



Lisbon School
of Economics
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Universidade de Lisboa

MASTER
MONETARY AND FINANCIAL ECONOMICS

MASTER'S FINAL WORK
DISSERTATION

**THE RELATIONSHIP BETWEEN MACROECONOMIC RATES OF
RETURN OF INVESTMENT AND THE SPEED OF CONVERGENCE: A
PANEL DATA ANALYSIS**

MATILDE TAVARES CALVINO DOS SANTOS



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JUNE - 2025



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SUPERVISION:

JOSÉ RICARDO BORGES ALVES



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The Relationship between Macroeconomic Rates of Return of Investment and the Speed of Convergence: A Panel Data Analysis

Matilde Santos

June 2025

Abstract

We analyse the impact of macroeconomic rates of return of investment on time-varying beta convergence coefficients. This dissertation aims to establish and empirically demonstrate a relationship between macroeconomic rates of return of investment and the speed of convergence of economies to their own steady state. First, we use the four different kinds of macroeconomic rates found in Afonso et al. (2025), then we compute the time-varying beta convergence coefficients for two different time lags, one of ten years and another of five, all according to the approach of Schlicht (2021). Finally, we regress the betas on the macroeconomic rates of return, controlling for some variables. Our panel data set contains 16 OECD countries and spans the years starting in 1980 and ending in 2022. We conclude that the impact of the macroeconomic rates of return on the speed of convergence is mostly positive but differs in magnitude depending on which kind of macroeconomic rate of return and on which set of control variables accompanies the regression.

Keywords: Macroeconomic Rates of Return; Conditional Convergence; Speed of Convergence; Time-Varying Coefficients

JEL: E13; E22; H54; O47

1. Introduction

The Neoclassical growth models for closed economies, Ramsey (1928), Solow (1956), Koopmans (1963), and Cass (1965) establish dynamics in the relationships between capital, output and consumption per capita and the initial level of capital per capita. More relevantly, these models predict an inverse relationship between the initial level of capital per capita and the growth rate of income per capita.

In these frameworks we have an exogenous source of growth, often denominated technology, and the solution to the model is globally stable. A globally stable solution implies the dynamics of the model predict that, given certain fundamentals (such as the savings rate, s , and population growth rate, n), economies tend to converge to a unique steady state, which has specific values for output; capital and consumption per capita and where the growth rates of output; capital and consumption are constant and equal to the population growth rate (n). Additionally, for any positive initial level of capital per capita, economies converge to their unique steady states on the basis of the fundamental equation of capital accumulation. The aforementioned equation is established on the assumption of diminishing returns to capital, which plays a key role in the models as it suggests that as an economy accumulates capital, one more additional unit of capital generates less and less output.

This is an extremely important result of neoclassical growth models as it means smaller values of capital per capita are associated with larger growth rates of output.

Thus, the models are predicting a specific dynamic of convergence: convergence in income. Convergence in income can be absolute as in when poor economies grow faster than rich ones. Alternatively, convergence can be conditional as in when economies grow faster, the further they are from their own steady-state value level of capital per capita.

This implication of convergence from neoclassical growth theory led to a contentious discussion among economists on the topic, with several theoretical and empirical works produced mainly in the late 1980s and all throughout the 1990s.

It is also important to note that within these models we can algebraically measure the speed of this convergence dynamic by a coefficient β . β measures by how much the growth rate declines as the capital stock increases. (Barro and Sala-i-Martin, 2004)

In the fiery debate regarding convergence, the β -convergence coefficient and the convergence implication itself have been linked to other macroeconomic studies such as financial development and integration (Cavallaro and Villani, 2021; Cavallaro and Villani, 2022). This dissertation also aims at establishing a relationship between the speed

of convergence and another economic concept, the concept of macroeconomic rates of return.

Macroeconomic rates of return seek to capture the overall return of an investment to the entire economy. Although this is clearly an important concept as it can have meaningful and far-reaching policy implications, macroeconomic rates of return have not been studied nearly as much as convergence.

The primordial work on this concept was done by Aschauer (1989), who computed the capital stock-to-output elasticities for the U.S. and found that different types of public capital stock have dissimilar effects on long-term productivity and, consequently, growth. Further relevant developments were made by Pereira (2000), who calculated the first annual macroeconomic rates of return by estimation of a Vector Autoregression (VAR) model, subsequently inducing an orthogonal shock to public investment (G), hence getting the long-term accumulated elasticity of Y (Gross Domestic Product, GDP) with respect to G , to calculate marginal productivity and thus the rate of return. This methodology set the foundations for the empirical work on macroeconomic rates of return that was to follow.

However, the problem with Pereira's approach was pointed out by Pina and St. Aubyn (2006). Macroeconomically, it is important to account for the full cost of investment, both public and private. So, Pina and St. Aubyn (2005, 2006) account for crowding in and crowding out effects of public investment. Throughout the years, additional important progress was made in the methodology to get macroeconomic rates of return, such as by Afonso and St. Aubyn (2009). For the purposes of this dissertation, the macroeconomic rates of return used are the ones found in Afonso et al. (2025).

As mentioned, it is the objective of this dissertation to shine some light into the possible relation between the concepts of macroeconomic rates of return and β -convergence via empirical evidence. The theoretical link between these two concepts has not been explored. However, given the framework of neoclassical growth models for closed economies and the definition of macroeconomic rates of return, it is possible we have a few ways to connect these two concepts.

From neoclassical theory, we have the assumption of diminishing marginal returns. Additionally, we often find equilibrium solutions from these models involve that the marginal productivity of capital is equal to the real interest rate (for example, this result is implied in the solution for the optimization problem of firms' choice).

For the purposes of this dissertation this implication can be extremely important as it has a direct link to the dynamics of convergence (Ertl and Rabitsch, 2025). The authors in the former paper, point out that since convergence occurs with capital accumulation dynamics, then marginal productivity of capital will decrease with the convergence process (given the diminishing marginal returns assumption), this, in turn, would entail that the real interest rate also decreases. The decrease in the real interest rate, no doubt, has a negative impact on the rate of return of capital.

Although the focus of this 2025 paper is the natural rate of interest, which is equal to the real rate of interest in a frictionless economy, the authors' framework and empirical results are pertinent for the motivation of this dissertation. Ertl and Rabitsch (2025) begin by pointing out evidence for the long-term decline in global real interest rates and then empirically test for convergence among a panel of European countries. The authors find evidence of unconditional beta convergence in line with the "law of iron" of a 2% convergence rate per year (Barro, 2012). The paper then goes on to do a Bayesian estimation for the natural rates of return for four emerging European economies between 2003 and 2019, allowing for convergence (the starting value of the capital stock is below the steady state value). Their conclusions are that the capital deepening process associated with convergence contributed to a decline in the natural rate of interest (even more than expected) and that ignoring convergence biases leads to an overestimation of the natural rate of interest.

This hypothesis is relevant and leads to believe that higher values of the speed of convergence lead to lower macroeconomic rates of return. Conversely, and using the author's rationale: when we have higher macroeconomic rates of return, the associated values of capital per capita are smaller (given diminishing marginal returns), so, the speed of convergence is higher. This is our expectation for the empirical work that will follow, a positive impact of macroeconomic rates of return on the speed of convergence.

2. Literature Review

2.1. Macroeconomic rates of return

The importance of government spending in the accumulation of public capital is observable in many countries from their policies. Countries establish public spending policies in such a way they believe government spending will yield positive returns that more than outweigh the cost of those investments. Since public capital expenditures are varied and extensive, including spending on infrastructure like roads; schools and

hospitals, it may be difficult to quantify these investments and their effect on the economy. Despite this, there is a permanence of public spending policies, especially in the most developed countries, indicating the belief that human capital, physical capital, research & development spending, among others will have a positive economic outcome sooner or later. This makes it clear that it is important to discuss how productive public investment and public capital really are and how their effects propagate through the economy, by means of interaction with other macroeconomic variables, such as private investment. Building on this last point, it is important to mention that theoretically there are two effects on private investment that can arise from an increase in public investment. If public investment is financed by tax revenues this may decrease disposable income, thus diminishing private investment. This argument may be used in favour of the golden rule of public finance, which entails resorting only to public debt to finance public investment expenditures. However, independently of the way it is financed, public investment may lead to more favourable conditions for private investment. For example, infrastructures like roads and bridges can make private investment more productive, hence leading to its increase.

In this context, the conversation regarding macroeconomic rates of return arises and despite the clear importance of the matter, literature regarding macroeconomic rates of return is scarce with its origins dating back to Aschauer (1989).

Aschauer (1989a, b) began the exploration of this issue in the context of the U.S. economy, proposing that the observed productivity slowdown at the time was linked to a decline in public investment. More specifically, Aschauer wanted to shift the conversation from the ways of financing public investment, which dominated academic literature at the time, and focus on how public sector decisions alter the private economy. For this reason, he intended to demonstrate to which degree public expenditures are productive and their role in long-term movements in productivity. From a Cobb-Douglas production function Aschauer regressed two equations, output per unit of capital and total factor productivity, using static ordinary least squares (OLS) regressions. From these regressions Aschauer estimated public capital stock-to-output elasticities, concluding the importance of public capital in the U.S.' productivity and subsequent output growth, given the fact that it acts as a productive input to private output and not just as a passive shock. Aschauer also made clear that different types of public capital had different explanatory power for productivity. In particular, non-military public capital stock,

namely “core” infrastructure was found to have a remarkable correlation with private sector productivity.

The methodology used by Aschauer was later criticized by Pereira (2000). Pereira wanted to extend Aschauer’s work in the pursuit of understanding the productivity value and effect of public investment on private sector performance, but he followed a different methodology. Pereira argued the estimation of static, univariate production levels by Aschauer (1989a, b) could lead to spurious estimates and simultaneity bias. Besides this, he argued Aschauer’s methodology was excluding the existence of dynamic feedbacks between variables which were very likely to exist. Thus, Pereira (2000) developed a new methodology and was the first to introduce and compute macroeconomic rates of return.

Pereira uses a VAR approach to assess the effects of public investment on private-sector variables in the U.S., arguing the need to measure both the direct and indirect effects of public investment on GDP, through the dynamic responses of private inputs. Following Aschauer (1989a, b), Pereira (2000) also specifies types of public investment. Namely, Pereira builds six VAR models: five for types of non-military public investment and one for aggregate public investment. Pereira finds all types of public investment have a positive effect on private output and private investment with mixed results regarding private employment. Despite this, aggregate public investment has a positive impact on all the private variables. In the end, core infrastructure public investments have the highest rates of return. Pereira concludes that public investment crowds in private investment and that public capital may promote long-run growth for the U.S.

The discussion of the macroeconomic rates of return continues in Pina and St. Aubyn (2005). The authors build on Pereira (2000)’s work and apply it to the Portuguese economy. They follow some of Pereira (2000)’s methodology, starting from a Cobb Douglas production function and also building a VAR model but make a new distinction. Pina and St. Aubyn (2005) differentiate between *ceteris paribus* rates of return: the discounted value of a stream of increases in GDP due to a unit increase in capital in the present (measured by the marginal productivity of the explicit production function) and the dynamic feedbacks rate of return: the discounted value of a stream of increases in GDP due to a unit increase in capital in the present (measured by the VAR). Pina and St. Aubyn found public capital innovations crowd in private investment and high rates of return values for public capital with dynamic feedbacks. The distinction made by Pina

and St. Aubyn (2005) of different types of rates of return is further emphasized by Pina and St. Aubyn (2006).

Pina and St. Aubyn (2006) criticized Pereira (2000), because although his approach includes the indirect effects of public investment on GDP through the dynamic responses of private inputs, macroeconomically it is important to account for the full cost of investment, both public and private. So, the authors argue that, using Pereira's approach, when there is crowding in (crowding out) of private investment we are underestimating (overestimating) the actual costs needed to have a certain return. Thus, we would be overestimating (underestimating) the rate of return. The innovation in Pina and St. Aubyn (2006) is, then, the computation of total macroeconomic rates of return (which include crowding in and crowding out effects), following an impulse on public investment. The authors find that public total rates of return are smaller than public partial rates of return and verifying the previous results: public investment crowds in private investment.

This new development led to more extended academic work on macroeconomic rates of return, notably, by Afonso and St. Aubyn (2009).

Afonso and St. Aubyn (2009) extends on Pina and St. Aubyn (2006). Instead of imposing on the VAR model a structural shock just on public investment, they also impose one on private investment. Hence, Afonso and St. Aubyn (2009) are the first to compute private macroeconomic rates of return. Thus, for the first time in the literature we observe the introduction of the four types of macroeconomic rates which will be used in this dissertation. These macroeconomic rates of return are computed through either a structural shock to public investment or a structural shock to private investment and by accounting for the partial or accounting for the full cost of that investment. These rates are, then, denominated partial rate of return of private investment, partial rate of return of public investment, total rate of return of private investment, total rate of return of public investment. The authors find that public investment crowds in private investment in most of the countries used in the sample and that in the countries where the opposite is found, they still experience some output expansion. For all countries in the sample private investment had a positive effect on GDP and, for most, private investment crowded in public investment. The partial rate of return of public investment is mostly positive, the total rate of return of public investment is generally lower and negative for some cases. The private rates of return follow the same pattern.

This Afonso and St. Aubyn (2009) paper is the more extended basis for the methodology of the macroeconomic rates of return used in this dissertation. Their work

is further developed by Afonso and St. Aubyn (2010), Afonso and St. Aubyn (2019) and Afonso et al. (2025). Afonso and St. Aubyn (2009), in particular, solidifies the statistical methods used so far in the computation of the macroeconomic rates of return and their results are similar to those found before.

Afonso and St. Aubyn (2010) is further research on the topic basing computation of partial rates of return on Pereira (2000) and calculation of total rates of return according to Pina and St. Aubyn (2006). The authors find private investment elasticity is always higher than public investment elasticity and similar rates of return to the ones found in Afonso and St. Aubyn (2009), as well.

Entirely based on the methodology of the Afonso and St. Aubyn (2009), Afonso and St. Aubyn (2019) work computes rates of return to include the context of the global financial crisis. The main conclusion is that their results do not differ from the ones in their 2009 paper, despite the very negative consequences that the global financial crisis (GFC) had on the set of countries analysed.

Lastly, and more importantly for this dissertation, is the academic work of Afonso et al. (2025). This paper, just as the aforementioned one, follows the methodology of Afonso and St. Aubyn (2009). It computes the four types of macroeconomic rates of return, from a VAR model which includes four variables: real public investment, real private investment, real output, real taxes and real interest rates. Afonso et al. (2025) computes the macroeconomic rates of return for 16 OECD countries over a time span of 42 years, from 1980 to 2022. The paper concluded that public investment generally yields higher macroeconomic returns than private investment and that public investment returns are more volatile than private investment returns. For the purpose of this dissertation these are the values of macroeconomic rates of return used.

2.2. Time-varying Beta-Convergence

As underlined before, the implications of convergence stemming from the neoclassical growth models for closed economies led to an intense debate and a plethora of empirical work, most of which took place in the late 1980s and throughout the 1990s.

The first empirical work on economic convergence was by William Baumol (1986). Since then, many researchers and growth economists have entered the debate and provided significant and pivotal theoretical and empirical outcomes.

The prediction by theory of convergence was met with lack of evidence for the concept of absolute convergence found in some 1990s studies, notably Barro (1991) and Pritchett (1997). This counter evidence geared the academic world to one of two directions.

The first reaction was a rejection of neoclassical models given the lack of real-world evidence for its results and turn to endogenous growth models, which were pioneered by Romer (1986) and do not predict diminishing returns to capital -the main driver of convergence. The second reaction lead the proponents of convergence theory and empirics to shift their emphasis instead to the underlying determinants of the steady state and to the explanatory variables of growth. With this second reaction, the idea of conditional beta convergence emerges.

The term β -convergence, introduced by Barro and Sala-i-Martin (1992), describes the inverse relationship between an economy's initial real GDP per capita and its subsequent average annual growth rate. This effect of initial per capita income on the income growth rate is measured based on a cross-sectional linear regression which regresses the growth rate (for a specific time period) on the level of income in the beginning of said time period. This methodology will become known in the literature as the “Barro regressions”.

The relationship between initial income and growth can be observed through the lenses of absolute beta convergence or conditional beta convergence, as mentioned before. Absolute beta-convergence occurs when poor economies grow at faster rate than richer ones, unconditionally. Conditional beta convergence occurs when, controlling for determinants of steady state income, economies with lower levels of per capita income have a higher growth rate than economies with higher levels of per capita income. In other words, economies converge faster, the further they are from their steady state value.

Another important concept of convergence, formalized by Friedman (1992) while the author was criticizing the “Barro regressions”, is the concept of δ -convergence. Sigma convergence implies that the cross-sectional variance of income per capita is falling over time.

Given these definitions of convergence, one might infer that beta convergence and sigma convergence happen simultaneously, meaning that one occurs when the other is observed. However, even though that can be the case (Sala-i-Martin, 1996b), important literature on the matter has concluded that beta convergence is a necessary but not a sufficient condition for sigma convergence to take place. (Fuceri, 2005) (Young et al., 2008). This means that even if poorer economies are growing faster than rich ones, it is

still possible for the overall dispersion of incomes to remain constant or perhaps even increase due to other economic factors or external shocks.

As previously mentioned, the term beta convergence emerged in 1992 by Barro and Sala-i-Martin. Besides the coining of the term, the authors presented robust evidence for the existence of conditional beta convergence and, more notably, concluded a convergence rate value of around 2% per year according to different datasets.

This last result is extremely important as it will be verified by future empirical studies on the matter, which have various time spans and differing country and region samples, leading to the robust result of a $\approx 2\%$ convergence rate per year and to the popularization of the term “law of iron” of convergence. Such examples of literature are Mankiw et al. (1992) which extends the framework to include human capital and finds robust evidence for conditional beta convergence. Moreover, Islam (1995), who introduced panel data to the methodology and found evidence of convergence in three sets of countries, although at a slightly higher rate. Sala-i-Martin (1996a, b) also conclude very robust and significant evidence for conditional beta convergence at the 2% value for different sets of countries, including for a sample of 110 economies. Moreover, Sala-i-Martin (1996a, b) show empirics concluding regions within countries also show robust evidence for absolute convergence. Barro (2012) solidified this evidence by taking many countries and running the “Barro Regressions” with control variables as proxies for the steady state, finding that in the short or long-term the convergence rates were always in the vicinity of 2% per year. Lastly, Kremer et al. (2021) concluded a trend toward absolute convergence since the late 1990s and actual absolute convergence since 2000. Besides this, the authors also state that conditional convergence is a robust phenomenon across many settings.

Even though the evidence of conditional beta convergence is seen as very robust in the literature, it is not without its criticisms.

The methodology used in most of this empirical evidence was criticized by several authors. For example, Quah (1993) accused the studies of imposing assumptions on the nature of long-term growth, when the data actually shows unstable patterns. Quah (1993) and Friedman (1992) deemed the “Barro regressions” as falling for Galton’s fallacy. Quah (1993) even went as far as to propose the focus should instead be on the dynamics of distribution of income across countries, stating that convergence may happen, but if it does it happens in clubs. This idea set the foundations for another concept and evidence seen in the empirical literature of convergence (Cavallaro and Villani, 2022; Cavallaro and Villani, 2021), the idea of club convergence. To put it simply, this concept predicts

convergence within sets of countries or regions (the clubs), so long as these economies have similar characteristics beyond the already mentioned Solow fundamentals, such as similar institutions or similar financial development.

The criticisms and suggestions continued, denouncing the “Barro Regressions” of leading to misinterpretation and misestimation of convergence (Vu, 2013). More notably, Boyle and McCarthy (1997) put forth a method they consider a more direct and unbiased way of measuring intra-distributional income mobility, method which is according to Kendall’s concordance rank-based index. The authors conclude sigma convergence existed until the early 1970s and then stabilized and that after 1972 there is no evidence of beta convergence.

Furthermore, Bernard and Durlauf (1995) highlighted the importance of distinguishing between beta convergence and stochastic convergence, given that their results, which added some time series methods to the literature, showed little evidence of convergence but instead provided evidence for substantial cointegration across the countries in their sample. To combat these criticisms in the literature, new statistical methods were introduced by authors such as Caselli et al. (1996) who brought in the Generalized Method of Moments (GMM) method attempting to correct for correlated individual effects and endogenous explanatory variables. Caselli et al. (1996) find evidence of convergence albeit at a higher rate than the “law of iron” suggests.

A point to note here before we continue to more developments on the convergence literature is regarding the “law of iron” value of $\approx 2\%$. A convergence rate of about 2% per year is low and would mean, given the framework, that the capital share (often assumed 30%), would take much higher values, closer to 70 or 80%. This is a puzzling implication, and it is something that some of the previously mentioned papers also point out.

Despite the criticisms it faced, the studies and conversation on convergence continued, although not as fiery as in the 1990s. In 2004, Sala-i-Martin et al. do cross-country panel regressions, regressing a vector of income growth rates on a big set of possible explanatory variables of growth and then use the Bayesian Averaging of Classical Estimates (BACE) approach to understand which of those variables are significantly partially correlated with long-term growth. Among other conclusions, the authors find that the fourth variable more significantly related to growth was the initial level of per capita income. This implies clear evidence for conditional beta convergence.

Another idea from this 2004 paper is that there are other variables that are extremely important to consider when we want to explain growth. As stated earlier, this focus on explanatory variables of growth happened as criticisms surged and the variables found to be significantly related to growth in the literature are ones such as human capital (Barro, 1991), sectoral composition of income (Barro and Sala-i-Martin, 1992) or democracy variables (Barro, 2012).

Expanding upon this and to conclude on the literature review of convergence, is the mention of Kremer et al. (2021). This paper brings forth the interesting idea that a lot of the variables that explain growth have undergone large changes over the last few decades and are converging substantially across countries toward the values and levels of the richer countries. The authors first test for absolute beta convergence and find that there is a trend toward absolute convergence since 1990s - that has lasted 25 years (1990-2025)- and they also find evidence of absolute convergence since 2000. Then, they test for conditional beta convergence establishing four different groups of explanatory variables for growth and two different time periods (within 1960-2015), having 1985 as the turning year. They find that the relationship between the explanatory variables and income has remained stable, but that their relationship with growth has weakened. Finally, the authors use the omitted variable bias method to calculate the gap between the absolute and conditional beta values. Their findings suggest a narrowing of this gap, which could be explained by the convergence of explanatory variables and/or by the fact that they lost predictive power for growth. Either way they pose the hypothesis of a convergence to absolute convergence across economies.

Finally, it is important for the purposes of this dissertation to mention that traditional beta convergence, assumes that the rate of convergence is constant over time. This is because most of the literature on this topic is based on linear regressions, which have the error term capture discrepancies between the theory and the empirics. In reality, economic factors—such as policy changes, financial crises, or technological shifts—can cause the convergence process to vary. This leads us to the contemplation of the concept of time-varying beta convergence.

Time-varying beta convergence allows the speed of convergence to change over time rather than being fixed. Instead of assuming a constant beta coefficient in growth regressions, it models beta as a function that evolves over time, capturing dynamic shifts in economic growth patterns. The idea of time-varying coefficients was put forth by Ekkehard Schlicht, who, in 2021, proposed a method for the estimation of time-varying

coefficients in linear models. This method ensures that coefficients change slowly over time and that they are highly correlated. Additionally, the estimation method can be seen as a generalization of the OLS method. Henceforth, the calculations of the beta coefficients for convergence in this dissertation will be done in a time-varying manner, according to Schlicht (2021).

3. Empirical framework

Having established the theoretical work done in neoclassical growth economics on convergence, some of the empirical results for convergence and the studies of macroeconomic rates of return, we can now move to the methodology used in this dissertation. As previously stated, the aim of this work is to investigate a possible long-term relation between macroeconomic rates of return and the speed of convergence, β .

For this, our methodology is divided into three distinct parts. Firstly, we will analyse the method used in the calculations for the macroeconomic rates of return found in Afonso et al. (2025). Secondly, we will estimate the time-varying conditional beta coefficients, as in the estimation of the speed of convergence for each country to its own steady state level. Finally, we will do a panel data regression analysis where we use the estimated β coefficients for conditional convergence of each country ($\beta_{i,t}$) as the dependent variable, the macroeconomic rates of return of Afonso et al. (2025) as our main independent variables and other independent variables as control.

3.1. Macroeconomic rates of return

We start with a comprehensive review of the method used by Afonso et al. (2025) in his obtention of the macroeconomic rates of return. The author departs from the neoclassical Cobb-Douglas production function, whose inputs are private capital (K_P), public capital (K_G) and labour (L):

$$Y = K_P^\alpha K_G^\gamma L_t^{1-\alpha-\gamma} \quad (1)$$

From this production function, the author calculates the marginal productivity of public and private capital (MPK_G and MPK_P, respectively) by taking first order derivatives on the equation above, as seen as follows:

$$MPK_P = \frac{\partial Y}{\partial K_P} = \alpha K_P^{\alpha-1} K_G^\gamma L_t^{1-\alpha-\gamma} = \alpha \frac{Y}{K_P} \quad (2)$$

$$MPK_G = \frac{\partial Y}{\partial K_G} = \gamma K_P^\alpha K_G^{\gamma-1} L_t^{1-\alpha-\gamma} = \gamma \frac{Y}{K_G} \quad (3)$$

where α and γ are the output elasticities to private and public investment, respectively. These elasticities are the crucial element in the basis of the calculation of macroeconomic rates of return (Aschauer, 1989), so we must estimate them. In order to empirically compute α and γ , Afonso et al. (2025) follows previously developed methodology (Afonso and St. Aubyn, 2010) using a VAR approach where X_t is a vector of five ordered endogenous variables (two of which are obviously private and public investment), c is the constant term, A_i is the matrix of the estimated autoregressive coefficients, ε_t is the error term and p is the optimal lag length determined by the often used Akaike information criterion (AIC) and Bayesian information criterion (BIC) criteria:

$$X_t = c + \sum_{i=1}^p A_i X_{t-i} + \varepsilon_t \quad (4)$$

Orthogonal shocks are imposed for every variable of the specification above, but these shocks can be interpreted as structural shocks given the use, at this point in the methodology, of Cholesky's decomposition method. Another important aspect of this specification and methods used in Afonso et al. (2025) is the ordering of the endogenous variables in the model, as it imposes responses with different timing upon the variables when one of them suffers a shock. Thus, becoming more in line with real world dynamics in how macroeconomic variables interact and affect each other. Drawing upon the VAR approach and correspondent impulse response functions (IRFs) that followed the imposition of shocks, Afonso et al. (2025) computes the output to private and public elasticities, α and γ , respectively.

The last step in the calculations of the macroeconomic rates of return is the establishment of the relationship between the marginal productivities and the rates of return, assuming the 20-year capital lifetime:

$$MPK_P = (1 + r_p)^{20} \Leftrightarrow r_p = (MPK_P)^{\frac{1}{20}} - 1 \quad (5)$$

$$MPK_G = (1 + r_G)^{20} \Leftrightarrow r_G = (MPK_G)^{\frac{1}{20}} - 1 \quad (6)$$

where MPK_P and MPK_G are as previously expressed. The results for r_P and r_G are defined as the partial macroeconomic rates of return for private and public investment, respectively, given that they do not account for crowding-in or crowding-out factors. This means, these rates are measuring the return of private or public investment on output without accounting for possible effects they can cause each other. For example, when increasing public investment for infrastructures like bridges, a crowding-in of private investment can happen given that now business and people have more favourable conditions. To account for these effects, Afonso et al. (2025) derives the macroeconomic rate of return of total investment from a shock to private (MPK_{Total,K_P}) or public investment (MPK_{Total,K_G}), calculating the total macroeconomic rate of return of private investment (r_{Total,K_P}) and the total macroeconomic rate of return of public investment (r_{Total,K_G}) as such:

$$MPK_{Total,K_P} = (1 + r_{Total,K_P})^{20} \Leftrightarrow r_{Total,K_P} = (MPK_{Total,K_P})^{\frac{1}{20}} - 1 \quad (7)$$

$$MPK_{Total,K_G} = (1 + r_{Total,K_G})^{20} \Leftrightarrow r_{Total,K_G} = (MPK_{Total,K_G})^{\frac{1}{20}} - 1 \quad (8)$$

where MPK_{Total} is the marginal productivity of total investment, defined as:

$$MPK_{Total} = \frac{\Delta Y}{\Delta K_P + \Delta K_G} = \frac{1}{MPK_P^{-1} + MPK_G^{-1}} \quad (9)$$

Now, we have a better understanding of the four variables which will be used in this dissertation: the partial macroeconomic rate of return of private investment (r_P , named hereafter as $ipriv_{partial}$), the partial macroeconomic rate of return of public investment (r_G , named hereafter as $ipub_{partial}$), the total macroeconomic rate of return of private investment (r_{Total,K_P} named hereafter as $ipriv_{total}$) and the total macroeconomic rate of return of public investment (r_{Total,K_G} named hereafter as $ipub_{total}$).

3.2. Time-Varying Beta convergence coefficients

The estimation of the of the time-varying beta convergence coefficients is done via a cross-sectional time series linear regression equation. Hence, the estimation of these coefficients will give us the values for the speed of convergence of the economies, in a time-varying manner, toward their own steady state values.

To be consistent with the neoclassical framework and the methodology that produced robust evidence for conditional convergence, we draw from the “Barro Regressions” (Barro, 1991; Barro and Sala-i-Martin, 1992).

The literature often considers a 10-year long interval time periods (Barro and Sala-i-Martin, 1992) which is consistent with the idea of growth being a long-run process. Besides this, and in light of more recent literature (Kremer et al., 2021), we also consider 5-year time periods in an attempt to capture more nuanced changes in the process of convergence over the entire time period analysed, but that are still congruent with the long-run process that is income growth.

For these estimations, we regress equations (10) and (11):

$$GDP_{pcgr_{i,t,t-10}} = \beta_0 + \beta ten_{i,t} GDP_{pc_{i,t-10}} \quad (10)$$

$$GDP_{pcgr_{i,t,t-5}} = \beta_0 + \beta five_{i,t} GDP_{pc_{i,t-5}} \quad (11)$$

where $GDP_{pcgr_{i,t,t-10}}$ and $GDP_{pcgr_{i,t,t-5}}$ are the annual average growth rate of per capita GDP between the years $t-10$ and t and $t-5$ and t , respectively. Additionally, $GDP_{pc_{i,t-10}}$ and $GDP_{pc_{i,t-5}}$ are the respective beginning of the 10-year and 5-year period levels of per capita GDP. It should also be noted that GDP is in natural logarithm.

To estimate equation (1), we adopt the aforementioned approach by Schlicht (2021), which allows us to obtain two time-varying series of conditional β convergence values for each country. Our data spans 1980 to 2022 so, using both a 10-year and 5-year lag, the time series for the time-varying beta coefficients of the 10-year time periods span 1990 to 2022 and the time series for the time-varying beta coefficients of the 5-year time periods comprises 1985 to 2022. Lastly, for convergence to be verified, the β values have to be negative.

3.3. The relationship between macroeconomic rates of return and the time-varying beta coefficients

Having established the methodologies behind the values of the macroeconomic rates of return and of the time-varying beta coefficients, we can describe our approach at attempting to relate the two variables.

We will do panel regression analysis comprised of 16 countries in the period 1980 to 2022, which is in accordance with the data available from Afonso et al. (2025).

Our methodology makes use of the previously obtained time-varying coefficients for conditional beta convergence, $\beta_{i,t}$. The first panel data regression will have the 10-year period time-varying beta coefficients ($\beta_{10,i,t}$) as the dependent variable. Our second regression will have the 5-year period time-varying beta coefficients ($\beta_{5,i,t}$) as the dependent variable.

Then, $\beta_{10,i,t}$ and $\beta_{5,i,t}$ will be separately regressed on the same explanatory variables. The betas will be regressed on our main independent variable, the macroeconomic rates of return ($MRR_{k,i,t}$) found in Afonso et al. (2025), and on a set of different combinations of nine control variables, which will soon be addressed and are here denominated by $X_{j,i,t}$.

Thus, the regression equations (12) and (13) can be expressed as follows:

$$\beta_{10,i,t} = \alpha_0 + \alpha_1 MRR_{k,i,t-10} + \alpha_j X_{j,i,t-10} + \varepsilon_{i,t} \quad (12)$$

$$\beta_{5,i,t} = \alpha_0 + \alpha_1 MRR_{k,i,t-5} + \alpha_j X_{j,i,t-5} + \varepsilon_{i,t} \quad (13)$$

where $MRR_{k,i,t}$ represents the main explanatory variable with k indexing for which of the four kinds of macroeconomic rates is used: $ipub_{partial}$, $ipub_{total}$, $ipriv_{partial}$, $ipub_{total}$. $X_{j,i,t}$ corresponds to the nine control variables with j indexing for which one(s) is (are) being utilized for country i at time t . We will run the two β convergence series (the one with a time-lag of five years and the one with a lag of ten) on each of the four macroeconomic rates of return as our basic regressions. Henceforth, we have a base set of eight regression equations, to which we will add combinations of control variables for a more comprehensive empirical analysis.

We hope this framework will enlighten the impact of the macroeconomic rates of return on the speed of convergence of an economy toward its own steady state.

Before we move on to the data employed in this model there are a few important mentions. The β values used as the dependent variable in the specification above were transformed to be in absolute terms. Furthermore, we understand that using estimates of β as the dependent variable may introduce accuracy concerns, as some coefficients could be estimated more precisely than others. To account for this, our conditional β convergence coefficients are weighted by the inverse of the standard error obtained in estimation of regressions (10) and (11). Furthermore, we employ a fixed effects estimator, which is an OLS estimation applied to transformed variables. The choice of this estimator is given the need to control for country-level and year-level characteristics in this panel dataset. An important implication of the use of the fixed effect estimator, is that it can induce multicollinearity in the model (Moon & Weidner, 2015).

3.4. Data and Stylized facts

Following the establishment of the methodological framework, the next step is to explore the variables used in the model, along with the countries and time span considered.

To begin, the empirical research in this paper relies on a cross-sectional timeseries dataset comprised of 16 OECD (Organization for Cooperation and Economic Development) countries, 13 of which are currently part of the European Union (EU). More specifically, the countries in the sample are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, Portugal, Spain, Sweden, United Kingdom and United States. The dataset spans the year 1980 to the year 2022. The choice of countries and of the time span is due to the data available in Afonso et al. (2025). It is important to note that we have an unbalanced panel, meaning that the number of observations varies across countries and variables. This slight incompleteness of some observations, however, does not undermine our regression results and analysis.

Regarding the countries in the sample, out of the 16 only two (Japan, and United States) were never part of the EU. The United Kingdom first joined the European Union in 1973, back then denominated EEC (European Economic Community), never having adopted the euro as its currency. In 2016 there was a national referendum put to vote in the UK, which led to the eventual exit (famously coined “Brexit”) of the UK from the EU in 2020. The remaining 13 countries have differing years of adhesion to the union and only two out of these 13 (Denmark and Sweden) have not adopted the euro as their

currency. The figure below illustrates the different years of the adhesion to the European Union, only for the relevant countries in this study.

Figure 1 - Current members of the European Union and the years of adhesion of the countries in our dataset.



Source: European Union Website, elaborated by author.

It is important to remark this membership to the EU of most of the countries in our sample as it implies, for several reasons, deep economic integration which has only intensified in the past decades, with the adoption of the euro as national currency by many of these countries and the issuance of mutualized debt in 2021 being such examples. This great integration process was, then, taken into consideration when choosing the set of control variables.

Moving away from the focus on EU countries, it is relevant to point out all the 16 countries in the sample are members of the OECD, are classified by the World Bank as high-income countries as of 2025 and considered part of the world's most development nations, all scoring values within the highest ranking category (≥ 0.8) in the UN's human development index (HDI).

Our dependent variable is β -convergence, measuring the speed of convergence of a country to its own steady state. Following the methodology explained before, we calculated this variable ourselves using real GDP per capita data extracted from the AMECO database. We then transformed these coefficient values and made them absolute.

Our main independent variables are the macroeconomic rates of return: partial and total and for public and private investment. These are taken directly from Afonso et al. (2025). From these values we can see that public investment typically generates greater

macroeconomic returns than private investment (with the exception of a five out of the 16 countries) but the public returns are more volatile.

Besides the use of macroeconomic rates of return as explanatory variables, we have included a set of nine control variables. The variables used are as follows: current account as a percentage of GDP (*ca*), public gross debt as a percentage of GDP (*debt*), unit labour costs in logarithmic form (*ulc*), adjusted wage share (*wage*), terms of trade in logarithmic form (*terms*), total factor productivity in logarithmic form (*tfp*), unemployment rate (*unemp*), labour-capital substitution in logarithmic form (*lcs*) and the real effective exchange rate (*reer*).

These variables were all taken from the AMECO database for the entirety of our sample countries and sample years.

Before advancing further, it is now important to discuss the motivation behind the choice of these variables. Starting with the debt ratio, this variable is of extreme importance for an economy, given the constraints and pressure it can put on a government's budget, its availability to make policy changes, induce economic growth, invest, among others... (Burriel et al., 2020). It is a variable that is especially relevant when we look at our set of countries, given that most of them are members of the EU and must comply with two main fiscal rules, as part of the Excessive Deficit Procedure (EDP), one of which is the goal of maintaining a 60% debt to GDP ratio.

The unemployment rate is also an extremely relevant economic variable, as high values of unemployment can have negative consequences for several macroeconomic variables, such as decrease of consumer spending and decrease in tax revenue. Additionally, unemployment also affects monetary macroeconomic dynamics, more notably, via the Phillips Curve (where the unemployment rate has a direct link to inflation rate).

Moreover, we have the inclusion of the current account and of the real effective exchange rate which follow similar reasonings. The idea behind the inclusion of the real effective exchange rate is to understand a country's capacity to stimulate aggregate demand via their exports. Hence, it can be seen as a measure of competitiveness, but also as a way to analyse currency values. Including the current account goes further than that as it also allows us to understand a country's capacity to finance itself, as it gives us clear connection to its financial flows via national accounting: CA (current account) + FA (Financial account) = 0. Furthermore, 11 countries in this sample share the same currency -the euro- and none of them, individually, has autonomy over monetary policy, i.e. none

of these countries, has the ability to devalue their currency in times of need in order to increase their trade balance and, in turn, increase their GDP. Because this powerful tool of monetary policy is unavailable to these sovereign countries and is exclusively carried out by the European Central Bank (ECB), differences in the current accounts of these 11 countries give us important insights on the dynamics and movements of macro variables, and its consequences. For example, after the GFC economies inside the European Union faced asymmetric shocks, countries with negative values in their current account such as Portugal and Greece took longer to recover, than countries like Germany, with higher productivity levels (hence, higher ability to lower prices and better attract higher levels of exports), recuperated faster.

Moving on, we have the inclusion of the labour-capital substitution index, which measures the relative intensity of the two factors of production (labour and capital) in the production process. From this definition and from the previously established concepts and methodology of macroeconomic rates of return, it is already clear that this can have implications for the impact of the rates of return on the speed of convergence. Furthermore, as seen in some of the empirical literature, such as Barro and Sala-i-Martin (1992), sectoral decomposition of income, i.e. from which industries does income originate from (does income originate from more capital-intensive industries or less capital-intensive, for example), can have important effects on the speed of convergence.

Moreover, we include two variables that measure productivity in distinct ways: total factor productivity (*tfp*) and unit labour costs (*ulc*). Total factor productivity compares total outputs relative to the total inputs used in production, while unit labour costs calculate the ratio of labour costs to labour productivity. The intention behind the inclusion of these two variables is that productivity has been linked to growth as one of its main proponents and it is also included in the process of obtention of the macroeconomic rates used. Additionally, and from a theoretical standpoint, productivity is used in many economic models as the sole driver of growth in the long run and often presented as an exogenous factor. This is the case in the neoclassical growth models mentioned in the beginning of this dissertation.

Finally, we will explain the motivation behind the last two control variables chosen. The wage share values represent the percentage of a country's GDP that is allocated to employee compensation, and it was included as it is important to account for income distribution between production factors. This idea stemmed from some of the critiques that the earlier literature on convergence faced, like Quah (1993), but, more relevantly, it

controls for the relative weight that the labour production factor has and, from the methods seen for the macroeconomic rates of return, this can be an important control variable.

Lastly, terms of trade which is a ratio of a country's export prices to their import prices was included for its importance in proxying for a country's "purchasing power", i.e. the ability of a country to pay with its exports.

Two additional notes should be made at this point. Firstly, we had also included the consumer price index (cpi) to account for inflationary pressures and their possible economic consequences, but we later removed it due to the fact that inflation was not included in the computations of the macroeconomic rates of return and our beta coefficients are, as seen before, computed using real GDP values.

Secondly, the control variables which were not originally in percentage were transformed and take a logarithmic form in our regression analysis.

Finally, a table with the summary descriptive statistics follows below.

Table 1. Summary descriptive statistics

Variables	Obs.	Mean	Std. Dev.	Min.	Max.
<i>ca</i>	450	0.00276	0.0455	-0.207	0.122
<i>debt</i>	487	0.823	0.436	0.112	2.584
<i>ulc</i>	688	83	21.48	31.3	166.6
<i>wage</i>	677	0.639	0.0514	0.303	0.758
<i>terms</i>	688	99.6	11.46	60.2	156
<i>tfp</i>	688	88.98	14.46	32.6	134.1
<i>unemp</i>	677	0.082	0.0423	0.019	0.278
<i>lcs</i>	688	92.95	7.069	71	108.6
<i>reer</i>	602	101.4	12.57	71.1	155
<i>ipub_{partial}</i>	384	0.018	0.0411	-0.148	0.14
<i>ipub_{total}</i>	384	0.0129	0.0386	-0.148	0.11
<i>ipriv_{partial}</i>	597	0.0125	0.018	-0.088	0.0663
<i>ipriv_{total}</i>	597	0.0107	0.0169	-0.0894	0.0605
<i>real gdppc</i>	688	30,042	16,642	2,523	106,195
<i>real gdppcgr</i>	672	3.717	10.04	-29.48	39.05
β_{10}	528	9.51	1.938	3.567	12.61
$\beta_{10_{sd}}$	528	1.322	0.172	0.949	1.815
β_5	608	18.81	4.282	4.933	25.14
$\beta_{5_{sd}}$	608	3.16	0.409	1.702	3.91

Source: Author's calculation.

With an overview of our control variables and motivations, we will establish how we used the variables before we move on to the empirical results and analysis.

As previously mentioned, from our baseline of eight regressions, we add combinations of the control variables. More specifically, besides the base regression (running one beta convergence series on one kind of macroeconomic rate) we have 17 other regressions

where the additions are just a combination of control variables, the combinations always includes the debt ratio and the unemployment rate. The decision in the specification of these 17 regressions was based on the correlation values between all the variables in our model, given that the inclusion of highly correlated variables can overfit the model and induce multicollinearity which produces unreliable estimates.

The obtained correlation matrix is presented below, where darker shades alert for high correlation values, either positive or negative.

Table 2 .Correlation Matrix of the employed variables.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) $ipub_{partial}$															
(2) $ipub_{total}$	0.932														
(3) $ipriv_{partial}$	-0.01	0.045													
(4) $ipriv_{total}$	0	0.045	0.951												
(5) β_{10}	0.268	0.141	-0.399	-0.403											
(6) β_5	0.086	0.116	-0.288	-0.402	0.657										
(7) ca	-0.025	-0.059	-0.183	-0.198	0.325	0.255									
(8) $debt$	0.124	-0.018	-0.01	0.013	0.234	-0.273	-0.12								
(9) ulc	0.042	-0.041	-0.017	-0.037	0.032	-0.259	0.08	0.342							
(10) $wage$	0.133	0.118	-0.063	-0.016	0.27	0.07	-0.012	-0.086	-0.032						
(11) $terms$	0.058	-0.006	-0.229	-0.195	0.226	-0.144	0.232	-0.005	0.486	0.132					
(12) tfp	-0.065	-0.091	0.051	0.116	0.139	-0.027	0.058	0.308	0.421	-0.086	-0.124				
(13) $unemp$	0.086	0.066	0.02	-0.028	0.022	0.176	-0.157	0.218	-0.036	-0.068	-0.234	-0.044			
(14) lcs	-0.123	-0.118	0.118	0.108	-0.004	-0.044	0.287	0.342	0.684	-0.15	0.089	0.735	-0.021		
(15) $reer$	0.177	0.08	0.063	0.008	-0.221	-0.329	-0.215	-0.135	0.467	0.015	0.505	-0.391	0.094	-0.076	

Source: Author's calculation.

From this matrix we can construct the following combinations of control variables which will be added to the baseline case of eight regressions. The following equation serves, then, as the more developed regression run, the same rationale is applied for the series of $\beta five_{i,t}$:

$$\beta ten_{i,t} = \alpha_0 + \alpha_1 MRR_{k,i,t-10} + \alpha_2 debt_{i,t-10} + \alpha_3 unemp_{i,t-10} + \alpha_4 Z_{l,i,t-10} + \alpha_5 \Psi_{m,i,t-10} + \varepsilon_{i,t} \quad (14)$$

$Z_{l,i,t-10}$ is a subset of the control variables that includes the labour capital substitution (lcs), wage share ($wage$), total factor productivity (tfp) and unit labour costs (ulc), with l indexing for which control variable is in the regression. $\Psi_{m,i,t-10}$ is a subset of the control variables which includes the current account (ca), the real effective exchange rate ($reer$) and terms of trade ($terms$), with m indexing for which control variable is in the regression being utilized for country i at time t . So, besides the baseline case of one beta run on one macro rate, we have 17 different combinations of control variables added.

4. Empirical Analysis

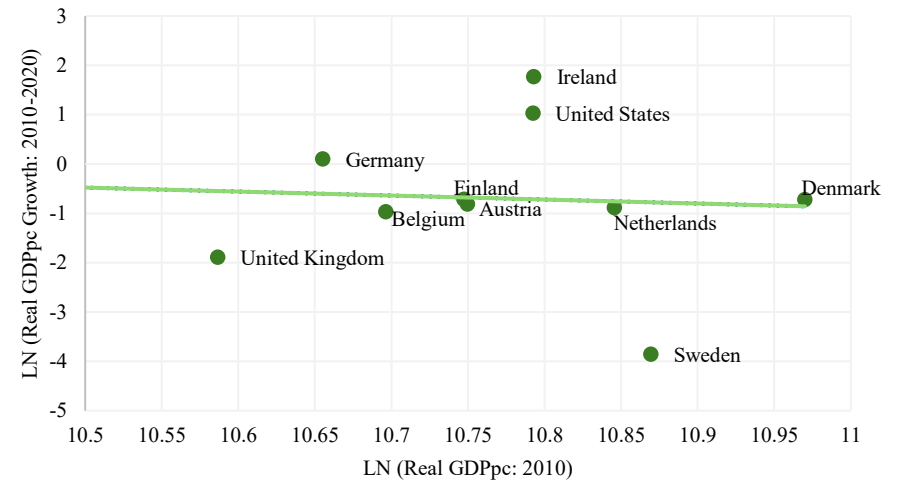
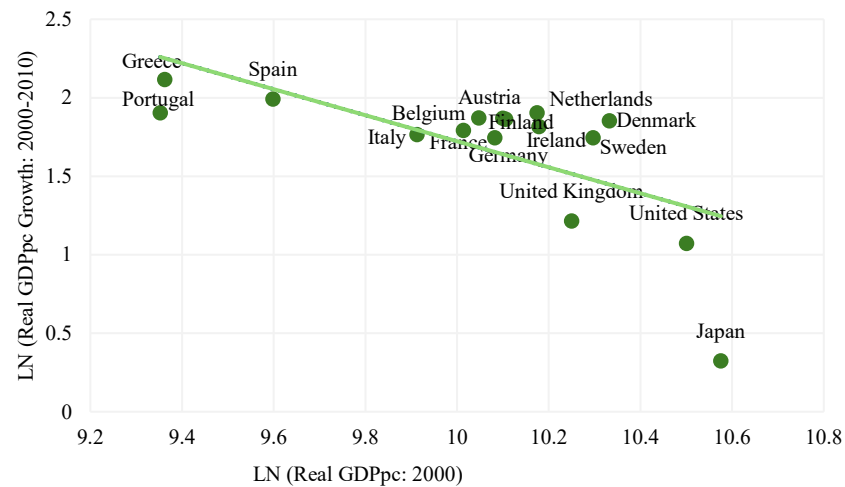
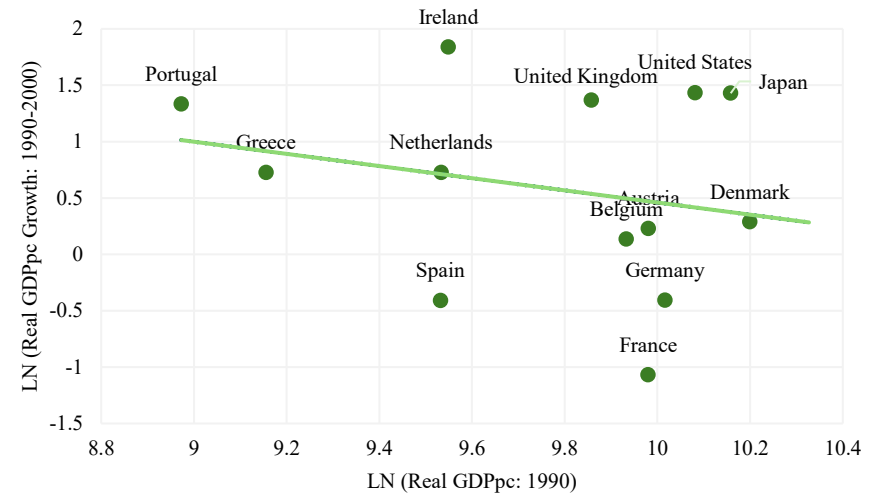
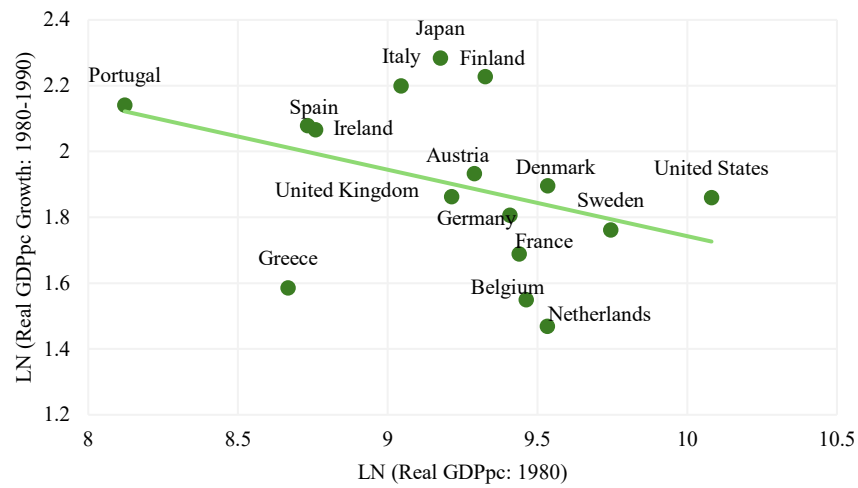
4.1. *The β convergence hypothesis*

As the starting point of our analysis, we will test our panel dataset for the hypothesis of β -convergence, whether countries with initial lower levels of GDP per capita have higher GDP per capita growth rates over time. In pursuit of this, we have plotted four linear graphs for the 10-year time lag with a trend line (as seen in figure 2 below).

From all these graphs, we can observe a convergence process between the 16 countries in our sample in the four different time periods specified: countries with lower values of GDP are “catching up” to richer countries. We can also conclude that convergence processes were different depending on the decade, we regard more rampant convergence processes in the 1980-1990 and 2000-2010 period. The period of 2010-2020 shows only a slight negative relation, which is most likely due to the recession caused by the global financial crisis. This crisis, that hit more gravely in Europe, mostly peripheral countries in Europe like Portugal and Greece in 2010-2011 in what was known as the sovereign debt crisis, had a slow recovery process with positive growth rates showing in 2015-2016, only for these do be made negative again by the covid-19 pandemic.

We notice some minor outliers such as Portugal, Greece and Japan, in the first three periods. It is important to note that missing values were due to negative growth rates, which when logged were taken from the sample. Additionally, similar graphs were plotted for 5-year time lags, and we found similar results. Henceforth, we can confirm the well-studied β convergence hypothesis for our dataset. (Barro and Sala-i-Martin, 1992; Barro, 2012).

Figure 2 – Initial GDP per capita vs 10-year Real GDP per capita Growth Rate: A four-period Comparison



Source: Elaborated by author

4.2. Empirical Results: An Overview

At last, we will proceed with the presentation of the empirical results and their examination. Thus, the following pages contain the panel data regression analysis and table results.

The main result is as expected: macroeconomic rates of return (MRRs) positively impact the speed of convergence. Even though the magnitude of this impact varies between β s and among the different kinds of macroeconomic rates of return. This implies that when public and/or private investments yield higher returns for the overall economy (whether dynamic interactions between economic variables are considered or not, i.e. whether we are analysing total or partial rates of return) economies tend to grow at a faster rate. Intuitively this is very understandable but, from a theoretical and empirical perspective (in growth economics), a direct connection between our chosen concepts of analysis - macroeconomic rates of return and the coefficient for the speed of convergence – has not been studied.

More specifically, just the isolated effect of MRRs on the speed of convergence is always positive with only two exceptions, the MRRs for public investment with a 10-year β . These two exceptions could be due to the fact that the effects of the MRRs on the speed of convergence are more diluted over a longer period of time and/or due to the nature of public investment itself. Public investment, as mentioned, can be of different kinds and thus, it can have different returns for the economy. As early in the literature as Aschauer (1989), we have evidence that states non-military public investment, more specifically infrastructure, has the highest rates of return which is later corroborated by Pereira (2000), while other types of public investment have small insignificant returns. So, that could be a reason for these negative effects.

Although, it is important to add that once just the debt ratio and the unemployment rate are controlled for, the effect of MRRs on β s constantly increases and even becomes positive in both of the previously mentioned negative cases. This result is very important because adding these two variables as control is very relevant in the context of our analysis. As is known, governments which have constantly high values for the debt ratio and want to continue operating a high ratio do so by either issuing bonds or increasing tax revenues, both of which can affect private investment negatively. Bond issuance increases market pressure and leads to higher interest rates, upping the borrowing cost of private investors, thus potentially leading to a decrease in private investment. Increasing tax revenue comes at the expense of decreasing disposable income, hence decreasing private

investment capacity. Regarding effects on public investment, in this matter (and more importantly for EU countries, which make up most of our sample and have a reference value of 60% for the debt ratio, high debt may pressure governments to decrease public investment in order to be fiscally sustainable. With regards to the unemployment rate, we observe that often governments act countercyclically to unemployment rates, so there may be a need to increase public investment to fight the negative consequences of high unemployment rates. On the other hand, higher unemployment rates are also signalling weak demand and thus they lead to formation of expectations about returns on investment which are lower. Moreover, there are other economic theories developed that can be used to describe further relations especially with GDP growth and debt, like the idea of debt-driven GDP -based on concepts from Domar (1944), Domar (1947), and Kalecki (1954) -which, simply put, proposes that debt acceleration can mitigate the negative effects of economic recessions, because it can be seen as a motor for GDP growth.

Having established possible ways that the unemployment rate and the debt ratio can interact with MRRs and GDP, we can better understand how controlling for these two variables is important in order to better dissect and understand how macroeconomic rates of return of public and private investment affect the speed of convergence, plus how that impact changes.

Notably, controlling for the current account (in addition to unemployment rate, debt ratio and labour-capital substitution/wage share/total factor productivity/unit-labour costs), leads the impact MRRs have on the speed of convergence to decrease, with three exceptions, and even turns the effect negative in some cases (all the latter cases are regarding the 10-year long β).

This is a noteworthy and expected result if we follow the aforementioned rationale by Ertl and Rabitsch (2025). A higher current account, leads to an increase in GDP and hence to higher values of per capita income and capital which, in turn, and according to diminishing returns, is associated with lower values of marginal productivity. Thus, resulting in lower values of MRR, which as seen in this empirical analysis, mostly leads to smaller speeds of convergence, *ceteris paribus*.

Additionally, when accounting for the real effective exchange rate (in addition to unemployment rate, debt ratio and labour-capital substitution/wage share/total factor productivity/unit-labour costs), the impact MRRs have on the β s also decreases, with one exception. The real effective exchange rate takes into account the value of the domestic country's currency in relation to a basket of foreign currencies, adjusting for inflation

differentials. So, a higher real effective exchange rate would mean the domestic country has a higher purchasing power, which can lead to a decrease in its exports (because now they don't have such competitive pricing), affecting GDP directly and potentially investment returns for export industries. By contrast, a lower real effective exchange rate can also increase import costs for importing industries leading them to have lower returns on investment. The latter investment type, that heavily takes imports as inputs for production like raw materials, can very easily be public investment, for investments such as infrastructure building, because they do often require foreign resources.

Adding total factor productivity for control (in addition to unemployment rate and debt ratio) and terms of trade (in addition to unemployment rate, debt ratio and labour-capital substitution/wage share/total factor productivity/unit-labour costs), the influence on the effect of MRRs on the speed of convergence is mixed.

Lastly, controlling for the wage share and unit labour costs (in addition to the unemployment rate and the debt ratio), the effect of MRRs of both public and private investment on the speed of convergence always decreases. Although both of these variables include employee compensation, they measure two different things. Wage share measures labour costs relative to GDP and unit labour costs measure labour costs related to productivity. The closeness in calculation may have led them to invoke the same effect on the impact that MRRs have on β . Higher wage shares usually mean labour costs have gone up, which (as labour is used as an input in the production function) can reduce rates of return, thus reducing the speed of convergence. Regarding unit labour costs, higher values of it usually mean either labour costs are increasing, or productivity is decreasing, with the latter being the case we get an automatic, and previously explained, direct implication of lower rates of return.

To conclude, on average, the biggest effects of MRRs on β s happen when we are analysing macroeconomic rates of return of private investment. For both private and public MRRs, the range of values for the influence on speed of convergence does not change much between partial or total rates. That said, the ranges of values are more heterogeneous when we are comparing the 5-year β s rather than looking into the 10-year β s. Additionally, just based on time period, the influence of MRRs is greater on average, when our analysis focuses on the 5-year β s rather than on the 10-year β s. This last result can be due to the fact that, as mentioned earlier, the effect of MRRs is diluted over longer periods of time.

Given the high number of regressions ran, we will follow with two sections to better dissect the differences between the effects of private and public macroeconomic rates of return on the speed of convergence.

4.2.1 Public Macroeconomic Rates of Return on β

As mentioned before, the effect of public macroeconomic rates of return of public investment on the speed of convergence is lower than the effect of private macroeconomic rates of return. This outcome was puzzling, given that from the data we used (Afonso et al., 2025) public investment had higher macroeconomic rates of return, in general, than private investment (because private investment levels are higher and through the diminishing marginal returns assumption, they lead to lower levels of marginal productivity, hence lower MRRs). However, there is more volatility in the public macroeconomic rates of return, maybe due to the fact that different types of public investments considerably different returns, which may have contributed to this result (Aschauer, 1989; Pereira, 2000).

More specifically, the values of the effect of this type of investment on β vary little, ranging from -0.17 to 1.66 , for partial and public rates and 5 and 10-year lags. This means that independently of the latter four factors, the effect of public investment MRRs on the speed of convergence is rather stable and relatively small, indicating that private investment MRRs may be more relevant for changes in the speed of convergence.

The isolated effects are also important to take note of, they are: -0.158 , -0.125 , 1.136 , 1.08 for the 10-year β partial rate, 10-year β total rate, 5-year β partial rate and 5-year β total rate, respectively. The magnitude of this coefficient does not vary greatly when we add the combinations from our set of control variables. However, for the 10-year β , depending on the specification, the effect can be positive or negative, showing some inconsistency in sign, but for the 5-year β the effect is always positive for all regression specifications.

Furthermore, controlling for labour-capital substitution (in addition to the unemployment rate and the debt ratio), always increases the effect of MRRs of public investment on the speed of convergence. As labour-capital substitution measures the intensity of the use of capital relative to the use of labour in the production process, it is understandable how this variable could change the effect that MRRs are having on the speed of convergence. A higher labour-capital substitution would mean we are employing more capital compared to labour and, following the diminishing marginal returns

assumption, this will lead to lower macroeconomic rates of return. The opposite is true for lower values of the labour-capital substitution ratio. With regards to public investment specifically, we would expect it to be more capital intensive in nature than private investment, so the way the effect of MRRs on β changed is slightly unexpected.

Table 3. Relationship between Macroeconomic Rate of Return of Public Investment, Partial, and 10-years' time-varying β -convergence.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
$ipub_partial_{t-10}$	-0.158 (0.507)	0.178 (0.460)	0.195 (0.473)	-0.082 (0.281)	0.008 (0.155)	0.169 (0.425)	-0.025 (0.335)	-0.090 (0.293)	-0.042 (0.182)	-0.036 (0.312)	0.172 (0.478)	-0.082 (0.266)	0.004 (0.170)	0.155 (0.436)	0.034 (0.280)	-0.068 (0.243)	0.029 (0.174)	0.034 (0.280)
$debt_{t-10}$		0.030 (0.052)	0.029 (0.051)	0.011 (0.054)	0.323** (0.116)	0.100 (0.089)	0.094 (0.082)	0.039 (0.081)	0.297** (0.095)	0.146 (0.099)	0.030 (0.051)	0.019 (0.036)	0.334** (0.112)	0.101 (0.106)	0.170* (0.092)	0.059 (0.087)	0.341** (0.125)	0.166 (0.112)
$unemp_{t-10}$		-0.288 (0.253)	-0.476 (0.882)	1.061 (0.645)	-0.712* (0.333)	-0.620 (0.746)	-0.299 (0.328)	0.301 (0.376)	-0.635 (0.389)	-0.451 (0.374)	-0.329 (0.284)	0.210 (0.325)	-0.596** (0.228)	-0.510* (0.259)	-0.589** (0.207)	0.247 (0.281)	-0.757* (0.417)	-0.574* (0.275)
lcs_{t-10}					0.004 (0.020)	-0.013 (0.014)												
ca_{t-10}				-1.714*** (0.349)				-1.266** (0.471)				-1.430*** (0.323)				-1.361*** (0.411)		
$reer_{t-10}$					0.007*** (0.002)				0.006** (0.002)				0.008** (0.003)				0.011 (0.007)	
$terms_{t-10}$						0.002 (0.002)				0.001 (0.002)				0.002 (0.003)				-0.000 (0.002)
$wage_{t-10}$							1.880** (0.726)	0.774 (0.723)	0.779 (0.523)	1.846** (0.722)								
tfp_{t-10}											-0.001 (0.005)	-0.004** (0.002)	0.004 (0.004)	-0.000 (0.005)				
ulc_{t-10}															0.003 (0.002)	0.001 (0.002)	-0.005 (0.009)	0.003 (0.002)
<i>Constant</i>	9.958*** (0.025)	9.572*** (0.032)	9.256*** (1.453)	10.269*** (1.221)	8.958*** (0.978)	9.206*** (1.404)	8.241*** (0.503)	8.644*** (0.497)	8.435*** (0.346)	8.153*** (0.536)	9.649*** (0.361)	9.516*** (0.137)	8.422*** (0.630)	9.450*** (0.587)	9.429*** (0.130)	9.064*** (0.197)	8.825*** (0.225)	9.441*** (0.198)
Obs.	258	189	189	167	140	189	189	167	140	189	189	167	140	189	189	167	140	189
R^2	0.742	0.534	0.535	0.648	0.744	0.542	0.612	0.652	0.757	0.615	0.535	0.656	0.758	0.541	0.591	0.644	0.747	0.591

Note: * indicates the level of significance of 10%, ** a level of 5% and *** a level of 1%. In brackets we report the robust standard errors. Obs. are the observations for each regression.

Table 4. Relationship between Macroeconomic Rate of Return of Public Investment, Total, and 10-years' time-varying β -convergence.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
$ipub_total_{t-10}$	-0.125 (0.565)	0.135 (0.483)	0.144 (0.495)	-0.132 (0.290)	-0.046 (0.162)	0.123 (0.448)	-0.014 (0.327)	-0.126 (0.288)	-0.061 (0.176)	-0.024 (0.307)	0.125 (0.515)	-0.169 (0.321)	-0.029 (0.169)	0.114 (0.476)	-0.018 (0.310)	-0.139 (0.279)	-0.006 (0.178)	-0.018 (0.312)
$debt_{t-10}$		0.035 (0.052)	0.035 (0.051)	0.013 (0.053)	0.328** (0.117)	0.107 (0.092)	0.093 (0.079)	0.040 (0.077)	0.299*** (0.094)	0.144 (0.096)	0.035 (0.049)	0.024 (0.035)	0.338** (0.113)	0.107 (0.110)	0.176* (0.093)	0.064 (0.084)	0.345** (0.126)	0.171 (0.116)
$unemp_{t-10}$		-0.294 (0.252)	-0.454 (0.887)	1.047 (0.615)	-0.693* (0.354)	-0.606 (0.742)	-0.297 (0.332)	0.290 (0.366)	-0.646 (0.384)	-0.449 (0.371)	-0.336 (0.298)	0.176 (0.319)	-0.610** (0.234)	-0.519* (0.250)	-0.606*** (0.195)	0.219 (0.265)	-0.771* (0.417)	-0.591** (0.271)
lcs_{t-10}			0.004 (0.020)	-0.013 (0.014)	-0.002 (0.011)	0.002 (0.021)												
ca_{t-10}				-1.712*** (0.347)				-1.269** (0.452)				-1.420*** (0.317)				-1.349*** (0.398)		
$reer_{t-10}$					0.007*** (0.002)				0.006** (0.002)				0.008** (0.003)				0.011 (0.007)	
$terms_{t-10}$						0.002 (0.002)				0.001 (0.002)				0.002 (0.003)				-0.000 (0.002)
$wage_{t-10}$							1.873** (0.716)	0.763 (0.682)	0.775 (0.508)	1.838** (0.710)								
tfp_{t-10}											-0.001 (0.005)	-0.004** (0.002)	0.004 (0.004)	-0.000 (0.005)				
ulc_{t-10}															0.003 (0.002)	0.001 (0.002)	-0.005 (0.009)	0.003 (0.002)
<i>Constant</i>	9.955*** (0.022)	9.575*** (0.032)	9.308*** (1.439)	10.276*** (1.163)	9.035*** (0.996)	9.251*** (1.381)	8.245*** (0.498)	8.655*** (0.466)	8.433*** (0.330)	8.158*** (0.531)	9.651*** (0.369)	9.535*** (0.141)	8.415*** (0.625)	9.448*** (0.604)	9.431*** (0.130)	9.063*** (0.197)	8.818*** (0.219)	9.443*** (0.198)
Obs.	258	189	189	167	140	189	189	167	140	189	189	167	140	189	189	167	140	189
R^2	0.742	0.533	0.534	0.649	0.744	0.540	0.612	0.653	0.758	0.615	0.534	0.658	0.758	0.540	0.591	0.645	0.746	0.591

Note: * indicates the level of significance of 10%, ** a level of 5% and *** a level of 1%. In brackets we report the robust standard errors. Obs. are the observations for each regression.

Table 5. Relationship between Macroeconomic Rate of Return of Public Investment, Partial, and 5-years' time-varying β -convergence.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
<i>ipub_partial</i> _{<i>t</i>-5}	1.136 (1.344)	1.384* (0.702)	1.659* (0.809)	1.538** (0.617)	0.735 (0.600)	1.658* (0.789)	0.904 (0.647)	1.246** (0.568)	0.715 (0.512)	0.913 (0.638)	1.576* (0.813)	1.478** (0.658)	1.155* (0.551)	1.611* (0.780)	1.211** (0.499)	1.213*** (0.389)	1.008* (0.481)	1.175** (0.486)
<i>debt</i> _{<i>t</i>-5}		0.395** (0.140)	0.391** (0.146)	0.473*** (0.102)	0.609*** (0.113)	0.438** (0.181)	0.506*** (0.127)	0.471*** (0.097)	0.615*** (0.105)	0.554** (0.187)	0.386** (0.142)	0.460*** (0.106)	0.611*** (0.122)	0.486** (0.165)	0.661*** (0.189)	0.636*** (0.140)	0.593*** (0.125)	0.600** (0.204)
<i>unemp</i> _{<i>t</i>-5}		1.663** (0.748)	0.897 (0.767)	2.417** (0.953)	1.488* (0.757)	0.763 (0.884)	1.602* (0.773)	3.189*** (1.039)	0.989** (0.433)	1.444 (0.912)	2.343** (1.065)	3.808*** (1.261)	1.159*** (0.346)	2.103* (1.023)	1.030 (0.887)	2.677** (1.176)	0.829* (0.436)	1.258 (0.905)
<i>lcs</i> _{<i>t</i>-5}			0.021 (0.017)	0.019 (0.012)	-0.019* (0.009)	0.020 (0.017)												
<i>ca</i> _{<i>t</i>-5}				-3.642*** (1.117)				-3.729*** (1.206)				-3.755*** (1.125)				-3.462** (1.221)		
<i>reer</i> _{<i>t</i>-5}					0.011*** (0.002)				0.009*** (0.002)				0.010*** (0.002)				-0.011 (0.009)	
<i>terms</i> _{<i>t</i>-5}						0.001 (0.003)				0.001 (0.003)				0.003 (0.002)				-0.003 (0.003)
<i>wage</i> _{<i>t</i>-5}							2.457** (0.999)	0.055 (0.911)	1.878*** (0.568)	2.439** (1.059)								
<i>tfp</i> _{<i>t</i>-5}											0.009 (0.007)	0.008 (0.005)	0.005 (0.003)	0.010 (0.007)				
<i>ulc</i> _{<i>t</i>-5}															0.006*** (0.002)	0.004** (0.001)	0.026** (0.009)	0.007*** (0.002)
<i>Constant</i>	20.232*** (0.078)	17.306*** (0.086)	15.781*** (1.314)	15.270*** (1.092)	20.362*** (0.996)	15.695*** (1.362)	15.583*** (0.749)	16.868*** (0.595)	17.764*** (0.480)	15.468*** (0.870)	16.607*** (0.591)	16.185*** (0.450)	18.406*** (0.487)	16.255*** (0.640)	17.009*** (0.117)	16.507*** (0.143)	19.162*** (0.475)	17.224*** (0.267)
Obs.	320	251	251	229	192	251	251	229	192	251	251	229	192	251	251	229	192	251
<i>R</i> ²	0.733	0.779	0.783	0.848	0.938	0.784	0.790	0.845	0.942	0.791	0.785	0.849	0.937	0.787	0.797	0.852	0.941	0.799

Note: * indicates the level of significance of 10%, ** a level of 5% and *** a level of 1%. In brackets we report the robust standard errors. Obs. are the observations for each regression.

Table 6. Relationship between Macroeconomic Rate of Return of Public Investment, Total, and 5-years' time-varying β -convergence.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
<i>ipub_total</i> _{<i>t</i>-5}	1.080 (1.295)	1.290 (0.748)	1.493* (0.836)	1.289* (0.642)	0.678 (0.586)	1.502* (0.816)	0.844 (0.635)	1.040* (0.581)	0.688 (0.498)	0.863 (0.631)	1.488* (0.836)	1.303* (0.671)	1.102* (0.584)	1.546* (0.809)	1.111* (0.559)	1.046** (0.447)	0.901 (0.545)	1.063* (0.550)
<i>debt</i> _{<i>t</i>-5}		0.419** (0.143)	0.420** (0.147)	0.505*** (0.103)	0.625*** (0.127)	0.479** (0.193)	0.525*** (0.129)	0.510*** (0.095)	0.630*** (0.111)	0.578** (0.193)	0.413** (0.143)	0.492*** (0.105)	0.635*** (0.137)	0.524** (0.176)	0.684*** (0.195)	0.664*** (0.144)	0.616*** (0.142)	0.627** (0.215)
<i>unemp</i> _{<i>t</i>-5}		1.709** (0.719)	1.072 (0.723)	2.568** (0.930)	1.568** (0.692)	0.903 (0.851)	1.628** (0.747)	3.143** (1.055)	1.008** (0.402)	1.453 (0.903)	2.394** (1.069)	3.781** (1.291)	1.182*** (0.344)	2.133* (1.027)	1.068 (0.867)	2.671** (1.194)	0.851* (0.405)	1.279 (0.894)
<i>lcs</i> _{<i>t</i>-5}			0.018 (0.017)	0.015 (0.011)	-0.021** (0.009)	0.017 (0.016)												
<i>ca</i> _{<i>t</i>-5}				-3.580*** (1.128)				-3.578** (1.205)				-3.671*** (1.119)				-3.392** (1.223)		
<i>reer</i> _{<i>t</i>-5}					0.011*** (0.002)				0.009*** (0.002)				0.010*** (0.002)				-0.010 (0.008)	
<i>terms</i> _{<i>t</i>-5}						0.002 (0.003)				0.002 (0.003)				0.003 (0.002)				-0.003 (0.003)
<i>wage</i> _{<i>t</i>-5}							2.560** (0.916)	0.339 (0.819)	1.958*** (0.554)	2.535** (0.971)								
<i>tfp</i> _{<i>t</i>-5}											0.009 (0.007)	0.008 (0.005)	0.005 (0.003)	0.011 (0.007)				
<i>ulc</i> _{<i>t</i>-5}															0.006*** (0.002)	0.004** (0.002)	0.024*** (0.008)	0.007*** (0.002)
<i>Constant</i>	20.255*** (0.060)	17.315*** (0.086)	16.034*** (1.260)	15.543*** (0.976)	20.510*** (0.941)	15.921*** (1.302)	15.516*** (0.694)	16.639*** (0.521)	17.708*** (0.472)	15.392*** (0.812)	16.617*** (0.586)	16.169*** (0.453)	18.389*** (0.491)	16.225*** (0.628)	17.017*** (0.120)	16.466*** (0.161)	19.117*** (0.458)	17.217*** (0.280)
Obs.	320	251	251	229	192	251	251	229	192	251	251	229	192	251	251	229	192	251
<i>R</i> ²	0.732	0.777	0.780	0.844	0.938	0.781	0.790	0.842	0.942	0.790	0.783	0.846	0.936	0.786	0.795	0.850	0.939	0.797

Note: * indicates the level of significance of 10%, ** a level of 5% and *** a level of 1%. In brackets we report the robust standard errors. Obs. are the observations for each regression.

4.2.2 Private Macroeconomic Rates of Return on β

To conclude our empirical analysis, we turn our attention to the private macroeconomic rates of return, which, as seen, are more relevant in terms of effect on β .

The values of the effect of this type of investment on β are more heterogeneous than the ones observed for private investment, ranging from -0.58 to 6.85 , for partial and public rates and 5 and 10-year lags. The smaller value belongs to one of the regression specifications for the 10-year β with the partial rate and the highest belongs to one of the specifications for the 5-year β with partial macroeconomic rate.

The isolated effects are also important to take note of, they are: 2.38 , 1.879 , 2.51 , 0.29 for the 10-year β partial rate, 10-year β total rate, 5-year β partial rate and 5-year β total rate, respectively. The magnitude of this coefficient varies slightly when we add the combinations from our set of control variables, with the aforementioned value of 0.29 being an outlier for the range of values we get from the effect of total macroeconomic rates of private investment on the 5-year β convergence. Furthermore, the MRRs of private investments have a positive effect on β in every regression specification with only three exceptions, again all regarding the 10-year β .

Lastly, controlling for labour-capital substitution (in addition to the unemployment rate and the debt ratio), always decreases the effect of MRRs of private investment on the speed of convergence. As previously elaborated, it is understandable that these variables could influence the impact of MRRs on the speed of convergence, but the way in which the influence happens is not as expected.

Table 7. Relationship between Macroeconomic Rate of Return of Private Investment, Partial, and 10-years' time-varying β -convergence.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
<i>ipriv_partial</i> _{t-10}	2.380 (2.022)	4.095* (1.965)	4.056* (2.286)	-0.577 (2.051)	2.498 (2.103)	4.424* (2.150)	3.818* (2.086)	1.284 (2.288)	3.199 (2.220)	4.133** (1.927)	4.352** (1.758)	0.801 (1.564)	3.094 (2.168)	4.547** (1.633)	3.508** (1.618)	1.110 (2.069)	3.047 (2.336)	3.700** (1.682)
<i>debt</i> _{t-10}		0.133* (0.070)	0.130* (0.065)	-0.032 (0.057)	0.141 (0.155)	0.228** (0.095)	0.135* (0.074)	-0.076 (0.099)	0.130 (0.149)	0.220** (0.092)	0.117 (0.070)	-0.068 (0.076)	0.117 (0.180)	0.206* (0.114)	0.195** (0.078)	-0.050 (0.084)	0.118 (0.171)	0.224** (0.084)
<i>unemp</i> _{t-10}		-0.997* (0.498)	-1.032 (0.601)	1.770*** (0.526)	0.069 (0.386)	-1.258** (0.554)	-0.970* (0.528)	-0.117 (0.634)	-0.732 (0.501)	-1.229** (0.574)	-0.948* (0.472)	-0.374 (0.763)	-0.699 (0.490)	-1.214** (0.550)	-1.051* (0.525)	-0.236 (0.621)	-0.695 (0.486)	-1.153* (0.572)
<i>lcs</i> _{t-10}			0.001 (0.012)	-0.037** (0.017)	-0.018*** (0.006)	-0.000 (0.011)												
<i>ca</i> _{t-10}				-1.423*** (0.392)				-0.961* (0.477)				-0.653 (0.659)				-0.785 (0.607)		
<i>reer</i> _{t-10}					0.006*** (0.002)				0.005** (0.002)				0.005 (0.003)				0.006 (0.005)	
<i>terms</i> _{t-10}						0.004* (0.002)				0.004* (0.002)				0.004 (0.002)				0.002 (0.002)
<i>wage</i> _{t-10}							0.881 (0.998)	-0.345 (0.915)	-0.318 (0.710)	0.773 (0.928)								
<i>tfp</i> _{t-10}											-0.004 (0.004)	-0.007*** (0.002)	-0.000 (0.004)	-0.002 (0.004)				
<i>ulc</i> _{t-10}															0.003* (0.002)	0.000 (0.002)	-0.001 (0.006)	0.003* (0.002)
<i>Constant</i>	9.670*** (0.130)	9.728*** (0.027)	9.663*** (0.876)	12.451*** (1.447)	10.668*** (0.520)	9.321*** (0.717)	9.108*** (0.727)	9.560*** (0.648)	9.596*** (0.617)	8.781*** (0.729)	9.949*** (0.265)	9.895*** (0.246)	9.452*** (0.583)	9.484*** (0.514)	9.541*** (0.109)	9.296*** (0.193)	9.387*** (0.308)	9.392*** (0.198)
Obs.	437	316	316	240	267	316	316	240	267	316	316	240	267	316	316	240	267	316
<i>R</i> ²	0.831	0.773	0.773	0.631	0.865	0.785	0.782	0.552	0.853	0.792	0.778	0.591	0.853	0.788	0.801	0.551	0.853	0.802

Note: * indicates the level of significance of 10%, ** a level of 5% and *** a level of 1%. In brackets we report the robust standard errors. Obs. are the observations for each regression.

Table 8. Relationship between Macroeconomic Rate of Return of Private Investment, Total, and 10-years' time-varying β -convergence.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
<i>ipriv_total</i> _{t-10}	1.879 (2.346)	3.789* (1.984)	3.726 (2.329)	-1.437 (1.937)	1.918 (2.082)	4.343* (2.275)	3.556 (2.115)	0.170 (2.091)	2.566 (2.216)	4.064* (1.973)	3.971** (1.845)	-0.253 (1.344)	2.508 (2.117)	4.386** (1.715)	3.097* (1.656)	0.094 (1.954)	2.495 (2.242)	3.405* (1.804)
<i>debt</i> _{t-10}		0.134* (0.072)	0.130* (0.068)	-0.035 (0.059)	0.135 (0.165)	0.232** (0.099)	0.135* (0.077)	-0.075 (0.105)	0.118 (0.159)	0.223** (0.093)	0.120 (0.074)	-0.071 (0.082)	0.111 (0.190)	0.215* (0.117)	0.199** (0.082)	-0.055 (0.088)	0.111 (0.180)	0.229** (0.088)
<i>unemp</i> _{t-10}		-0.913* (0.471)	-0.964 (0.637)	1.744*** (0.490)	0.152 (0.359)	-1.160* (0.581)	-0.887* (0.495)	-0.195 (0.680)	-0.650 (0.463)	-1.133* (0.556)	-0.869* (0.447)	-0.445 (0.790)	-0.632 (0.450)	-1.133* (0.535)	-0.994* (0.508)	-0.287 (0.648)	-0.632 (0.456)	-1.092* (0.556)
<i>lcs</i> _{t-10}			0.001 (0.012)	-0.037** (0.016)	-0.018*** (0.006)	-0.000 (0.011)												
<i>ca</i> _{t-10}				-1.378*** (0.394)				-0.859 (0.496)				-0.578 (0.656)				-0.727 (0.604)		
<i>reer</i> _{t-10}					0.006*** (0.002)				0.005** (0.002)				0.005 (0.003)				0.005 (0.004)	
<i>terms</i> _{t-10}						0.004* (0.002)				0.004** (0.002)				0.004 (0.003)				0.002 (0.002)
<i>wage</i> _{t-10}							0.942 (1.015)	-0.253 (0.907)	-0.213 (0.765)	0.827 (0.932)								
<i>tfp</i> _{t-10}											-0.003 (0.004)	-0.007*** (0.002)	-0.000 (0.004)	-0.002 (0.004)				
<i>ulc</i> _{t-10}															0.004* (0.002)	0.000 (0.002)	-0.000 (0.005)	0.003 (0.002)
<i>Constant</i>	9.692*** (0.126)	9.702*** (0.028)	9.614*** (0.891)	12.559*** (1.414)	10.708*** (0.519)	9.265*** (0.704)	9.040*** (0.734)	9.528*** (0.644)	9.530*** (0.650)	8.691*** (0.731)	9.895*** (0.270)	9.936*** (0.248)	9.417*** (0.600)	9.384*** (0.522)	9.518*** (0.105)	9.330*** (0.207)	9.405*** (0.312)	9.351*** (0.203)
Obs.	437	316	316	240	267	316	316	240	267	316	316	240	267	316	316	240	267	316
<i>R</i> ²	0.829	0.766	0.766	0.634	0.862	0.779	0.776	0.548	0.849	0.787	0.770	0.590	0.849	0.781	0.794	0.547	0.849	0.796

Note: * indicates the level of significance of 10%, ** a level of 5% and *** a level of 1%. In brackets we report the robust standard errors. Obs. are the observations for each regression.

Table 9. Relationship between Macroeconomic Rate of Return of Private Investment, Partial, and 5-years' time-varying β -convergence.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
<i>ipriv_partial</i> _{<i>t</i>-5}	2.508 (7.927)	6.552* (3.253)	6.486* (3.580)	5.004 (3.523)	1.546 (2.633)	6.638* (3.571)	5.554 (3.547)	5.708 (4.202)	1.806 (3.167)	5.624 (3.500)	6.603* (3.169)	5.180 (3.282)	2.419 (2.826)	6.494* (3.207)	5.244* (2.664)	6.835 (4.339)	1.993 (2.570)	4.445 (2.551)
<i>debt</i> _{<i>t</i>-5}		0.655*** (0.160)	0.649*** (0.128)	0.443*** (0.143)	0.357* (0.188)	0.686*** (0.172)	0.699*** (0.175)	0.462** (0.184)	0.300 (0.221)	0.715*** (0.221)	0.632*** (0.155)	0.405* (0.197)	0.252 (0.226)	0.605*** (0.204)	0.855*** (0.181)	0.598** (0.208)	0.342 (0.214)	0.762*** (0.186)
<i>unemp</i> _{<i>t</i>-5}		-0.316 (0.731)	-0.388 (0.826)	4.161*** (1.112)	1.549*** (0.509)	-0.535 (0.985)	-0.390 (0.793)	2.142* (1.035)	0.810 (0.501)	-0.454 (0.853)	-0.931 (0.987)	1.556 (1.545)	0.390 (0.700)	-0.836 (1.049)	-0.739 (0.853)	1.722 (1.171)	0.654 (0.531)	-0.291 (0.736)
<i>lcs</i> _{<i>t</i>-5}			0.003 (0.023)	-0.041 (0.032)	-0.025*** (0.005)	0.002 (0.023)												
<i>ca</i> _{<i>t</i>-5}				-3.435*** (1.073)				-2.637* (1.238)				-2.851** (1.203)				-2.662** (1.112)		
<i>reer</i> _{<i>t</i>-5}					0.013*** (0.003)				0.011*** (0.003)				0.009*** (0.002)				-0.003 (0.011)	
<i>terms</i> _{<i>t</i>-5}						0.002 (0.003)				0.001 (0.003)				-0.001 (0.003)				-0.006 (0.004)
<i>wage</i> _{<i>t</i>-5}							2.598*** (0.446)	1.270 (0.934)	1.127 (0.658)	2.585*** (0.443)								
<i>tfp</i> _{<i>t</i>-5}											-0.015** (0.006)	-0.012 (0.010)	-0.011*** (0.003)	-0.015** (0.006)				
<i>ulc</i> _{<i>t</i>-5}															0.009*** (0.002)	0.006** (0.002)	0.020 (0.012)	0.011*** (0.002)
<i>Constant</i>	20.296*** (0.714)	20.755*** (0.059)	20.565*** (1.782)	21.187*** (2.763)	22.966*** (0.478)	20.387*** (1.866)	18.927*** (0.307)	16.825*** (0.530)	20.480*** (0.263)	18.858*** (0.484)	21.696*** (0.408)	18.721*** (0.997)	22.111*** (0.263)	21.851*** (0.628)	20.280*** (0.049)	17.138*** (0.212)	21.706*** (0.521)	20.837*** (0.359)
Obs.	517	396	396	320	337	396	396	320	337	396	396	320	337	396	396	320	337	396
<i>R</i> ²	0.797	0.837	0.838	0.795	0.940	0.838	0.851	0.782	0.937	0.851	0.853	0.791	0.942	0.853	0.857	0.789	0.937	0.860

Note: * indicates the level of significance of 10%, ** a level of 5% and *** a level of 1%. In brackets we report the robust standard errors. Obs. are the observations for each regression.

Table 10. Relationship between Macroeconomic Rate of Return of Private Investment, Total, and 5-years' time-varying β -convergence.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
<i>ipriv_total</i> _{<i>t</i>-5}	0.293 (8.982)	6.289 (3.743)	6.218 (4.071)	3.440 (2.959)	0.722 (2.264)	6.554 (4.120)	5.519 (3.905)	4.070 (3.491)	0.989 (2.783)	5.706 (3.899)	6.255 (3.741)	3.440 (2.647)	1.407 (2.633)	6.146 (3.836)	4.922 (2.867)	5.380 (3.818)	0.964 (2.439)	3.779 (2.774)
<i>debt</i> _{<i>t</i>-5}		0.661*** (0.152)	0.655*** (0.122)	0.440** (0.150)	0.350* (0.195)	0.704*** (0.178)	0.703*** (0.167)	0.466** (0.199)	0.292 (0.231)	0.729*** (0.219)	0.639*** (0.150)	0.399* (0.213)	0.243 (0.236)	0.623*** (0.211)	0.862*** (0.172)	0.600** (0.219)	0.333 (0.223)	0.775*** (0.188)
<i>unemp</i> _{<i>t</i>-5}		-0.136 (0.642)	-0.196 (0.788)	4.324*** (1.184)	1.638*** (0.520)	-0.376 (0.954)	-0.232 (0.691)	2.168* (1.042)	0.890* (0.495)	-0.332 (0.788)	-0.748 (0.895)	1.565 (1.574)	0.491 (0.659)	-0.696 (0.993)	-0.603 (0.787)	1.811 (1.166)	0.741 (0.526)	-0.203 (0.714)
<i>lcs</i> _{<i>t</i>-5}			0.002 (0.024)	-0.044 (0.033)	-0.026*** (0.006)	0.002 (0.023)												
<i>ca</i> _{<i>t</i>-5}				-3.361*** (1.028)				-2.459* (1.227)				-2.732** (1.179)				-2.570** (1.095)		
<i>reer</i> _{<i>t</i>-5}					0.013*** (0.003)				0.011*** (0.003)				0.009*** (0.002)				-0.003 (0.010)	
<i>terms</i> _{<i>t</i>-5}						0.002 (0.003)				0.001 (0.003)				-0.001 (0.004)				-0.006 (0.004)
<i>wage</i> _{<i>t</i>-5}							2.671*** (0.447)	1.473 (0.971)	1.188* (0.633)	2.648*** (0.452)								
<i>tfp</i> _{<i>t</i>-5}											-0.015** (0.006)	-0.013 (0.010)	-0.011*** (0.003)	-0.015** (0.006)				
<i>ulc</i> _{<i>t</i>-5}															0.009*** (0.002)	0.006** (0.002)	0.020 (0.012)	0.011*** (0.002)
<i>Constant</i>	20.360*** (0.696)	20.709*** (0.073)	20.557*** (1.812)	21.393*** (2.884)	23.014*** (0.498)	20.327*** (1.879)	18.835*** (0.307)	16.690*** (0.580)	20.449*** (0.264)	18.719*** (0.480)	21.644*** (0.405)	18.793*** (1.039)	22.109*** (0.279)	21.736*** (0.663)	20.240*** (0.053)	17.113*** (0.257)	21.730*** (0.499)	20.790*** (0.369)
Obs.	517	396	396	320	337	396	396	320	337	396	396	320	337	396	396	320	337	396
<i>R</i> ²	0.796	0.836	0.836	0.791	0.940	0.836	0.851	0.777	0.937	0.851	0.851	0.787	0.941	0.851	0.856	0.784	0.936	0.859

Note: * indicates the level of significance of 10%, ** a level of 5% and *** a level of 1%. In brackets we report the robust standard errors. Obs. are the observations for each regression.

5. Conclusions and policy implications

It is easy to understand that, although not widely studied, macroeconomic rates of return can provide great insight to economies and especially to public policy makers for evaluation on the return of types of investment, efficient allocation of tax-revenue money, and so on...Having said this, with this dissertation we hoped to add to the conversation by establishing a relation between macroeconomic rates of return and the widely studied and researched robust concept of β convergence. More specifically, we wanted to assess the impact that macroeconomic rates of return had on the speed of convergence, the latter being measured by time-varying β coefficients in this dissertation.

At first glance, it would seem that these concepts could be related given they share theoretical frameworks and include some of the same variables in their calculations. However, the link was not straightforward and has not been empirically studied. Ertl and Rabitsch (2025) presented a hypothesis for the link, as described before, but they had a different starting point. If we follow those authors rationale but begin with the idea of higher macroeconomic rates of return, we know that they are associated with lower values of capital per capita (given diminishing marginal returns), and, so, following the robust theory of convergence, we know this implies higher growth rates hence, higher values for the speed of convergence. With this proposition we established our expectations for the results of the empirics. Expectations which were confirmed: the impact of macroeconomic rates of return on the speed of convergence is mostly positive.

To validate these expectations, we used the four kinds of macroeconomic rates of return calculated by Afonso et al. (2025) and estimated the speed of convergence (β) coefficients in a time-varying manner, and for two different time lags – one with a 10-year lag and another with a 5-year lag, according to Schlicht (2021). Before we established the relationship between the two topics empirically, we tested for convergence and verified its existence in our sample, both for the 10-year lag and for the 5-year. Finally, we constructed a set of panel regressions where our dependent variable was the estimated 10-year β or the 5-year β , the main independent variable were the macroeconomic rates of return and there was a set of control variables.

Our results show a positive impact of macroeconomic rates of return on the speed of convergence. More notably, the isolated effect of macroeconomic rates on β is always positive with two exceptions. However, when we control for the unemployment rate and for the debt ratio, the impact of macroeconomic rates on the speed of convergence is positive for all the main regressions.

More notably, controlling for the current account (in addition to unemployment rate, debt ratio and labour-capital substitution/wage share/total factor productivity/unit-labour costs), the impact MRRs have on the β s decreases, with three exceptions, and even turns the effect negative. This is in line with the logic expressed before, given that a higher current account would imply higher GDP, hence lower speeds of convergence, through the effect on macroeconomic rates.

Additionally, on average, the biggest effects of MRRs on β s happen when we are analysing macroeconomic rates of return of private investment. Despite this, the values of the impact of macro rates on the speed of convergence vary little between partial and total rates but are more heterogeneous when we are regarding the 5-year β s, than the 10-year β s.

These results can be very relevant, specifically for public policy makers, because they can see that via good returns on public investments and private investments (which they can incentivize), they converge to higher values of GDP in a faster manner, hence improving the situation of the country or region faster.

In conclusion, we believe that we have an answer for the dissertation question of whether there is a relationship between macroeconomic rates of return and the speed of convergence. The answer is that there seems to be a relationship and that the effect of MRRs on β convergence is largely positive. Although we followed a simple rationale to pose this relationship, we believe it would be important to establish better theoretical foundations on this relationship. Furthermore, it would also be relevant to test this relationship on a more heterogeneous group of countries and add more and different control variables to establish robust and significant results in the literature.

Regarding the control variables, we believe it would be beneficial to include variables such as policy stability and democratic indicators, and education related variables. Another note for future research for this specific set of countries is that it could also be intriguing to add a structural break in the regression analysis for the GFC of 2007/2008 to see the possible changes in effects.

Regardless, it is certain that if the relationship established continues to produce robust results, the policy implications behind good returns for public and private investment are of extreme importance.

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