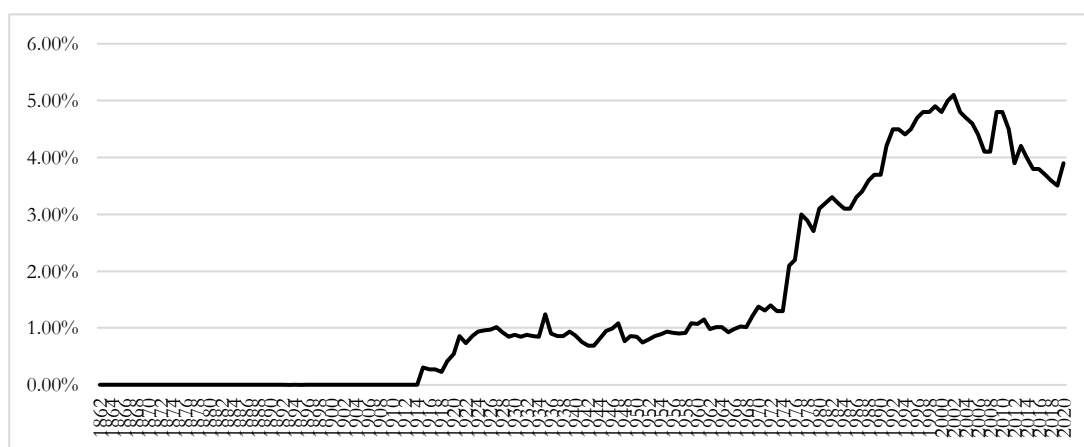


Figure 8: Public investment in education (as % of the real GDP), Portugal, 1861-2020

Note: Missing values were calculated using linear interpolation.

Source: Own elaboration based on data from Mata (1985), Valério (1982), INE, PORDATA, INE (2001) and Banco de Portugal.

3.2.6. Public investment in R&D

The series of public investment in R&D (as a percentage of real GDP) was constructed based on data from OECD⁶ for the period between 1982 and 2019 and DGEEC, DSECTSI and EMID (2021) for the year 2020.

The series from OECD consists in gross domestic expenditure on R&D funded by the government sector in million euros. The data from DGEEC, DSECTSI and EMID (2021) comprises expenditures on R&D funded by the government and is also in million euros.

To express the series as a percentage of real GDP, we used real GDP data from Banco de Portugal and INE (2021) for the period from 1982 to 2020 in million euros. Figure 9 shows the resultant series.

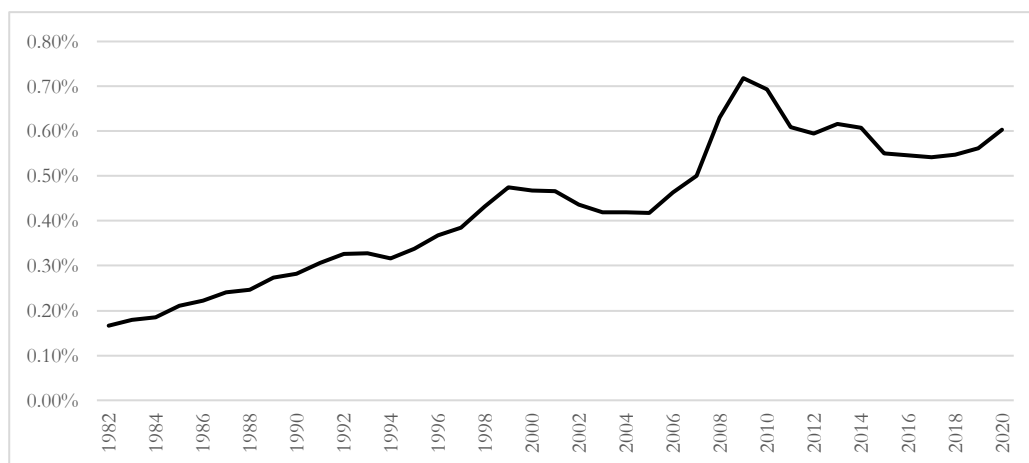


Figure 9: Public investment in R&D (as % of the real GDP), Portugal, 1982-2020

Source: Own elaboration based on data from OECD, DGEEC, DSECTSI and EMID (2021), Banco de Portugal and INE (2021)

⁶ In https://stats.oecd.org/Index.aspx?DataSetCode=GERD_SOF#, last accessed February 2022.

4. Empirical results

4.1. Descriptive analysis

In 1861 the real GDP per capita (in constant prices) was 1407 dollars. By 2020, it reached 26330 dollars, which reflects a real annual average growth rate of 1.9%. Despite the substantial progress, the evolution of the material wellbeing was not uniform (see Figure 2).

The evolution of the ratio of public investment in real GDP is also upward trended (Figure 3), albeit much more volatile, and observing a pronounced decrease after 2011. In 1861, the ratio of public investment in real GDP was of 0%, while in 2020 it was of 2.2%.

This very long period can be divided into four main sub-periods (see Table 2): 1) The “Great divergence” (1861-1913); 2) The World Wars period (1914-1944); 3) the industrialization period (1945-1973); and 4) the European period (1974-2020).

The “Great divergence” (1861-1913) period encompasses part of the nineteenth century and the beginning of the twentieth century, before the First World War. This period was characterized by a very slow economic growth, below 1% per annum, on average, exhibiting a real divergence to the most industrialized European countries at the time (Amaral, 2019), and an average percentage of public investment in relation to real GDP of 0.39%. Despite a few spells of industrialization in the *Regeneração/Fontismo* period, the Portuguese economy continued to be one of the most rural economies of Europe (Amaral, 2019).

Table 2: Evolution of the real GDP per capita and public investment by main historical periods

Period		Number of years	Real GDP per capita a.a.g.r., %	Public investment in % of the real GDP (average)
1861-1913	The “Great divergence”	52	0.7	0.39
1914-1944	World Wars period	30	1.4	0.57
1945-1973	Industrialization period	28	5.0	2.20
1974-2020	The European period	46	1.9	3.53
1974-1985	FMI adjustment programs	11	1.5	3.48
1986-1998	EEC and Euro adhesion	12	3.9	3.90
1999-2020	Great stagnation and Troika	21	0.7	3.33

The period of “Regeneration/Fontismo” occurred between 1851 and the 1890s, was characterized by the idea of “conciliation” between the radical left-wing and right-wing liberal factions. According to the moderates, that “conciliation” would contribute to the

growth of the economy, with the Government contributing to modern infrastructures construction, namely means of transportation (Amaral, 2019). During the “Regeneration/*Fontismo*” period, public investment in percentage of real GDP registered rises and declines, but in the whole period it increased significantly.

During the “Great divergence” period, there was a strong emigration process from Portugal to other countries, particularly to Brazil. Those emigrants were responsible for a huge quantity of transfers into Portugal. It is estimated that those remittances range between 2 and 3% of real GDP from the 1870s to the 1891-1892 crisis (Amaral, 2019). However, the unstable political situation in Brazil had consequences on emigrant transfers. The absence of these transfers resulted in an international payments crisis and to the depreciation of the Portuguese real. The international financial crisis resulted in the Portuguese abandonment of the gold-standard in 1891 and in the suspension of the payment of part of its external public debt service in 1892 (Nunes, Mata & Valério, 1989). Despite a small recovery of the volume of emigrant remittances during the 1890s, they stayed relatively low. Consequently, and with closed access to international capital markets, the Portuguese Governments could not continue with the type of fiscal policy implemented in the “Regeneration” period. Therefore, they adopted a more disciplined fiscal policy, which resulted in smaller deficits (Amaral, 2019). This more disciplined fiscal policy had translated in a significant decrease of public investment in percentage of real GDP.

Summing up, in the ‘Great divergence’ period the ratio of public investment to the real GDP registered up and downs, ending up with a very low average ratio, of 0.39% of the real GDP.

In the two World Wars period (1914-1944), and despite the catastrophic consequences of both conflicts, Portugal registered a faster economic growth when compared to the previous one, with an average annual growth rate of 1.4% and an interruption in the real divergence to the most developed economies of Europe observed in the nineteenth century (Amaral, 2019). In this period, the average of public investment in percentage of real GDP was of 0.57%, which was higher than that of the previous period, marking the increasing of the importance of public investment in the Portuguese economy.

After the First World War, in the mid-1920s, Portugal recovered economic stability, achieving some prosperity in the latter years of the same decade. Nevertheless, that was not sufficient to avoid the overthrowing of the democratic regime by the army in 1926, swiftly replaced by a Military Dictatorship. This authoritarian political regime lasted until the 1970s

(Nunes et al., 1989). During this regime, fiscal reforms were implemented in 1928 and 1929 (Amaral, 2019), which marked the beginning of the end of the Portuguese macroeconomic imbalances. In 1933, a new Constitution was established, which ended the Military Dictatorship and installed a new authoritarian regime, the “Estado Novo” regime (Amaral, 2019). This regime followed policies such as the so called “industrial conditioning” system to prevent negative effects of “excessive competition” and the “de-nationalization” of the Portuguese economy. Besides this system, other forms of intervention were implemented by the Government, namely a primitive version of central planning in the “Law of Economic Reconstitution”; the direct participation in the ownership of various companies; the continuation of the protectionism already implemented in previous periods; and the “agricultural reform”, to improve the structure of agriculture (Amaral, 2019).

Portugal was neutral in the Second World War (1939-1945) and, thus, the effects of this war were much less serious than the ones of the First World War (Nunes et al., 1989), but it still had a heavy impact on the Portuguese economy (Amaral, 2019). On the one hand, the war resulted in difficulties regarding the shortage of external supplies of essential goods for the Portuguese economy. On the other hand, there was an increase of the demand for Portuguese goods, increasing its exports, since some traditional Portuguese exports were valued by the two sides of the war (namely cork and tinned fish), but also goods in which Portugal was not so efficient (such as wool, cotton, glass) and, in addition, raw materials, namely tin and tungsten (Amaral, 2019).

After the Second World War, Portugal began its industrialization period (1945-1973). This period was the one that registered the faster economic growth of all periods, with an average annual growth rate of 5.0%. The expansion of the Portuguese economy during this period was due to some factors, such as the sustained growth in the world economy, the substantial remittances from emigrants and the participation in the European economic integration, but also due to internal factors (Nunes et al., 1989), namely the industrialization of the country and the end of the Portuguese tradition of protectionism and lack of openness (Amaral, 2019). This faster economic growth was accompanied by an increase of public investment in percentage of real GDP, which translates in an average of 2.2%, being significantly higher than in the two previous periods.

From the mid-1940s until 1960, the industrialization policy adopted by the Portuguese Government was one of import-substitution. This policy consisted in the promotion of

electrical projects and of new industries with the Government implementing a series of development plans (“*Planos de Fomento*”), participating in the capital of some companies, issuing bonds that would be used in the industry investment and underwriting industrial loans in the capital market (Amaral, 2019). From 1960, Portugal started to open its economy to the outside world, participating in the international cooperation following the Second World War (Amaral, 2019), namely the Marshall Plan, the European Free Trade Association (EFTA) in 1959, the Organization for European Economic Cooperation (OEEC), the International Monetary Fund (IMF) and the World Bank in 1960, the General Agreement on Tariffs and Trade (GATT) in 1962 and the free trade agreement with the European Economic Community (EEC) in 1972. Because of the free trade, “industrial conditioning” had to be reformed and, thus, the rules of this system were modified in 1965 (Amaral, 2019).

In 1974 the European period started (1974-2020), which was characterized by a significantly slower economic growth, when compared to the previous period, of 1.9% per annum, on average, which was related to the 1973 oil crisis and the Portuguese political revolution that ended with the authoritarian regime (Amaral, 2019). However, public investment in percentage of real GDP was of 3.53% on average, the highest average up to that moment. This period can be divided in three sub-periods: 1) 1974-1985, which include the IMF adjustment programs (1977-79 and 1983-85); 2) 1986-1998, which include the EEC and Euro adhesions; and 3) 1999-2020, which is referred as the “Great stagnation” (Alexandre, Aguiar-Conraria & Bação, 2019) and include the “Troika adjustment program” (2011-2014).

In the early 1970s, the Portuguese economy faced some shocks, namely the end of the Bretton Woods system in 1971, the oil crisis of 1973 and the Carnation Revolution in 1974 that ended with the “Estado Novo” regime. As a consequence of the revolution, some policies implemented during the authoritarian regime were abolished, namely the “industrial conditioning” system and the corporatist structure (Amaral, 2019). Besides these changes, a new legislation was established, more favorable to labor, to large nationalization programs and the “Agrarian Reform”. All these transformations can explain the significant effect that the revolution had on the Portuguese economy (Amaral, 2019). In addition to these transformations, the economy faced inflationary pressures due to the international crisis and the rise in the wages (Amaral, 2019). Because of all these modifications, Portugal started to register serious discrepancies in international payments balance, resulting in two IMF Stand-By Arrangements, one in 1977-1979 and an additional one in 1983-1985. The first program

operated in an efficient manner, regarding international balance and it did not have a negative effect on the Portuguese economic growth, since the economy continued to grow (Amaral, 2019). However, this positive evolution was reverted by another oil crisis in 1979 that resulted in the second IMF Stand-By Arrangement. This second arrangement led to a reduction of the imbalances in international payments, but also to a slower economic growth (Amaral, 2019). Besides registering a slower economic growth, public investment in percentage of real GDP decreased from 1981 to 1986, which can be explained by the measures implemented in the second IMF Stand-By Arrangement. During the period from 1974 to 1985, the Portuguese economy registered an average annual growth rate of 1.5%, with a volatile economic growth, and public investment in percentage of real GDP was of 3.48%, on average.

From 1986 to 1998 Portugal registered an average annual growth rate of 3.9% with a strong economic growth from 1986 to 1992, which was a result of the new opportunities that the participation in the EEC brought (Amaral, 2019), and an increase in the ratio of public investment to real GDP, reaching 3.90%, on average.

From 1999 to 2008, Portuguese real GDP per capita increased, but at a much slower pace than in the previous period, which can be partially explained by the adoption of monetary and exchange rate policies at the level of the Euro system that resulted in a real exchange rate appreciation and, as a consequence, a reduction of competitiveness (Amaral, 2019).

As a response to the world financial and economic crisis that began between 2007 and 2008, a stimulus package was implemented by the Portuguese Government in 2008, which led to a deterioration of the Portuguese deficit in 2009 (Amaral, 2019). As consequence of that deterioration, Portugal was forced to enter in an era of austerity, implementing a rescue plan from “Troika” (European Commission, IMF and European Central Bank) from 2011 to 2014. This program led to a rebalancing of the current account (Amaral, 2019), but also to a negative economic growth from 2010 to 2013. From 2013, Portugal started to register a positive economic growth until 2019. From 2019 to 2020, Portuguese real GDP per capita decreased, which can be explained by the Covid-19 pandemic.

In the whole period of “Great stagnation”, 1999-2020, Portugal registered an average annual growth rate of 0.7% and a ratio of public investment to real GDP of 3.33% on average, a lower percentage than in the two previous sub-periods, which can be explained by the measures adopted by the Portuguese Government associated to the Troika program.

4.2. Results of the estimations

4.2.1. Unit-root tests

The econometric analysis is developed for the whole period, 1861-2020 and for the relevant sub-periods referred earlier - 1861-1913, 1914-1944, 1945-1973, and 1974-2020 – in order to take into account the fact that structural changes were observed over such a long period of time.

We begin the analysis by testing the stationarity of the variables to avoid spurious regression or misspecification (Engle & Granger, 1987). This means that we assess whether the variables are stationary or not and which is their order of integration (that is, the number of unit roots they have).

The visual representation of the variables (see Figure A1, in Annex) suggests that the variables in levels present a trend, implying that their means and/or variances change over time. Thus, the graphical representation suggests that the variables in levels are not stationary. On the other hand, the variables in first differences do not seem to present a trend. Accordingly, the variables seem to have one unit root, that is, they seem to be integrated of order one, $I(1)$.

To test the stationarity of the variables, we used the Augmented Dickey Fuller (ADF) (Dickey & Fuller, 1981), Phillips-Perron (Phillips & Perron, 1988) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) (Kwiatkowski, Phillips, Schmidt & Shin, 1992) tests. Given that both variables in levels showed a clear up trend (see Figure A1, in Annex), we included a constant and a time trend in the tests.

The results are consistent between the three tests (Table 3), showing that the null hypothesis, stating there is one-unit root, is not rejected in the Augmented Dickey Fuller (ADF) (Dickey & Fuller, 1981) and Phillips-Perron (Phillips & Perron, 1988) tests when we consider the variables in levels, but is rejected when we consider the variables in their first differences. In the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) (Kwiatkowski et al., 1992) test, the null hypothesis that the variables are stationary is rejected when we consider the variables in levels, but is not rejected when we consider the variables in their first differences. This indicates that the variables in levels are non-stationary, whereas the variables differenced once are stationary.

Table 3: Non-stationarity tests of the series under study

	1861-2020			1861-1913 (31 years)			1914-1944 (30 years)			1945-1973 (28 years)			1974-2020 (46 years)		
	ADF test (p-value)	PP test (p-value)	KPSS test (critical value at 1%=0.216)	ADF test (p-value)	PP test (p-value)	KPSS test (critical value at 1%=0.216)	ADF test (p-value)	PP test (p-value)	KPSS test (critical value at 1%=0.216)	ADF test (p-value)	PP test (p-value)	KPSS test (critical value at 1%=0.216)	ADF test (p-value)	PP test (p-value)	KPSS test (critical value at 1%=0.216)
Levels															
Real GDP per capita	-1.706 (0.748)	-1.700 (0.751)	0.743***	-2.070 (0.563)	-2.314 (0.426)	0.091	-0.970 (0.764) ^(a)	-0.551 (0.882) ^(a)	0.154**	-0.411 (0.987)	0.080 (0.995)	0.267***	-0.366 (0.988)	-0.783 (0.967)	0.282***
PI/real GDP	-2.264 (0.454)	-2.362 (0.400)	0.301***	-2.598 (0.281)	-2.641 (0.261)	0.244***	-3.127 (0.100)	-2.945 (0.148)	0.111	-2.821 (0.190)	-2.837 (0.184)	0.121*	-2.114 (0.538)	-2.144 (0.521)	0.224***
First differences															
Real GDP per capita	-12.911*** (0.000)	-12.978*** (0.000)	0.214	-7.153*** (0.000)	-7.156*** (0.000)	0.062	-7.926*** (0.000)	-8.460*** (0.000)	0.061	-7.392*** (0.000)	-8.251*** (0.000)	0.053	-5.393*** (0.000)	-5.522*** (0.000)	0.107
PI/real GDP	-10.676*** (0.000)	-10.521*** (0.000)	0.073	-6.226*** (0.000)	-6.179*** (0.000)	0.050	-4.917*** (0.000)	-5.159*** (0.000)	0.049	-4.612*** (0.001)	-4.554*** (0.001)	0.062	-5.856*** (0.000)	-5.777*** (0.000)	0.047

Note: ***(**)[*] statistically significant at 1%(5%)[10%]; variable real GDP per capita is in logarithm; ADF and PP tests: H0: Random walk with or without drift; Except when stated, we considered a trend in the ADF and PP tests; KPSS' H0: The variable is trend stationary.

Source: Own computation using Stata 16.1.

Thus, both variables are $I(1)$, and consequently the series may be cointegrated in the long run. This means that there could be one or more stationary linear combinations of the series, indicating that the variables can have a stable long-term relationship between them. Then, we assess how many cointegration vectors exist and estimate their normalized specification employing the methodology advanced by Johansen (1988).

Besides testing the stationarity of the variables in the whole period analyzed, we have also tested the stationarity of the variables in the four main sub-periods studied. The results were the same for the third (1945-1973) and fourth (1974-2020) sub-periods, which means that both variables are $I(1)$ in the third and fourth sub-periods and consequently the series may be cointegrated in these two sub-periods.

For the first (1861-1913) and second (1914-1944) sub-periods the results of the Augmented Dickey Fuller (Dickey & Fuller, 1981) and the Phillips-Perron (Phillips & Perron, 1988) tests were the same, whereas there were differences regarding the Kwiatkowski-Phillips-Schmidt-Shin (Kwiatkowski et al., 1992) test. In the first sub-period (1861-1913), the null hypothesis that the real GDP per capita variable is stationary is not rejected when we consider the variable in levels and when we consider it in its first differences. This indicates that the real GDP per capita variable is stationary in levels and when differenced once, according to the Kwiatkowski-Phillips-Schmidt-Shin (Kwiatkowski et al.) test.

On the other hand, the public investment in percentage of real GDP variable in levels is non-stationary, whereas when differenced once is stationary. In the second sub-period (1914-1944), the null hypothesis that the public investment in percentage of real GDP variable is stationary is not rejected when we consider the variable in levels and when we consider it in its first differences.

Thus, the public investment in percentage of real GDP variable is stationary in levels and when differenced once, in accordance with the Kwiatkowski-Phillips-Schmidt-Shin (Kwiatkowski et al., 1992) test. On the contrary, the real GDP per capita variable in levels is non-stationary, whereas when differenced once is stationary.

Finally, we tested the stationarity of the different types of public investment (Table 4).

Table 4: Non-stationarity tests of the series under study

	1861-2020		
	ADF test (p-value)	PP test (p-value)	KPSS test (critical value at 1%=0.216)
Levels			
PI in machinery and equipment/real GDP	-2.095 (0.549)	-2.400 (0.379)	0.118
PI in building construction/real GDP	-2.505 (0.325)	-2.749 (0.216)	0.067
PI in infrastructures/real GDP	-3.278* (0.070)	-3.093 (0.108)	0.307***
PI in healthcare/real GDP	-1.840 (0.685)	-1.621 (0.784)	0.715***
PI in education/real GDP	-1.755 (0.726)	-1.782 (0.713)	0.543***
PI in R&D/real GDP	-1.689 (0.756)	-2.151 (0.518)	0.108
First differences			
PI in machinery and equipment/real GDP	-6.227*** (0.000)	-6.247*** (0.000)	0.075
PI in building construction/real GDP	-5.780*** (0.000)	-5.753*** (0.000)	0.040
PI in infrastructures/real GDP	-14.455*** (0.000)	-14.772*** (0.000)	0.053
PI in healthcare/real GDP	-15.192*** (0.000)	-15.204*** (0.000)	0.031
PI in education/real GDP	-12.099*** (0.000)	-12.002*** (0.000)	0.115
PI in R&D/real GDP	-3.502* (0.039)	-3.374* (0.055)	0.045

Note: ***(**)[*] statistically significant at 1%(5%)[10%]; p-value in brackets; variable real GDP per capita is in logarithm; ADF and PP tests: H0: Random walk with or without drift; Except when stated, we considered a trend in the ADF and PP tests; KPSS' H0: The variable is trend stationary.

Source: Own computation using Stata 16.1.

Regarding the variables public investment in machinery and equipment, building construction and R&D, in the Augmented Dickey Fuller (ADF) (Dickey & Fuller, 1981) and Phillips-Perron (Phillips & Perron, 1988) tests, the null hypothesis that there is one-unit root is not rejected when we consider the variables in levels, but is rejected when we consider the variables in their first differences. Thus, according to the Augmented Dickey Fuller (ADF) (Dickey & Fuller, 1981) and Phillips-Perron (Phillips & Perron, 1988) tests, the variables public investment in machinery and equipment, building construction and R&D are non-stationary in levels but are stationary when differenced once, which means that the variables are I(1). On the other hand, in the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) (Kwiatkowski et al., 1992) test, the null hypothesis that the variables are trend stationary is not rejected when we consider the variables in levels, meaning that, according to this test, the variables public investment in machinery and equipment, building construction and R&D in levels are trend stationary.

In regard to public investment in infrastructures, the null hypothesis that there is one-unit root is not rejected in the Phillips-Perron test (Phillips & Perron, 1988) when we consider the variables in levels, but is rejected when we consider the variables in their first differences, implying that the variable public investment in infrastructures is non-stationary in levels but is stationary when differenced once, which means that the variable is $I(1)$, according to the Phillips-Perron test (Phillips & Perron, 1988). In the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Kwiatkowski et al., 1992), the null hypothesis that the variable is trend stationary is rejected when we consider the variables in levels, but is not rejected when differenced once, meaning that, according to this test, the variable is also $I(1)$. However, the null hypothesis that there is one-unit root is rejected in the Augmented Dickey Fuller test (ADF) (Dickey & Fuller, 1981), at the 10% level, when we consider the variable in levels, which implies that the variable is stationary in levels.

Regarding the variables public investment in health care and public investment in education, in the Augmented Dickey Fuller (ADF) (Dickey & Fuller, 1981) and Phillips-Perron (Phillips & Perron, 1988) tests, the null hypothesis that there is one-unit root is not rejected when we consider the variables in levels, but is rejected when we consider the variables in their first differences. Thus, according to the Augmented Dickey Fuller (ADF) (Dickey & Fuller, 1981) and Phillips-Perron (Phillips & Perron, 1988) tests, the variables public investment in health care and public investment in education are non-stationary in levels but are stationary when differenced once, which means that the variables are $I(1)$. Additionally, in the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Kwiatkowski et al., 1992), the null hypothesis that the variables are trend stationary is rejected when we consider the variables in levels but is not rejected when differenced once, meaning that, according to this test, the variables are also $I(1)$.

4.2.2. Cointegration test and long-run relationships

After concluding that both series are integrated of the same order, $I(1)$, we now move to the Johansen cointegration test (Johansen, 1988), to assess the number of cointegration vectors (see Table 5).

Table 5: Johansen cointegration test of real GDP per capita and global public investment intensity

r	Trace statistic				
	1861-2020	1861-1913	1914-1944	1945-1973	1974-2020
None (5% critical value)	43.378 (19.960)	13.978* (19.960)	20.990 (19.960)	21.172 (12.530)	23.615 (19.960)
At most 1 (5% critical value)	6.156* (9.420)	5.466 (9.420)	4.297* (9.420)	7.530 (3.840)	5.035* (9.420)

Notes: * selected rank. Trace test is a Johansen cointegration test for the null hypothesis that, among real GDP per capita (ln) and PI/real GDP, there are r linearly independent cointegration relations, that is, the 2 variables share $2-r$ stochastic tendencies; ** represents the rejection of the null hypothesis that among the 2 variables there are r linearly independent cointegration relations (compared to the alternative that there are $r+1$ linearly independent cointegration relations) with a 5% statistical significance.

Source: Own computation using Stata 16.1.

The Johansen test assumes a restricted constant in the model (since we concluded that is the most adequate specification of the model) and uses 1 lag in levels (as suggested by the varsoc command). In Stata 16.1 we use vecrank command to assess the number of cointegrating equations by applying Johansen's multiple-trace test method.

We present the cointegration test results in Table 5. The Trace test rejects the null hypothesis that the real GDP per capita and public investment in real GDP have no cointegration relationship at the 5% level, since the trace statistic at $r = 0$ of 43.378 exceeds its critical value of 19.960. This means that, at the 5% level, the Trace test rejects that there are no cointegration equations and, thus, rejects that $r = 0$. However, the Trace test does not reject the null hypothesis that there are one or fewer cointegration equation ($r = 1$), because the trace statistic at $r = 1$ of 6.156 is less than its critical value of 9.420. Since Johansen's procedure for estimating r is to accept as the first r for which the null hypothesis is not rejected, we accept $r = 1$ as our estimate of the number of cointegration equations between the two variables.

For the first sub-period (1861-1913), the Trace test does not reject the null hypothesis that real GDP per capita and public investment in real GDP have no cointegration relationship at the 5% level, since the trace statistic at $r = 0$ is lower than its critical value of 19.960, whatever specification is considered (the values presented in Table 5 are related to the restricted constant specification). This means that, at the 5% level, the Trace test does not reject that there are no cointegration equations and, thus, does not reject that $r = 0$, which implies that there is no cointegration relationship between real GDP per capita and public investment in real GDP in the first sub-period.

For the second sub-period (1914-1944), the Johansen test assumes a restricted constant in the model (because we concluded that is the most adequate specification of the model) and uses 2 lags in levels (as indicated by the varsoc command). The Trace test rejects the null hypothesis that real GDP per capita and public investment in real GDP have no cointegration relationship at the 5% level, since the trace statistic at $r = 0$ of 20.990 exceeds its critical value of 19.960. This means that, at the 5% level, the Trace test rejects that there are no cointegration equations and, thus, rejects that $r = 0$. However, the Trace test does not reject the null hypothesis that there are one or fewer cointegration equations ($r = 1$), because the trace statistic at $r = 1$ of 4.297 is less than its critical value of 9.420. Thus, we accept $r = 1$ as our estimate of the number of cointegration equations between the two variables.

Regarding the third sub-period (1945-1973), the Johansen test considers no constant and no trend in the model (since we found that is the most adequate specification of the model) and uses 3 lags in levels (as suggested by the varsoc command). The Trace test rejects the null hypothesis that real GDP per capita and public investment in real GDP have no cointegration relationship at the 5% level, since the trace statistic at $r = 0$ of 21.172 exceeds its critical value of 12.530. Therefore, at the 5% level, the Trace test rejects that there are no cointegration equations and, consequently, rejects that $r = 0$. Similarly, the Trace test rejects the null hypothesis that real GDP per capita and public investment in real GDP have one or fewer cointegration equations ($r = 1$) at the 5% level, since the trace statistic at $r = 1$ of 7.530 exceeds its critical value of 3.840. For that reason, we accept $r = 2$ as our estimate of the number of cointegration equations between the two variables.

In regard to the fourth sub-period (1974-2020), the Johansen test assumes a restricted constant in the model and uses 1 lag in levels. The Trace test rejects the null hypothesis that real GDP per capita and public investment in real GDP have no cointegration relationship at the 5% level, since the trace statistic at $r = 0$ of 23.615 exceeds its critical value of 19.960. This means that, at the 5% level, the Trace test rejects that there are no cointegration equations and, thus, rejects that $r = 0$. However, the Trace test does not reject the null hypothesis that there are one or fewer cointegration equations ($r = 1$), because the trace statistic at $r = 1$ of 5.035 is less than its critical value of 9.420. Thus, we accept $r = 1$ as our estimate of the number of cointegration equations between the two variables.

The results for the cointegration test for the different types of public investment are presented in Table 6.

In the case of public investment in machinery and equipment, the Johansen test assumes no constant and no trend in the model (since we concluded that is the most adequate specification of the model) and uses 4 lags in levels (as suggested by the varsoc command). For public investment in building construction, the Johansen test also assumes no constant and no trend in the model and uses 2 lags in levels. Regarding public investment in infrastructures, the Johansen test assumes an unrestricted constant in the model and uses 1 lag. In regard to public investment in health care, the Johansen test assumes a restricted constant in the model and uses 4 lags. In the case of public investment in education, the Johansen test assumes an unrestricted constant in the model and uses 1 lag. Finally, for public investment in R&D, the Johansen test assumes a restricted constant in the model and uses 2 lags.

In Stata 16.1 we use vecrank command to assess the number of cointegrating equations by applying Johansen's multiple-trace test method.

Table 6: Johansen cointegration test with the variable

r	Trace statistic					
	PI in machinery and equipment/ real GDP (1947-1995)	PI in building construction / real GDP (1947-1995)	PI in infrastructure / real GDP (1861-2020)	PI in health/ real GDP (1861-2020)	PI in education/ real GDP (1861-2020)	PI in R&D/real GDP (1982-2020)
None (5% critical value)	13.100 (12.530)	19.754 (12.530)	17.256 (15.410)	45.284 (19.960)	16.304 (15.410)	20.063 (19.960)
At most 1 (5% critical value)	0.096* (3.840)	5.300* (3.840)	2.564* (3.760)	3.528* (9.420)	0.761* (3.760)	7.436* (9.420)

Notes: * selected rank. Trace test is a Johansen cointegration test for the null hypothesis that, among real GDP per capita (ln) and PI/real GDP, there are r linearly independent cointegration relations, that is, the 2 variables share $2-r$ stochastic tendencies (e.g., because the trace statistic at $r = 1$ of 5.518 is less than its critical value, we cannot reject the null hypothesis that there are two or fewer cointegrating equations).

Source: Own computation using Stata 16.1.

For all types of public investment, the Trace test rejects the null hypothesis that real GDP per capita and public investment in real GDP have no cointegration relationship at the 5% level, since the trace statistic at $r = 0$ exceeds its critical value (Table 6). This means that, at the 5% level, the Trace test rejects that there are no cointegration equations and, thus, rejects that $r = 0$. However, the Trace test does not reject the null hypothesis that there are one or fewer cointegration equations ($r = 1$), because the trace statistic at $r = 1$ is less than its critical

value (Table 6). Since Johansen's procedure for estimating r is to accept as the first r for which the null hypothesis is not rejected, we accept $r = 1$ as our estimate of the number of cointegration equations between each type of public investment and real GDP per capita.

The structural regression to be estimated comprises a relationship between real GDP per capita ($gdp\ pc$), in logarithm, and the ratio of public investment to real GDP (pi_gdp), for the Portuguese economy from 1861 and 2020 expressed by

$$gdp\ pc_t = \beta_1 + \beta_2 pi_gdp + \mu_t \quad (4.1)$$

In cointegration notation, using (1), the vectors of potentially endogenous variables z_t and the normalized cointegrating vector β can be represented as

$$z_t = (gdp\ pc_t \quad pi_gdp_t); \beta = (1 \quad -\beta_2). \quad (4.2)$$

We present the estimates of the parameters in the cointegration equation and their standard errors in Table 7.

We proceed with post-estimation specification tests which indicate whether the vector error-correction models (VECM) associated with the cointegration relationships are well specified. Concretely, for the whole period (1861-2020), the overall Jarque-Bera statistics reject the null hypothesis that the disturbances in the VECM are normally distributed, but for each sub-period that present cointegration vectors, we can accept the null hypothesis that the disturbances in the VECMs are normally distributed (see Table 7). According to the Lagrange multiplier test, and for all the models estimated, we cannot reject the null hypothesis that there is no autocorrelation in the residuals, so there is no hint of model misspecification. Finally, the eigenvalue stability condition suggests that, excluding the full period and the most recent period (1974-2020) models, the estimated cointegration equations are stationary, since the estimated root is not close to 1.

The estimation results indicate that public investment (proxied by the ratio between public investment and real GDP) is associated with increased real GDP per capita. Specifically, in accordance with the long run cointegration of the Model A1, an increase in 1 percentage point in public investment is associated with a statistically significant increase of 1.46% in real GDP per capita (Table 7).

This result is aligned with the Keynesian theoretical approach on this topic that we have already analyzed in Section 2.2. and which considers that public investment is positively

associated with economic growth, since it crowds-in private investment (Anderson et al., 2006) and contributes to an expansion of aggregate demand and production and job creation (Khanchaoui et al., 2020). On the other hand, it goes against the neoclassical theoretical approach which states that public investment undermines economic growth by diverting scarce resources from their efficient usage (Rawat & Khan, 2020), having a crowding-out effect on private investment (Qazi & Ammad, 2021) while also reducing aggregate demand (Bah & Kpognon, 2021).

At the empirical level, there is an absence of studies that have analyzed the Portuguese economy with such a wide time span (over 100 years). Existing evidence, such as the one provided by Pina and Aubyn (2005) covers the period from 1960 to 2001 and concluded that public investment (proxied by public capital stock per worker) fostered economic growth (proxied by output per worker), with a 0.01 shock in public investment resulting in an output per worker 0.33% above the baseline 40 years after. Covering an even more recent period, 1996-2017, of the Portuguese economy Domanska (2020) found that lagged public gross fixed capital formation led to a real GDP growth slowdown of 0.06%.

Table 7: Long-term relations between real GDP per capita and the ratio of public investment in real GDP (PI/real GDP), Portugal, 1861-2020

		Model A1	Model A2	Model A3	Model A4	Model A5
		1861-2020	1861-1913	1914-1944	1945-1973	1974-2020
PI/real GDP (standard errors)		1.458*** (0.367)		0.583*** (0.092)	5.013*** (0.564)	0.248 (0.240)
Lags		1		2	3	1
Number of cointegration vectors		1	0	1	2	1
Cointegration vector specification		Restricted constant		Restricted constant	No constant and no trend	Restricted constant
Jarque-Bera test (overall) ⁽¹⁾		369.585*** (0.000)		8.316* (0.081)	6.396 (0.171)	4.387 (0.356)
Lagrange-multiplier test ⁽²⁾	AR (1)	4.592 (0.332)		5.684 (0.224)	16.118** (0.003)	2.470 (0.650)
	AR (2)	3.846 (0.427)		4.948 (0.293)	6.212 (0.184)	4.078 (0.396)
Eigenvalue stability condition ⁽³⁾		0.991		0.479	0.233	0.983

Variable real GDP per capita is in logarithm; The number of lags was established according to the Schwarz's Bayesian information criterion (SIC); All cointegration vectors include a constant. (1) H0: the disturbances in the VECM are normally distributed; (2) H0: no autocorrelation at lag order; (3) the cointegrating equations are stationary when the estimated root is not close to 1.

Source: Own computation using Stata 16.1.

Regarding the sub-periods, no evidence of a long run relation between public investment intensity and economic growth exists for the Regeneration/Fontismo period (1861-1913). In the World Wars period (1914-1944), results suggest that public investment is associated with increased real GDP per capita. In concrete, an increase in 1 percentage point in public investment is statistically and significantly associated with an increase of 0.58% in real GDP per capita (Table 7).

The long run semi-elasticity between public investment intensity and economic growth is even stronger in the industrialization period (1945-1973), with an increase in 1 percentage point in public investment (as percentage of the real GDP) being associated with a statistically significant increase of 5.01% in real GDP per capita (Table 7).

Although there is evidence of the existence of one cointegration vector in the most recent period (1974-2020), the long run semi-elasticity between public investment intensity and economic growth is positive but not statistically significant.

The analysis by sub-periods permits to uncover that the long run correlation between public investment intensity and economic growth is distinct depending on the magnitude and nature of the structural changes the economy is facing. Indeed, the period of noticeable structural change, characterized by an increase (decrease) in the industry (agriculture) weight in total employment and product, the industrialization phase, 1944-1973, the long run association between public investment and economic growth is the strongest. In contrast, the deindustrialization / tertiarization phase, 1974-2020, coincides with a non-significant long run association between public investment and economic growth.

Regarding the different types of public investment, we present the estimates of the parameters in the cointegration equation and their standard errors in Table 8. We proceed with the post-estimation specification tests. In all the models, the overall Jarque-Bera statistics reject the null hypothesis that the disturbances in the VECM are normally distributed. Regarding the Lagrange multiplier test, at 5% significance, we accept the null hypothesis that there is no autocorrelation in the residuals at lag order 1 or 2, meaning that there is no evidence of residual autocorrelation, thus the models are well specified. Finally, the eigenvalue stability condition suggests that the estimated cointegration equation is probably not stationary, since the estimated root is close to 1.

Table 8: Long-term relations between real GDP per capita and the distinct types of PI (in percentage of the real GDP), Portugal

		Model B1	Model B2	Model B3	Model B4	Model B5	Model B6
Public investment in... as % of the real GDP		Infrastructure (1861-2020)	Machinery and equipment (1947-1995)	Building construction (1947-1995)	Health (1861-2020)	Education (1861-2020)	R&D (1982-2020)
Specific type of PI/real GDP (standard errors)		0.887*** (0.104)	8.875*** (2.418)	2.510*** (0.295)	0.505*** (0.033)	0.563*** (0.046)	2.291*** (0.318)
Lags		1	4	2	4	1	2
Number of cointegration vectors		1	1	1	1	1	1
Number of obs		159	45	47	156	159	37
Cointegration vector specification		Unrestricted constant	No constant/ trend	No constant/ trend	Restricted constant	Unrestricted Constant	Restricted constant
Log likelihood		227.321	158.329	89.786	264.530	354.586	167.449
SBIC		-2.699	-5.767	-3.247	-2.873	-4.300	-8.270
Jarque-Bera test (overall) ⁽¹⁾		302.441 (0.000)	20.172 (0.000)	41.067 (0.000)	369.598 (0.000)	210.509 (0.000)	26.327 (0.000)
Lagrange-multiplier test ⁽²⁾	AR (1)	1.714 (0.788)	2.199 (0.699)	2.545 (0.636)	2.392 (0.664)	0.521 (0.971)	2.547 (0.636)
	AR (2)	6.097 (0.192)	9.382 (0.052)	1.842 (0.764)	2.782 (0.594)	3.931 (0.415)	4.254 (0.373)
Eigenvalue stability condition ⁽³⁾		0.818	0.989	0.958	0.978	0.946	0.811

Variable real GDP per capita is in logarithm; The number of lags was established according to the Schwarz's Bayesian information criterion (SIC); All cointegration vectors include a constant. (1) H0: the disturbances in the VECM are normally distributed; (2) H0: no autocorrelation at lag order; (3) the cointegrating equations are stationary when the estimated root is not close to 1.

Source: Own computation using Stata 16.1.

The estimation results indicate that all types of public investment (proxied by the ratio between each type of public investment and real GDP) are associated with increased real GDP per capita. However, the long run correlation between public investment intensity and economic growth is distinct depending on the type of public investment. In fact, comparing the results of the cointegration tests for the different types of public investment, we can verify that public investment in machinery and equipment is the one that had the greatest association with the Portuguese economic growth (an increase in 1 percentage point in public investment in machinery and equipment is associated with a statistically significant increase of 8.47% in real GDP per capita), followed by public investment in building construction and public investment in R&D, with an increase in 1 percentage point in these types of public investment being associated, respectively, with statistically significant increases in real GDP per capita of 2.51% and 2.29%. It is possible to notice that the three types of public investment that have a lower association with the Portuguese economic growth are the ones

that were analyzed through the longest period of time (between 1861 and 2020, corresponding to a period of 159 years): an increase in 1 percentage point in public investment in infrastructures, public investment, in education and public investment in health, is associated, respectively, with statistically significant increases in real GDP per capita of 0.89%, 0.56% and 0.51%.

4.2.3. Granger causality test

Granger (1969) proposed that in the event that one or more time-series are cointegrated, a (Granger) causality may exist between them, either one-way or in both directions. Therefore, since we have already confirmed that there is one cointegration relationship between real GDP per capita and public investment in real GDP, we move to a Granger causality test (Granger, 1969).

For the case of our core time series, real GDP per capita ($gdp\ pc$) and public investment in real GDP (pi_gdp), pi_gdp is said to Granger-cause $gdp\ pc$ if the latter can be better predicted using the histories of both pi_gdp and $gdp\ pc$. In accordance, we can test for the absence of Granger causality by estimating the following vector autoregressive models (VAR):

$$gdp\ pc_t = a_0 + a_1 gdp\ pc_{t-1} + \dots + a_p gdp\ pc_{t-p} + b_1 pi_gdp_{t-1} + \dots + b_p pi_gdp_{t-p} + \mu_t \quad (4.3)$$

$$pi_gdp_t = c_0 + c_1 pi_gdp_{t-1} + \dots + c_p pi_gdp_{t-p} + d_1 gdp\ pc_{t-1} + \dots + d_p gdp\ pc_{t-p} + v_t \quad (4.4)$$

Then, testing $H_0: b_1 = b_2 = \dots = b_p = 0$ against H_1 : 'Not H_0 ', is a test that pi_gdp does not Granger cause $gdp\ pc$. In the same way, testing $H_0: d_1 = d_2 = \dots = d_p = 0$ against H_1 : 'Not H_0 ', is a test that $gdp\ pc$ does not Granger cause pi_gdp . In each case, a rejection of the null hypothesis implies there is Granger causality. Table 9 presents the results of the Granger causality test.

We have also moved to a Granger causality test (Granger, 1969) for the second (1914-1944) and third (1945-1973) sub-periods, since we confirmed that there is one cointegration relationship between the two variables for the second sub-period and two cointegration relationships for the third sub-period. Because we concluded that there is no cointegration relationship between the two variables in the first sub-period (1861-1913) and that the cointegration relationship existent in the fourth sub-period (1974-2020) is not statistically significant, we have not implemented a Granger causality test (Granger, 1969) for these two sub-periods.

Table 9: Granger causality test

Null hypothesis	1861-2020	1914-1944	1945-1973
pi_gdp <i>does not</i> Granger cause gdp pc	2.646 (0.104)	1.265 (0.261)	1.267 (0.260)
gdp pc <i>does not</i> Granger cause pi_gdp	3.375* (0.066)	25.710*** (0.000)	0.565 (0.452)

Note: *** (**) [*] statistically significant at 1% (5%) [10%]. Variable real gdp pc is in logarithm. Wald test chi-square are displayed with p-values in brackets.

Source: Own computation using Stata 16.1.

Results suggest that in the very long run, public investment does not Granger cause real GDP per capita. In contrast, we conclude that real GDP per capita ‘Granger causes’ public investment. This means that economic growth (proxied by real GDP per capita) (Granger) causes public investment but not the opposite. Thus, in the very long run, the direction of the relationship between economic growth and public investment is from economic growth to public investment.

The result that, in the very long run, public investment does not Granger cause real GDP per capita is aligned with the findings of various authors, namely Mittnik and Neumann (2003), who concluded that, between 1968 and 1994, there was no evidence that public investment determined economic growth of Germany; the authors justified this outcome by the possibility that the share of productive investment had diminished over time but also the possibility that debt financing had risen throughout the period analyzed and may had affected in a negative way public investment productivity. Ghani and Din (2006) also found that there was not enough statistical evidence of an impact of public investment on the economic growth of Pakistan between 1973 and 2004.

We nevertheless concluded that real GDP per capita Granger causes public investment. This result is consistent with the theory, namely with Wagner’s law which states that when a society becomes wealthier, the public sector tends to increase (Shelton, 2007). The essence of this law is that the proportion of civilian government expenditure (excluding defense spending) to GDP is associated with GDP per capita in a positive way (Shelton, 2007).

Our result is in accordance with the empirical results of Batool and Goldmann (2021) who concluded that there was a strong causality from GDP to public transport infrastructure capital in Pakistan between 1973 and 2014, suggesting that investments in infrastructure resulted from economic boosts (Batool & Goldmann, 2021). Additionally, Popescu and Diaconu (2021) found that GDP Granger caused government spending in Romania from

1995 to 2018, which confirms the liberal criticism regarding the involvement of the State in helping economies (Popescu & Diaconu, 2021). The authors refer, nevertheless, that the impact of the multiplication of government spending on national income is a short-term phenomenon.

In regard to the sub-periods, the result obtained for the World Wars period (1914-1944) is in line with the result for the period as a whole: public investment does not Granger cause real GDP per capita, but real GDP per capita ‘Granger causes’ public investment. On the other hand, results for the industrialization period (1945-1973) suggest that over the long run not only public investment does not Granger cause real GDP per capita, but also that real GDP per capita does not Granger cause public investment. Therefore, for the third sub-period (1945-1973) we did not find evidence of a Granger causality in either direction.

Results for the different types of public investment are presented in Table 10.

Table 10: Granger causality test

Null hypothesis	PI in machinery and equipment (1947-1995)	PI in building construction (1947-1995)	PI in infrastructure (1861-2020)	PI in health (1861-2020)	PI in education (1861-2020)	PI in R&D (1982-2020)
The specific type of PI <i>does not</i> Granger cause real GDPpc	4.863** (0.027)	2.750* (0.097)	0.146 (0.703)	39.056*** (0.000)	3.013* (0.083)	2.062 (0.151)
Real GDPpc <i>does not</i> Granger cause the specific type of PI	31.507*** (0.000)	11.285*** (0.001)	11.691*** (0.001)	59.540*** (0.000)	10.688*** (0.001)	12.269*** (0.000)

Note: *** (**) [*] statistically significant at 1% (5%) [10%]. Variable real gdp pc is in logarithm. Wald test chi-square are displayed with p-values in brackets.

Source: Own computation using Stata 16.1.

Results suggest that public investment in machinery and equipment, building construction, health, and education (Granger) cause real GDP per capita. Specifically, an increase in 1 percentage point in public investment in machinery and equipment is associated with a statistically significant increase of 8.47% in real GDP per capita, while an increase in 1 percentage point in public investment in building construction, public investment in education and public investment in health is associated, respectively, with statistically significant increases in real GDP per capita of 2.51%, 0.56% and 0.51%.

On the other hand, public investment in infrastructure and R&D do not Granger cause real GDP per capita. We further conclude that in the long run real GDP per capita (Granger) causes all types of public investment.

Summing up, in the very long run, for the Portuguese economy, increased levels of economic progress (proxied by real GDP per capita) foster global and all types of public investment, and public investment in machinery and equipment, building construction, health and education contribute to economic growth.

The results for public investment in machinery and equipment and building construction are aligned with the findings of Pereira and Pinho (2008) who concluded that the two disaggregated measures of public investment in durable goods studied had a positive effect on the long-term economic growth of Portugal from 1976 to 2003. In addition, the result for public investment in health is aligned with the theory regarding this topic that indicates that public investment in health contributes positively to economic growth, namely through its contribution to population health and, as a consequence, to labor productivity (Cylus et al., 2018). Such result is also aligned with the empirical evidence of the studies we have analyzed, namely with that of Pereira et al. (2017) who conclude that public investment in health care had a positive impact on the Portuguese economic growth between 1978 and 2011 and with that of Qazi and Ammad (2021) who found out that public investment in health impacted positively the economic growth of Pakistan from 1964 to 2014.

The conclusion obtained for public investment in education is in accordance with the theoretical literature we have analyzed, which states that this type of public investment is positively associated with economic growth since education contributes to the increase of labor productivity, to a higher skilled labor force, which leads to a rise in the workers' income, and to the decrease of unemployment (Hien, 2018). Empirically, the conclusion is in accordance with the findings of Qazi and Ammad (2021) who found out that education investment positively impacted the economic growth of Pakistan between 1964 and 2014. In addition, the result for public investment in R&D is different from the findings of Kim et al. (2021) who conclude that public investment in R&D had a positive impact on gross national income in China between 1985 and 2015.

Our results for public investment in infrastructures are different from those achieved by De Frutos et al. (1998), Kalyvitis (2003), Pereira and Andr  z (2006), Pereira and Andr  z (2010), Kustepeli et al. (2012), Moller and Wacker (2017), Ntembe et al. (2018), Javid (2019), Kim et

al. (2021) and Nhlengethwa et al. (2021) who have conclude that public infrastructures investment impacted positively and significantly on economic growth.

The non-significant results achieved for the Portuguese case over the very long run, in what concerns the impact of public investment in infrastructure, might be related to several factors (Javid, 2019): nonlinear association between investment in infrastructures and growth, the existence of crowding-out results, the source of funds for this type of investment, the availability of human capital as a complementary input, the quality of institutions, political stability, and corruption. The assessment of the effective relevance of each of these factors would require additional empirical analyses that are beyond the necessarily strict scope of the present dissertation.

5. Conclusion

The impact of public investment on economic growth is one of the most important and debated topics at the scientific and policy levels (Afonso & St. Aubyn, 2019), with the debate at the empirical level being far from settled or clear-cut (Ghani & Din, 2006; Aregbeyen & Mohammed, 2016; Qazi & Ammad, 2021).

The adoption of a very long-run perspective on the determinants of economic growth helps to understand the factors that matter the most for that growth, which can by itself be of great usefulness for policy makers (Wallis et al., 2018). Moreover, the paucity of studies that analyze both the impact of global public investment and of different types of public investment (Yilmaz, 2018), demands further empirical analyses.

In this context, the main objectives of the present dissertation were to assess, resorting to Johansen cointegration and Granger causality tests, the impact of public investment on the Portuguese economic growth from 1861 to 2020 and evaluate whether distinct types of public investment impacted differently on the Portuguese economic growth.

Three main results are worth to summarize here.

First, we found that in the very long run (1861-2020), an increase in 1 percentage point in (global) public investment is associated with a statistically significant increase of 1.46% in real GDP per capita; notwithstanding, no evidence exists of a very long run (Granger) causality of public investment in economic growth. Instead, in the very long run, increased levels of real GDP per capita (Granger) caused (global) public investment.

Second, the analysis by sub-periods permits to uncover that the long run correlation between public investment intensity and economic growth is distinct depending on the magnitude and nature of the structural changes the economy is facing; indeed, in the period of noticeable structural change, the industrialization phase (1944-1973), the long run association between public investment and economic growth is the strongest; in contrast, the deindustrialization/tertiarization phase, 1974-2020, coincides with a statistically non-significant long run association between public investment and economic growth.

Third, in the very long run, distinct types of public investment correlate and impact differently on Portuguese economy growth. Specifically, public investment in machinery and equipment is the one that had the largest long run association with economic growth, with

an increase in 1 percentage point in public investment in machinery and equipment being associated with a statistically significant increase of 8.47% in real GDP per capita. The magnitude of the long run elasticity is statistically significant, though smaller, for the other types of public investment; by decreasing order of magnitude, we have, building construction, R&D, infrastructures, education, and health. The results of the Granger causality tests show that, in the long run, public investment in machinery and equipment, building construction, education and health Granger caused Portuguese real GDP per capita, while no evidence was found that public investment in R&D and infrastructures Granger caused real GDP per capita. The long run progress in material wellbeing fosters all types of public investment.

The results of this study contribute to the existing literature at three main levels, theoretical, methodological, and empirical. At the theoretical level, it presents a comprehensive and holistic synthesis of the impact of global and distinct types of public investment on economic growth, confronting several theoretical perspectives in one unique theoretical framework, which permits the testing of the relevant hypotheses. At the methodological level, it required the construction of very long run time series which involved the gathering of data from several historical sources; albeit such process is likely to entail questionable assumptions and simplifications, we were able to present continuous time series of public investment (global and by types) for a long period (1861-2020) for the Portuguese economy (Table A1 in Annex) that might foster additional empirical analyses. At the empirical level, it is one of the few studies that present evidence on the impact of (global and types of) public investment over a long period of time (159 years), considering the sub-periods of the Portuguese economy and thus being able to assess the distinct impact of public investment according to the major structural economic changes, ruralization, industrialization, and tertiarization.

Our results have some relevant implications for economic policy and economic research. First, the very long run elasticity between public investment (global and by types) and the real GDP per capita is positive and statistically significant, which means that no evidence of the very long run exists of the crowding out effect suggested by neoclassical economics. The long run elasticity of global public investment is particularly high and significant in the industrialization period (1944-1973), which draws attention for the importance of considering the issue of structural changes and non-linearities when studying this type of phenomenon. Second, evidence based on Granger causality tests produced mixed evidence

about the direction of causality between (global and types of) public investment and the real GDP per capita. On the one side, strong statistical evidence exists that economic growth is a pre-condition (precedes) for public investment regardless the type. On the other side, for public investment in machinery and equipment, building construction, education, and health enough statistical evidence exists that such types of public investment precede or (Granger) cause real GDP per capita, whereas no evidence of (Granger) causality exists for global, R&D and infrastructure public investment. Thus, with some caution, as Granger causality does not consider structural changes or nonlinearities, results seem to suggest that if the aim of public authorities is economic growth, priority should be given to public investment in machinery and equipment, building construction, education, and health.

Despite the above referred contributions to the literature, this dissertation has some noteworthy limitations. First, the data for most variables does not have continuous series, thus we had to use linear interpolation to calculate the missing values. This can result in econometric problems, namely size distortion (Ghysels & Miller, 2014). Second, although we have made the analysis by sub-period, the econometric techniques used do not accommodate for exogenous shocks and time nonlinearities. Thus, an interesting path for future investigation would be to estimate the relevant specifications resorting to alternative techniques, namely the Markov Switching Autoregressive Models, which permit to accommodate for exogenous shocks (such as the World Wars and the Troika period) and time nonlinearities, namely accounting for the fact that the impact of public investment on economic growth may be different in periods of economic expansion/ higher growth and periods of decline/lower growth.

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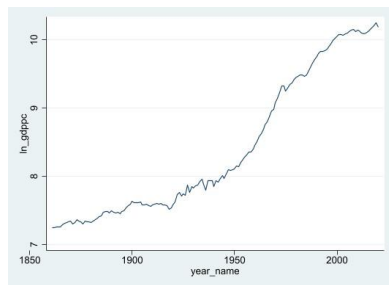
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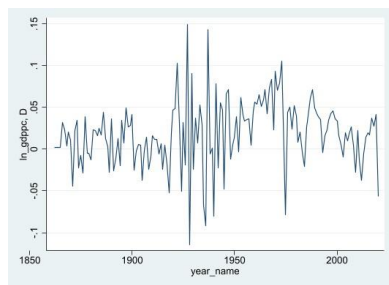
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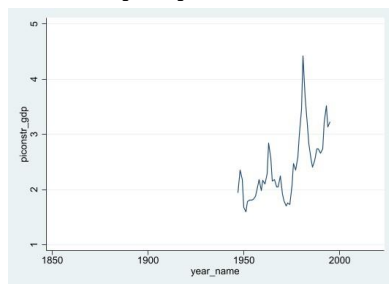
Annex



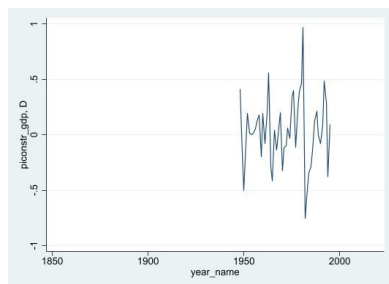
Real GDP per capita – levels



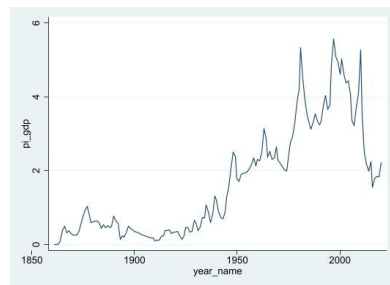
Real GDP per capita – first differences



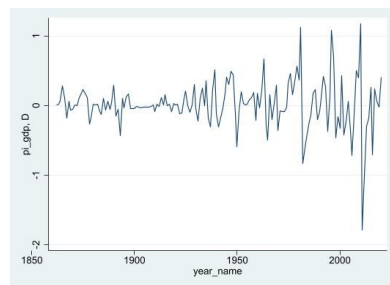
PI in construction in % of real GDP – levels



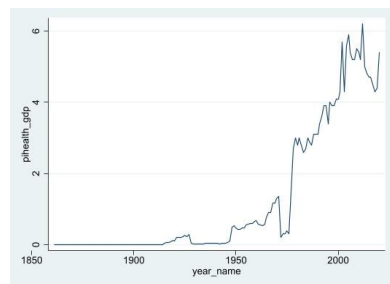
PI in construction in % of real GDP – first differences



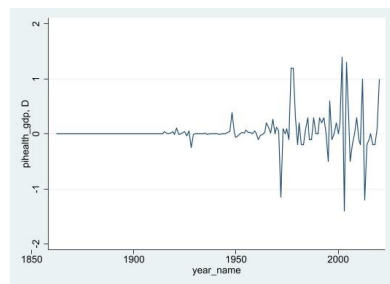
Public investment in % of real GDP – levels



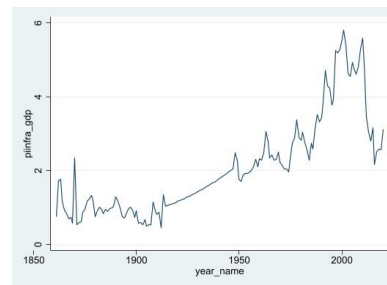
Public investment in % of real GDP – first differences



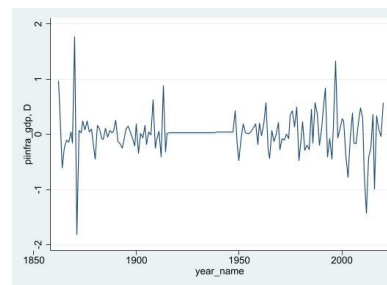
PI in health in % of real GDP – levels



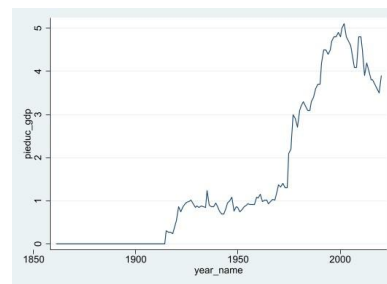
PI in health in % of real GDP – first differences



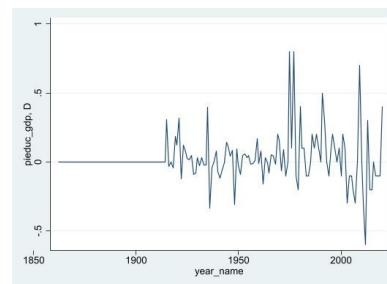
PI in infrastructures in % of real GDP – levels



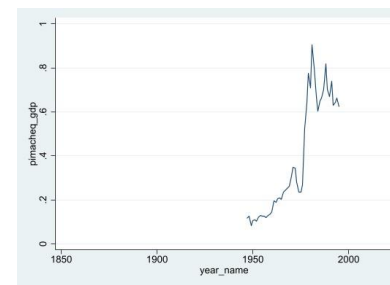
PI in infrastructures in % of real GDP – first differences



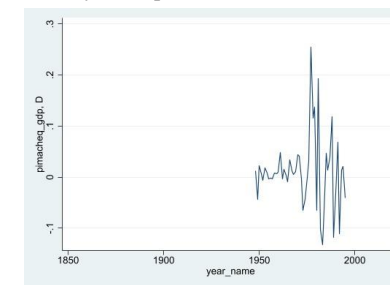
PI in education in % of real GDP – levels



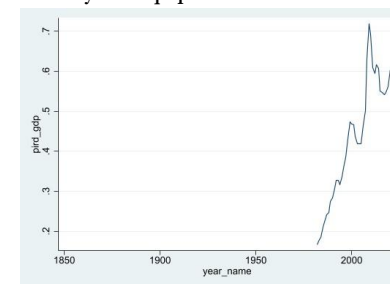
PI in education in % of real GDP – first differences



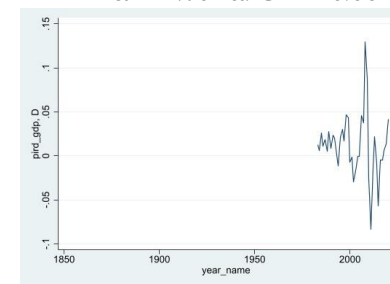
PI in machinery and equipment in % of real GDP – levels



PI in machinery and equipment in % of real GDP – first differences



PI in R&D in % of real GDP – levels



PI in R&D in % of real GDP – first differences

Figure A 1: Time series of the relevant variables in levels and differences

Table A 1: Data used in the estimations

Year	Real GDP per capita	Public investment (% real GDP)	Public investment in Infrastructure (% real GDP)	Public investment in Machinery and Equipment (% real GDP)	Public investment in Building Construction (% real GDP)	Public investment in Health (% real GDP)	Public investment in Education (% real GDP)	Public investment in R&D (% real GDP)
1861	1407	0.002	0.762			0.000	0.000	
1862	1410	0.008	1.731			0.000	0.000	
1863	1413	0.028	1.778			0.000	0.000	
1864	1417	0.101	1.172			0.000	0.000	
1865	1420	0.384	0.941			0.000	0.000	
1866	1466	0.498	0.840			0.000	0.000	
1867	1500	0.314	0.698			0.000	0.000	
1868	1506	0.374	0.742			0.000	0.000	
1869	1537	0.309	0.580			0.000	0.000	
1870	1554	0.255	2.347			0.000	0.000	
1871	1487	0.267	0.529			0.000	0.000	
1872	1521	0.263	0.598			0.000	0.000	
1873	1575	0.374	0.626			0.000	0.000	
1874	1540	0.529	0.870			0.000	0.000	
1875	1529	0.755	0.947			0.000	0.000	
1876	1486	0.933	1.181			0.000	0.000	
1877	1545	1.043	1.227			0.000	0.000	
1878	1537	0.782	1.325			0.000	0.000	
1879	1529	0.601	1.198			0.000	0.000	
1880	1510	0.620	0.747			0.000	0.000	
1881	1546	0.626	0.906			0.000	0.000	
1882	1581	0.643	1.006			0.000	0.000	
1883	1607	0.557	0.930			0.000	0.000	
1884	1648	0.428	0.838			0.000	0.000	
1885	1677	0.531	0.947			0.000	0.000	
1886	1753	0.463	0.896			0.000	0.000	
1887	1776	0.518	0.965			0.000	0.000	
1888	1782	0.457	0.993			0.000	0.000	
1889	1734	0.491	1.043			0.000	0.000	
1890	1798	0.783	1.300			0.000	0.000	
1891	1752	0.629	1.173			0.000	0.000	
1892	1733	0.568	1.000			0.000	0.000	
1893	1755	0.137	0.752			0.000	0.000	
1894	1720	0.236	0.706			0.000	0.000	
1895	1780	0.202	0.807			0.000	0.000	
1896	1793	0.326	0.961			0.000	0.000	
1897	1884	0.489	1.010			0.000	0.000	
1898	1935	0.443	0.935			0.000	0.000	
1899	1991	0.402	0.731			0.000	0.000	
1900	2075	0.361	0.914			0.000	0.000	
1901	2023	0.343	0.567			0.000	0.000	
1902	2018	0.317	0.588			0.000	0.000	
1903	2029	0.283	0.529			0.000	0.000	
1904	2039	0.258	0.685			0.000	0.000	
1905	1965	0.237	0.502			0.000	0.000	
1906	1962	0.218	0.539			0.000	0.000	
1907	1991	0.197	0.534			0.000	0.000	
1908	1943	0.178	1.159			0.000	0.000	
1909	1926	0.188	0.906			0.000	0.000	
1910	1957	0.099	0.810			0.000	0.000	
1911	1980	0.121	0.870			0.000	0.000	
1912	2004	0.110	0.465			0.000	0.000	
1913	1992	0.225	1.342			0.000	0.000	
1914	2005	0.231	1.026			0.000	0.000	
1915	1957	0.381	1.047			0.041	0.306	
1916	1967	0.376	1.070			0.051	0.275	
1917	1932	0.391	1.092			0.056	0.273	

Year	Real GDP per capita	Public investment (% real GDP)	Public investment in Infrastructure (% real GDP)	Public investment in Machinery and Equipment (% real GDP)	Public investment in Building Construction (% real GDP)	Public investment in Health (% real GDP)	Public investment in Education (% real GDP)	Public investment in R&D (% real GDP)
1918	1833	0.299	1.116			0.075	0.230	
1919	1870	0.328	1.139			0.117	0.418	
1920	1959	0.340	1.164			0.109	0.539	
1921	2056	0.362	1.188			0.212	0.858	
1922	2279	0.248	1.214			0.197	0.736	
1923	2348	0.143	1.239			0.204	0.858	
1924	2233	0.245	1.266			0.229	0.934	
1925	2305	0.453	1.293			0.265	0.959	
1926	2262	0.447	1.320			0.234	0.973	
1927	2627	0.345	1.348			0.289	1.019	
1928	2343	0.347	1.377			0.040	0.930	
1929	2566	0.653	1.406			0.025	0.848	
1930	2504	0.602	1.436			0.027	0.880	
1931	2600	0.379	1.467			0.027	0.852	
1932	2619	0.482	1.498			0.026	0.883	
1933	2761	0.730	1.530			0.028	0.863	
1934	2844	0.724	1.562			0.028	0.843	
1935	2660	1.081	1.596			0.046	1.239	
1936	2428	0.896	1.630			0.031	0.904	
1937	2801	0.589	1.664			0.030	0.860	
1938	2785	0.815	1.700			0.032	0.863	
1939	2788	1.322	1.736			0.035	0.942	
1940	2574	1.205	1.773			0.031	0.871	
1941	2785	0.901	1.810			0.033	0.752	
1942	2723	0.728	1.849			0.027	0.691	
1943	2879	0.688	1.888			0.030	0.686	
1944	3017	0.867	1.928			0.037	0.830	
1945	2876	1.275	1.969			0.036	0.949	
1946	3073	1.577	2.011			0.062	0.992	
1947	3301	2.070	2.054	0.114	1.939	0.107	1.079	
1948	3261	2.504	2.476	0.126	2.350	0.489	0.768	
1949	3279	2.389	2.258	0.082	2.176	0.531	0.862	
1950	3325	1.795	1.777	0.105	1.673	0.470	0.842	
1951	3456	1.713	1.703	0.111	1.593	0.432	0.751	
1952	3445	1.908	1.891	0.104	1.787	0.438	0.799	
1953	3663	1.938	1.924	0.122	1.802	0.470	0.856	
1954	3814	1.945	1.935	0.130	1.805	0.480	0.889	
1955	3945	1.964	1.946	0.126	1.820	0.553	0.933	
1956	4087	2.046	2.001	0.124	1.877	0.583	0.914	
1957	4238	2.163	2.117	0.121	1.996	0.606	0.904	
1958	4259	2.352	2.305	0.129	2.176	0.603	0.913	
1959	4454	2.135	2.117	0.136	1.982	0.652	1.083	
1960	4712	2.309	2.318	0.145	2.173	0.671	1.071	
1961	4972	2.269	2.288	0.194	2.095	0.573	1.147	
1962	5308	2.483	2.482	0.190	2.292	0.551	0.988	
1963	5585	3.149	3.056	0.206	2.850	0.542	1.016	
1964	5926	2.867	2.777	0.210	2.567	0.573	1.011	
1965	6363	2.374	2.348	0.201	2.147	0.769	0.929	
1966	6637	2.524	2.421	0.234	2.186	0.894	0.983	
1967	7143	2.316	2.292	0.247	2.045	0.903	1.027	
1968	7767	2.349	2.298	0.251	2.046	1.166	1.012	
1969	7949	2.639	2.510	0.263	2.247	1.170	1.214	
1970	8724	2.279	2.228	0.308	1.920	1.296	1.374	
1971	9358	2.199	2.148	0.349	1.799	1.353	1.312	
1972	10130	2.108	2.043	0.345	1.698	0.200	1.400	
1973	11258	2.019	2.042	0.280	1.762	0.300	1.300	
1974	11234	1.995	1.967	0.237	1.730	0.300	1.300	
1975	10388	2.316	2.308	0.237	2.072	0.400	2.100	
1976	10861	2.773	2.741	0.268	2.472	0.300	2.200	

Year	Real GDP per capita	Public investment (% real GDP)	Public investment in Infrastructure (% real GDP)	Public investment in Machinery and Equipment (% real GDP)	Public investment in Building Construction (% real GDP)	Public investment in Health (% real GDP)	Public investment in Education (% real GDP)	Public investment in R&D (% real GDP)
1977	11422	2.932	2.881	0.523	2.358	1.500	3.000	
1978	11700	3.275	3.372	0.639	2.590	2.700	2.900	
1979	12326	3.843	2.901	0.776	2.984	3.000	2.700	
1980	12822	4.209	2.818	0.710	3.449	2.800	3.100	
1981	12934	5.326	3.050	0.904	4.418	3.000	3.200	
1982	13198	4.491	2.755	0.801	3.665	2.800	3.300	0.166
1983	13158	3.893	2.564	0.669	3.176	2.600	3.200	0.179
1984	12894	3.494	2.285	0.603	2.829	2.700	3.100	0.185
1985	13240	3.266	2.738	0.649	2.546	3.000	3.100	0.211
1986	13774	3.125	2.576	0.664	2.401	2.900	3.300	0.222
1987	14641	3.302	3.150	0.702	2.525	2.800	3.400	0.241
1988	15729	3.534	3.524	0.820	2.740	3.100	3.600	0.246
1989	16533	3.333	3.328	0.702	2.732	3.100	3.700	0.274
1990	17256	3.244	3.441	0.671	2.656	3.100	3.700	0.283
1991	17950	3.348	3.865	0.739	2.734	3.400	4.200	0.307
1992	18599	3.761	4.705	0.629	3.219	3.600	4.500	0.327
1993	18520	4.033	4.300	0.643	3.514	3.900	4.500	0.328
1994	18819	3.659	4.227	0.664	3.137	3.900	4.400	0.317
1995	19262	3.786	3.773	0.624	3.231	3.400	4.500	0.337
1996	19939	4.869	3.915			4.000	4.700	0.368
1997	20810	5.570	5.251			3.900	4.800	0.385
1998	21782	5.102	5.187			3.900	4.800	0.432
1999	22590	4.936	5.288			4.100	4.900	0.475
2000	23372	4.608	5.572			4.100	4.800	0.467
2001	23751	5.033	5.808			4.300	5.000	0.466
2002	23896	4.608	5.405			5.700	5.100	0.437
2003	23678	4.376	4.627			4.300	4.800	0.420
2004	24143	4.437	4.558			5.600	4.700	0.419
2005	24378	4.079	4.943			5.900	4.600	0.418
2006	24809	3.356	4.782			5.400	4.400	0.464
2007	25477	3.217	4.616			5.200	4.100	0.501
2008	25591	3.713	4.822			5.200	4.100	0.631
2009	24902	4.108	5.297			5.500	4.800	0.718
2010	25463	5.277	5.594			5.400	4.800	0.693
2011	25133	3.486	4.894			5.200	4.500	0.609
2012	24218	2.471	3.468			6.200	3.900	0.595
2013	24076	2.171	3.047			5.000	4.200	0.617
2014	24423	1.991	2.795			4.800	4.000	0.608
2015	24915	2.251	3.160			4.700	3.800	0.551
2016	25346	1.542	2.164			4.700	3.800	0.546
2017	26299	1.784	2.505			4.500	3.700	0.541
2018	27036	1.847	2.593			4.300	3.600	0.548
2019	28184	1.821	2.557			4.400	3.500	0.562
2020	26643	2.225	3.123			5.400	3.900	0.603

Sources: For real GDP per capita: Bolt and van Zanden (2020); PORDATA. For public investment (% real GDP): Mata (1985); Valério (1982); Banco de Portugal (2000); PORDATA; INE (2001). For public investment in infrastructure (% real GDP): Mata (1985); Banco de Portugal (2000); Pereira and Pereira (2015); INE (2001). For public investment in machinery and equipment (% real GDP): Banco de Portugal (2000); INE (2001). For public investment in building construction (% real GDP): Banco de Portugal (2000); INE (2001). For public investment in health (% real GDP) and public investment in education (% real GDP): Mata (1985); Valério (1982); INE (1951); INE (1961); INE (1962); INE (1971); INE (1973); PORDATA; INE (2001); Banco de Portugal (2000). For public investment in R&D (% real GDP): OECD; DGEEC, DSECTSI and EMID (2021); Banco de Portugal and INE (2021).

Notes: We interpolate the missing values of real GDP per capita in the period from 1862 to 1864 using the annual average growth rate between years of available data. Regarding the period from 2018 to 2020, we used linear interpolation based on the annual growth rate implicit in PORDATA's series. For series public investment (% real GDP), we interpolate the missing values in the years 1863-1864, 1869, 1871, 1873-1874, 1878, 1880-1881 and 1898-1907, using the annual average growth rate between years of available data. For public investment in infrastructures (% real GDP), we used the annual average growth rate between years of available data and interpolated the values for the period between 1915 and 1947. For the years from 2012 to 2020, we extended the values of Pereira and Pereira (2015), assuming an identical growth rate in each of these years to the global public investment growth rate. The series of public investment in health (% real GDP) and public investment in education (% real GDP) have missing data for the years 1861, 1863-1864, 1869, 1871, 1873-1874, 1878, 1880-1881 and 1898-1907. For those years, we used the annual average growth rate between years of available data and interpolated the missing values.