Integrative Mechanisms for Addressing Spatial Justice and Territorial Inequalities in Europe

D3.1. Review of economic growth models, measurement of convergence and growth indicators

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Acronyms and Abbreviations

AUEB	Athens University of Economics and Business
CEEC	Central and Eastern European Countries
EMU	Economic and Monetary Union
EU	European Union
GDP	Gross Domestic Product
GNP	Gross National Product
NMS	New Member States
NUTS	The Nomenclature of Territorial Units for Statistics
OECD	The Organisation for Economic Co-operation and Development
PPP	Purchasing Power Parity
R&D	Research and Development
UNDP	United Nations Development Programme
WP	Work Package

Contents

1. Introduction

Disparities in the standard of living between countries or regions within countries are very substantial. Are these disparities likely to be persistent or just temporary in the course of economic growth? This is a question that has attracted the attention of some of the sharpest minds in Economics. The relevant theoretical and empirical literatures are enormous. The conclusions are not always straightforward. This survey, almost by definition selective, aims to highlight the findings of some of the most important contributions.

The next two sections focus on the predictions of theoretical economic models. Section 2 deals with earlier models that put a lot of emphasis on capital accumulation and treat technology as exogenous. Section 3 presents the next wave of models that tried to endogenize technology, while also emphasizing the role of human capital, innovation and R&D. The predictions of these two groups of models differ, sometimes quite considerably.

The two subsequent sections deal with more practical problems. How should we measure convergence? What approaches can we find in the literature? And, moreover, when these approaches are applied to real data, what kind of results do they give us? Do economies tend to converge or diverge (or neither)? Are similar trends observed in regions within countries or in unions of countries? Methodological issues are analyzed in Section 4, while the results of a number of empirical convergence studies are presented in Section 5. The latter are grouped into three categories: convergence of regions within countries, convergence of countries in economic unions and convergence at a global scale.

Finally, Section 6 reviews briefly the literature on the most appropriate indicator of the standard of living and its implications for the selection of an appropriate indicators of economic growth, especially in the context of the current research project.

2. Exogenous growth models

2.1. Introduction

The neoclassical growth theory has its roots at the seminal work of Robert Solow (1956). The neoclassical production function assumes that output is created using the stock of accumulated physical capital and labor, which is of one type only. Further, it is assumed that there are decreasing returns with respect to each input of production. Therefore, an increase in capital will result in a lower relative increase in output given that the amount of labor remains unchanged. Eventually, more capital stock will not produce more output and output growth will cease.

If technology improves, the productivities of labor and capital increase and this prevents a decrease in the rate of return of the investment. Technological progress is assumed to be exogenous and this seriously limits the ability of the model to explain adequately the growth processes observed in the real world.

2.2. The Solow- Swan growth model

The first "exogenous" growth model was developed independently by Solow (1956) and Swan (1956). The model assumes a neoclassical production function that uses capital and labor as inputs and leads the economy to a steady state equilibrium.

The model can be outlined as follows. Consider a Robinson Crusoe economy[1], i.e. one where households own the inputs but also manage the technology and produce the output. All of the economy's production inputs can be simply summarized into the following three: physical capital $K(t)$, labor $L(t)$, and technology (or knowledge) $T(t)$. Capital includes land, machinery and all physical material required in the production, while labor includes the quality

1 A "Robinson Crusoe economy", named after Daniel Defoe's hero, is a simple analytical framework used by economists in order to study a number of fundamental economic issues. In its simplest form, it is an economy with one consumer/producer and two goods. It is interesting to note that one can introduce competitive markets in the Solow-Swan model and obtain the same results.

and quantity of the working force. These two inputs are rival and, hence, cannot be simultaneously used by more than one producer. On the other hand, technology is assumed to be non-rival and, therefore, several producers can use it at the same time. It is important to note that technology can differ between countries or across time. Let $Y(t)$ denote the level of the output. The production function is given by:

$$Y(t) = F[K(t), L(t), T(t)]$$

Assume a closed economy, meaning that households cannot buy from or sell to foreign agents. Output is a homogeneous good and can be either invested, $I(t)$, or consumed, $C(t)$. The fraction of output that is been invested can be dedicated to either create new capital or replace the depreciated (old) capital. Furthermore, assume that there is no government spending (and, hence, taxation). Based on the aforementioned assumptions, production output is shared between investment and consumption:

$$Y(t) = C(t) + I(t)$$

The amount of output that is saved, $S(t) \equiv Y(t) - C(t)$, is equal to the amount that is invested, $I(t)$.

Even though saving is a complicated decision, Solow (1956) and Swan (1956) assume in this simple model that the saving rate, i.e. the proportion of output saved, is constant and exogenous, $0 \leq s \leq 1$. Consequently, the saving rate equals the investment rate. Physical capital is homogeneous and is depreciated at a constant rate $d > 0$.

Hence, the change in the capital stock is given by:

$$\dot{K}(t) = I(t) - dK(t) = s \cdot F[K(t), L(t), T(t)]$$

where $\dot{K}(t) = \partial K(t)/\partial t$. Furthermore, it is assumed that labor, $L(t)$, grows at an exogenous rate equal to the population growth rate $n = \dot{L}/L \geq 0$, while technology, $T(t)$ is constant.

The neoclassical production function, $F\ (K, L, T)$, exhibits constant returns to scale with respect to both its rival arguments, while it exhibits positive and diminishing returns to each individual input. Additionally, it satisfies the Inada (1963) conditions.[2] The above properties guarantee that inputs are also essential in the sense that a positive amount of output requires a strictly positive amount of each of them. Lastly, the price of labor and capital equals their marginal product.

[2] These conditions are related to the specific shape of the production function and guarantee the stability of the growth path.

It is useful to present the model in per capita terms. Due to the assumption of constant returns to scale, the production function becomes $y = f(k)$ where $k \equiv K/L$ is the capital-labor ratio. Now the net increase in the physical capital is given by:

$$\dot{k} = s \cdot f(k) - (n + d) \cdot k$$

This is the main equation of the model and it depends solely on k[3]. Note that $(n + d)$ represents the depreciation rate of the capital- labor ratio. In addition, the term $s \cdot f(k)$ is the investment required to preserve capital per worker. The steady state of the economy is reached at $\dot{k} = 0$, i.e. when $s \cdot f(k) = (n + d) \cdot k$.

It is useful to outline the main outcomes of the Solow model. Firstly, in the steady state the growth rate of output is exogenous and does not depend on the saving rate and technical progress. Secondly, capital per worker rises when saving rate increases and consequently output per worker increases. However, the growth rate of output remains intact. Thirdly, assuming no continuing improvements in technology and diminishing returns to capital, growth per worker will cease. Lastly, the model predicts what is widely known as conditional convergence. This is, countries that are similar with respect to factors affecting growth, such as education, saving rate, population growth rate, technology, etc. will eventually reach the same steady state equilibrium. This implies that a poor country with similar characteristics to those of a rich country will converge to the same steady state growth rates in the long run.

2.2.1 Technological Progress

So far, it has been assumed that technology is exogenous and constant over time. Consequently, in the long run all per capita variables remain constant. This outcome of the model is not realistic according to a vast amount of empirical evidence. Assuming constant technology and diminishing returns, it is not possible to preserve per capita growth solely by capital per worker accumulation.

It is possible to introduce various forms of technological forms that allow firms to produce a given amount of output using less physical capital (capital augmenting) or less labor (labor augmenting). In addition, there are those that save both inputs in equal proportions (neutral) (see Hicks,1932, Harrod, 1942 and Solow, 1969). It can be shown that in the Solow model only labor-augmenting technology can lead to a steady state with constant long-run

[3] For more on the derivation of this non-linear equation, see Barro and Sala-i-Martin (2004), Chapter 1.

growth rates (Barro and Sala-i-Martin, 2004). Robinson (1938) and Uzawa (1961) show that this definition implies the following production function:

$$Y = F[K, L, T(t)]$$

Assume now that the technology, T (t), grows at a constant rate, x. The condition for the net change in the physical capital stock is

$$\dot{K} = s \cdot F[K, L \cdot T(t)] - dK$$

In per capita form it becomes:

$$\dot{k} = s \cdot F[k, T(t)] - (n + d) \cdot k$$

The growth rate of $(\dot{k}/k)^*$ and of y* in the steady state is constant and equal to x.

Let us now introduce the variable $\hat{L} \equiv L \cdot T(t)$ called the effective amount of labor. We denote output per unit of effective labor by $\hat{y} \equiv Y/[L \cdot T(t)]$ and is given by $\hat{y} \equiv f(\hat{k}) \equiv F(\hat{k}, 1)$. In equilibrium it must be that

$$s \cdot f(\hat{k}^*) = (x + n + d) \cdot \hat{k}^*$$

Note that $\hat{k}, \hat{y}$ and $\hat{c}$ are constant in the steady state. On the other hand, k, y and c grow at an exogenous rate x, equal to the rate of technological progress.

This last prediction of the model has been empirically tested and the results have failed to validate it (although the measurement of technological progress is far from uncontroversial). What was found instead, is that the income per capita of an economy converges to its steady state value, after controlling for a number of determinant variables (conditional convergence). Conditional convergence depends on several factors. These include, among others, the saving rate, the size of the population, the initial endowment of human resources, the production function as well as government policies.

2.2.1. Human Capital

One of the main policy implications of the neoclassical model is the suggestion to invest in countries with a higher marginal product of capital. Based on this, one would anticipate that capital flows from more wealthy economies to less wealthy ones. These flows are expected to happen independently of space or time. This kind of flows have been observed and have risen notably since the early 1990s. Nevertheless, most investments take place within the country of origin of the capital, while the vast majority of foreign direct investments takes place among developed countries (World Bank 2004a, 2004b and 2008). This finding, analyzed by Lucas (1990), is widely known as “the Lucas paradox”. The author suggests that differences in human capital endowment, as well as imperfections in the capital market may be able to explain why the predictions of the neoclassical model on capital flows come in disagreement with the real world data.

One way to include human capital in the neoclassical model is the following. Consider the following Cobb- Douglas production function that receives labor, L, human capital, H and physical capital, K, as inputs:

$$Y = AK^{\alpha}H^{\eta}[T(t) \cdot L]^{1-\alpha-\eta}$$

where technology, T grows at a constant rate x. As before, the production function can be presented in the output per unit of effective labor form as:

$$\hat{y} = \hat{A}k^{\alpha}\hat{h}^{\eta}$$

Output can be either consumed or invested in the two types of capital. If both types of capital depreciate at the same rate, d, and agents consume a constant fraction of their income, i-s, the accumulation is given by:

$$\hat{k} + \hat{h} = sA\hat{k}^{\alpha}\hat{h}^{\eta} - (d + n + x) \cdot (\hat{k} + \hat{h})$$

The allocation of savings between the two types of capital will be the one that equates their rates of return.

Mankiw, Romer and Weil (1992) examine this question by altering the assumption that the overall saving rate is exogenous and constant. They assume rather that the investment rates in each type of capital are exogenous and constant. Specifically, the growth rate of physical capital is:

$$\dot{\hat{k}} = s_k\tilde{A}\hat{k}^{\alpha-1}\hat{h}^{\eta} - (d + n + x)$$

While the growth rate of human capital is:

$$\dot{\hat{h}} = s_h\tilde{A}\hat{k}^{\alpha}\hat{h}^{\eta-1} - (d + n + x)$$

where s_k and $s_h$are exogenous constants. In this model, the rates of returns to human and physical capital are not equated.

They examine economies that converge to their steady state equilibrium when both human and physical capital per worker increase. While the qualitative conclusions remain close to those of the Solow model, the inclusion of human capital has a substantial impact on the quantitative results. Their model finds empirical support in the macroeconomic data that reveal differences of initial income levels between countries, and explains the reasons that it may not be appealing to invest in a country solely because of its low level of physical capital.

Takahashi (2012) employees a neoclassical growth model with these two types of capital - human and physical - and derives the first-order approximate path of each capital type.

The results show that the short-run effect of capital enhancement on economic growth depends on the type of the capital injection. The author shows that, depending on the technology, the short run growth effect of investing on one type of capital can differ substantially from the other. Taking this into account, the capital type with the larger growth effect should be injected. This finding may have important implications for the assessment of foreign aid or public sector projects that target capital enhancement. Breton (2013) further enhances the Mankiw, Romer and Weil results by showing that the (macro) effect of human capital from schooling on the productivity of physical capital is consistent with the (micro) effect of schooling on workers' salaries. Specifically, the author estimates the national stock of human capital in 36 countries in 1990 that is a result of a past investment in schooling. He shows that the marginal product of human capital to workers this year, is consistent with the marginal return on investment in schooling in the earnings of workers.

2.3. The Ramsey- Cass- Koopmans growth model

In the neoclassical model discussed above, the saving rate is assumed to be exogenous and constant. This implies that consumers are not allowed to behave optimally. Hence, it is not possible to examine how incentives such as interest rates or tax rates can affect the behavior of the economy. To solve this problem, Cass (1965) and Koopmans (1965) elaborated on a model proposed by Ramsey (1928). They allow for the consumption path to be determined by optimizing firms and households that interact in a competitive framework. Households live infinitely and choose their saving rate and their level of consumption in order to maximize the utility of their dynasty, under an intertemporal budget constraint.

Assume identical households in terms of preferences, endowment, wages, productivity and population growth. The households provide labor services and in return receives wages. Furthermore, they purchase goods for consumption, receive interest income on assets and save by accumulating assets. Each household contains at least one adult individual, who is a working member of the current generation. This individual has a finite life and takes account of the welfare and resources of the next generation. The current generation maximizes utility over an infinite horizon, subject to its budget constraint. The family is expected to grow at an exogenous and constant rate n, according to:

$$L(t) = e^{nt}$$

Let *C(t)* denote the total consumption, then *c(t)≡C(t)/L(t)* is the consumption of an adult person. The representative household maximizes its utility, *U*, given by

$$U = \int_0^\infty u[c(t)] \cdot e^{nt} \cdot e^{-\rho t} dt$$

The utility function *u(c)* is concave, increasing in *c*, and satisfies the Inada conditions. The positive term *ρ,* denotes the rate of time preference and the positive value implies that individual prefer to consume goods now, rather than later.

As in the Solow- Swan model, we still assume a closed economy, but households can now borrow and lend from each other, ending up holding zero net loans in equilibrium. Let *r (t)* denote the interest rate, *a(t)* the household's net assets per person and *w(t)* the wage rate. In per capita terms, the household's budget constraint thus becomes:

$$\dot{a} = w + ra - c - na$$

The representative household maximizes its utility function *U*, subject to its budget constraint, the stock of initial assets and under the limitation required to rule out Ponzi games[4].

Firms on the other hand, produce goods pay wages and rental payments to receive labor and capital inputs. The neoclassical production function is of the form:

$$Y(t) = F[K(t), L(t), T(t)]$$

where Y denotes the output, K is the physical capital and, L denotes the labor defined as in the Solow model. Technology T(t), grows at a constant rate x ≥ 0 and the production can be written in intensive form, using effective labor, $\hat{L} \equiv L \cdot T(t)$ as:

$$\hat{y} \equiv Y/[L \cdot T(t)] \equiv f(\hat{k})$$

The firm maximizes its profit, given by:

$$\pi = \hat{L} \cdot [f(\hat{k}) - (r + d) \cdot \hat{k} - we^{-xt}]$$

It is now clear how in the Ramsey-Cass-Koopmans (RCK) model, the consumption path is determined by households and firms with an optimizing behavior in a competitive environment. The model suggests that the saving rate is a function of the per capita capital stock. The optimizing conditions exclude the inefficient saving rate that was possible in the Solow model. The increase or decrease of the saving rates in relation to the level of economic development affects the speed of convergence to the steady state. It is important to note that the further an economy is from its steady state, the faster it grows, i.e. the convergence property

[4] A Ponzi game is, essentially, a financial fraud in which the financier pays off early investors with the money contributed by later investors, with no actual investment. The limitation of no Pozni games translates to: $\lim_{t \to \infty} \{a(t) \cdot \exp[-\int_0^t [r(v) - n] dv]\} \geq 0$. See more in Barro and Sala-i-Martin (2004), Chapter 2, pp 88-89.

still holds. Furthermore, this model is in line with the empirical evidence suggesting that during the transition to the steady state, saving rates usually increase with per capita income.

2.4. Discussion

The neoclassical model predicts that an economy will converge to its steady state equilibrium in the long run. Furthermore, permanent growth can only be achieved by technological progress. Shifts in population growth and in saving rates can only have level effects in the absolute value of the long-run real per capita income. Further, it implies that relatively poorer economies grow faster than richer ones and will eventually catch up with the latter. There are several explanations for this. Firstly, it can be attributed to the lags in the diffusion of technology. Real income disparities tend to decrease as poor economies receive better information and knowledge. Additionally, it can be explained through the efficient allocation of the international capital flows. It is fair to assume that the rate of return to capital is higher in poor economies and as a result capital should flow from more to less wealthy countries. Nevertheless, in practice, this is something that is not usually observed ("Lucas' paradox").

An empirical investigation by Baumol (1986) found a strong correlation between a country's initial level of wealth and its output growth between 1870 and 1979. However, DeLong (1988) challenged the reliability of these results based on the absence of randomness of the sampled economies and the potentially high measurement errors of the estimated levels of initial income. After correcting for these factors, DeLong reports weak evidence to support the convergence hypothesis.

The augmented Solow model includes both human and physical capital. This model predicts that in the long run the income per capita of the poorer economies will converge to that of the richer economies, given that they both have the same saving rates in terms of human and physical capital, a process widely known as conditional convergence. In reality, saving rates vary between economies for several reasons. For instance, financial constraints can determine the investment in schooling which in turn determines partially the saving rates for human capital improvements. Those differences may depend on cultural and other idiosyncratic characteristics of each country (Breton, 2013).

The work of Cass (1965) and Koopmans (1965) completes the original neoclassical growth model. Caselli and Ventura (2000) extended the model to allow for heterogeneity among households while Barro (1999) incorporated time-inconsistent preferences. We have so far encountered the Ramsey, Cass and Koopmans model assuming a closed economy and no government spending or taxes. Furthermore, we have assumed no installation costs of the physical capital investment and infinite dynasties. A number of models elaborating on the benchmark model can be found in the literature, that depart from these assumptions.

Following these developments, growth theory started becoming quite technical with limited empirical applications. On the other hand, development economists, concentrated on applied research using models that were empirically useful but technically unsophisticated.

Between the early 1950s and the late 1970s an output per worker convergence of the poorer countries has not been generally observed. Despite this, there are cases of relatively poor countries that have indeed converged to the level of the richer countries as predicted by the Solow model. For instance, Japan raised its saving rates during the 1950s and 1960s and experienced high output per worker growth rates. During the 1970s, when its saving rated stabilized, the output growth rate slowed down as predicted by the neoclassical model (Barro and Sala-i-Martin, 2004).

Moreover, the income per capita levels of the southern states of the United States gradually converged to those of the northern states, confirming the conditional convergence theory within a country. Additionally, Barro and Sala-i-Martin (2004) present further evidence of cross- country conditional convergence.

The World Bank (2004a) reports that the growth rates of GDP in developed countries are generally lower than those in developing countries. Specifically, during the 1965-1999 period, the average GDP growth rate per year was 3.2 percent in high- income economies, 4.2 percent in middle- income economies and 4.1 percent in low-income economies. It is important to note that this is not translated into convergence between those economies, as the low- income economies tend to have a higher population growth. In fact, during the same period the population growth rates were 0.8, 1.7 and 2.3 percent respectively. Consequently, the gap in the GNP per capita between the high and the low- income countries continued to grow; during the last forty years of the 20th century it has doubled, with the average income of the 20 wealthiest countries having a size more than 30 times higher than that of the 20 poorest countries. At the end of the century, less than 22 percent of the global GDP was produced by developing countries, although they accounted for almost 85 percent of the world's population. The situations seems to have reversed since the last years of the twentieth century, with GDP per capita growing faster in poorer countries than in OECD countries.

Even though the Solow-Swan model is certainly a highly important contribution to the growth theory, it has a number of important shortcomings. Firstly, it assumes flexible factor prices and this may lead to problems in the path towards steady growth. Furthermore, it assumes homogenous capital goods, an unrealistic assumption which may further enhance the aforementioned possible problems. Most importantly, it treats technological progress as exogenous in the growth process. As a result, it does not account for any inducement of the process that could result by investment in research, learning or capital accumulation.

In most of the 1970s and 1980s, the main focus of economics shifted to the role of short-term fluctuations (for example, introduction of rational expectations in business-cycle models, adjustment of general equilibrium models to the theory of real business-cycles, etc.), while growth modeling was relatively neglected. Moreover, within the latter there was a gradual shift from exogenous to endogenous growth models.

3. Endogenous growth models

3.1. Introduction

As discussed earlier, the early version of the Solow model predicts unconditional convergence, something that found no support in the real world data. The empirical evidence pointed instead to convergence conditional on a number of determining factors. A model proposed by Barro and Sala-i-Martin (1992a) is viewed as the transition between the exogenous and the endogenous theory of growth. They depart from the assumption of worldwide common technology, proposing a technology-gap across countries. Technology flows from more developed to less developed countries and the rate of the diffusion is crucial to determine the speed of converge between them. Technology can be transformed into human and physical capital. The efforts of the new literature were concentrated in explaining the empirical facts while sorting the deficiencies of the neoclassical approach (see, for example Temple, 1999; Sala-i-Martin, 2002 and Loayza and Soto 2002).

By the end of the 1980s, economists made inroads into the measurement of technological change and capital accumulation. Earlier, Denison (1962 and 1979), attempted to explain economic growth in an accounting framework, using the capital and labor growth. The residual represented productivity or technological growth. Lucas (1988) incorporated human capital into a growth model that was export-led and emphasized the effects of learning-by-doing on production. Moreover, Mankiw, Romer and Weil (1992) further developed the analysis of the human capital in the neoclassical model.

In the traditional neoclassical model technology is exogenous. Hence, this framework cannot explain how economic growth is generated and the long-run per-capita economic growth rate is not influenced by policies or incentives – a clearly unsatisfactory property, as pointed out by Solow (2000) himself. Lacking technological change, it implies that the economy will reach a steady state where the per capita growth will equal zero. The vital assumption leading to this, is the diminishing returns to capital. A novel way to depart from this assumption, is to treat technology as endogenous. Yet there are several problems one needs to overcome to achieve this, the most important of which is the non-rival nature of technology and new ideas. So far, it has been assumed that technology is immediately available to all and is identical worldwide. Nevertheless, in the real world some ideas can be excludable, for instance patents can restrain access to them for other producers. This was the starting point in growth theory that led to what it became known as the "endogenous growth" theory. Romer (1986) and Lucas (1988) were the first to contribute in the literature.

As long as technology remains non-excludable and non-rival, intentional effort to produce new ideas is not sustainable in the competitive framework, as the firm will not be compensated for its efforts with positive profits. It is clear that the next step would be to relax this strong assumption and allow a firm to pay a cost to make technology excludable. In this case, due to the constant returns to scale, the producer with the superior technology would have an incentive to employ all inputs of the economy and earn monopoly power. The competitive model assumption would no longer hold. Moreover, all firms would have the incentive to do the same. As long as sufficient number of firms equally improve their technology, competition will move the input prices up, turning the profit to zero again. The result is that firms are not able to afford to pay the cost. All these firms make losses, so this equilibrium of technological progress is not possible. On the other hand, the incentive for each firm is high due to the enormous potential profit. These problems led a number of researchers to incorporate some elements of imperfect competition in growth theory, such as R&D activities. Romer (1990) and Aghion and Howitt (1992) were pioneers of this literature. Besides, the new endogenous growth theory incorporated in the analysis concepts such as population, public policy, education, international trade, etc. Further, there is a rich economic literature highlighting the importance of financial development on economic growth. The economies of scale that appear due to the efficiency of financial markets can induce economic growth. In this context, there have been various attempts to pin down the channels that connect financial markets to economic growth, as well as to identify if the development of financial structures improves economic performance (see, for example, Roubini and Sala-i-Martin, 1992).

In this section we focus on three main types of endogenous growth models. Specifically, the different mechanisms proposed to sustain endogenous positive growth is the inclusion of intentional R&D activities, the human capital accumulation models and finally the drop of the neoclassical assumption of decreasing returns to physical capital.

3.2. Growth models with R&D

A first mechanism through which endogeneity can be introduced to the model was suggested by Romer (1987 and 1990). This approach is based on the inclusion of R&D activities in the model, so that economic growth is determined by the endogenous technological progress (Ribeiro, 2003).

Romer (1986) considers knowledge as an input in the production function of the form:

$$Y = A(R)F(R_i, K_i, L_i)$$

where Y is the output and A denotes the public stock of knowledge from R&D, R. The function F is assumed to be homogeneous of degree 1 in all its inputs, namely the firm's private stock of knowledge from R&D, R_i, the firm's capital stock, K_i, and the firm's labor stock, L_i . Note that R_i is treated as a rival good. The three crucial elements of Romer's model are the diminishing returns in the knowledge production, the increasing returns in the output production and the externalities. It is assumed that the spillovers of research results by a firm spread instantly to the rest of the economy. The new knowledge, which is determined by the level of investment in research, constitutes the main determinant of the long-run growth. Investment in research is an endogenous factor, chosen by rational profit maximizing firms.

It was only in the late eighties that successful theories of explaining technological progress have been presented. Including a technological progress in the neoclassical model was a challenging task; the standard assumptions on competitiveness do not hold anymore. The returns to scale in the production function are increasing if technology is a production factor. There have been several suggestions on how to avoid this rough point. Shell (1967) perceives technology as a public good that does not receive any compensation as it is provided by the government. Arrow (1962) and Sheshinski (1967) suggest that ideas result from investment or as unintentional products during the process of production ("learning-by-doing") and discoveries spread throughout the economy, a mechanism known as "knowledge spillover effects".

Arrow (1962) was the first author to introduce to the literature the idea of learning by doing as an endogenous process. The idea is that all knowledge is incorporated in new capital goods, but once they are built they cannot be further improved by subsequent learning. A simplified version of the model is:

$$Y_i = A(K)F(K_i, L_i)$$

where Y_i, is the output of firm i, A denotes the technology, K is the aggregate stock of capital, K_i is the stock of capital of firm i and its L_i stock of labor.

Arrow shows that if the labor stock remains constant, growth will ultimately stop as there is very little investment and production.

Grossman and Helpman (1990), study the role of the trade regime on the long run growth. They assume far-sighted firms that maximize their profit through investment and model the resulting endogenous technological progress. They argue that the research productivity level depends on the "stock of knowledge capital", which is translated to the local economy level of engineering, scientific and industrial know-how. They also claim that the higher the value of domestic knowledge capital, the higher the extent of contact between the local agents. Finally, they derive the effect of this on the relationship between growth and trade.

Helpman (1992), notes that this kind of models do not explain the intentional efforts to create novel ideas and products – an obvious inconsistency with the real world. There is a plethora of examples of intentional R&D efforts in the creation of new technology and products in industrial economies. As the creation of new products is now dependent on deliberate R&D efforts, it is necessary to depart from the competitive set up of the neoclassical models and work in an imperfect competition framework. Romer (1987 and 1990) was the first to introduce such a model. He develops a model with profit-seeking firms who engage in deliberate R&D effort to discover new ideas and technologies. Following Ethier (1982), he uses the format of Dixit and Stiglitz utility function and reinterprets it as a production function, in order to model the preference for variety. Output is, thereby, an increasing function of the differentiated capital goods used in the production of final goods. The fact that imperfect competition was introduced in the capital goods sector allows the firms to be modelled as entities with a profit-seeking behavior that intentionally engage in R&D activities in order to acquire monopolistic rents. The key contribution of Romer is that this mechanism explains technological growth which, in turn, explains the positive sustained per capita growth, hence making the model endogenous.

Aghion and Howitt (1992) assume that a sequence of uncertain research activities results in a series of innovations that generate economic growth. Two positive externalities are implied by their model. The first one relies on the fact that consumer surplus is higher than the monopoly rents. The second one arises from the idea that one invention constitutes the basic for the next one. Nevertheless, there is a third negative externality resulting from the fact that the new invention turns the old one useless and replaces it, thus destroying capital.

Kremer and Thomson (1998) develop an overlapping-generations set-up in an apprentice-mentor context. Young workers interact with the more experienced ones and benefit from this interaction. Their model effectively predicts high adjustment costs for sharp increases in human capital.

3.3. Growth models with human capital

Human capital based models use human capital accumulation instead of technological change, as the origin of endogenous growth. The main approach is by Uzawa (1965) and Lucas (1988) and it is therefore referred to as the Uzawa-Lucas model. The basic idea is that investment in education produces the human capital which is the main determinant of the growth process. There is a distinction between the internal effects and the external effects. The former takes places when the worker becomes more productive due to some training, while the latter are spillover effects that increase the productivity of other workers. It is the investment in human capital, and not in the physical capital, that improve the level of technology. The output of firm i is given by:

$$Y_i = A(K_i)(H_i)H^e$$

Where A is the technology, K_i is the physical capital, H_i is the human capital, H denotes the average human capital level of the economy and e is a parameter that represents the power of the human capital's external effects to each firm's productivity. The model generates fully endogenous growth and the growth engine is the human capital accumulation.

There are several examples of other human capital based models that can be found in the literature. As before, they assume that the technology for the production of the final good differs from that used for human capital accumulation. For instance, Rebelo (1991) explores the differences in growth rates among countries. The author uses models in which the aforementioned disparities result from differences in government policies. These differences can also cause labor migration from a country that grows slower to a country that grows faster. In this class of models, there are no increasing returns but growth is endogenous due to the existence of a capital good that may be produced without inputs that cannot be accumulated (for example, land). Another study, by Becker et al. (1990) explains why societies with low human capital, choose to have larger families and invest little in each member. They use an endogenous fertility model with an increasing rate of return on human capital as its stock increases. They find two stable steady states; the first has smaller families and rising physical and human capital and the second has larger families and low human capital.

3.4. Growth models with non-decreasing returns to capital

Another way to acquire endogenous growth is to depart from one of the standard assumptions of the neoclassical models, namely the diminishing returns to physical capital. Among others, King and Rebello (1990), Jones and Manuelli (1990), and Barro and Sala-i-Martin (1995) propose such models. As discussed earlier, in a neoclassical framework without technological progress, per capital growth rate will be driven to zero due to diminishing returns to physical capital. Jones and Manuelli (1990) propose a model with a production function in which the first Inada condition is violated, resulting to sustained endogenous growth. King and Rebelo (1990) suggest that human and physical capital are produced under different production functions but they are both being produced with non-diminishing returns. Barro and Sala-i-Martin (1995) propose a model with a production function with constant returns to scale and assume that output can be used for either investment in capital (physical or human) or consumption.

The simplest endogenous model that drops the diminishing returns to capital assumption is the AK model. In this version of the model it is assumed that the saving rate is exogenous and constant. It also implies that the average and marginal products of capital are constant, therefore the convergence property does not hold. This production function is a special case of a Cobb- Douglas function which exhibits constant returns to scale. Consider a production function of the following form:

$$Y = AK^{\alpha}L^{1-\alpha}$$

where Y denotes the total production in the country, A the total factor productivity, K the physical capital, L the labor and α measures the output elasticity. In the special case where α=1, the decreasing returns to capital assumption does not hold and the production function becomes linear with respect to physical capital. Another version of the model is of the form:

$$Y = AK$$

where K now denotes both human and physical capital and A>0 is the (constant) level of technology. In terms of per capita output the model becomes:

$$\frac{Y}{L} = A \cdot \frac{K}{L} \quad \text{or} \quad y = Ak$$

Hence, the marginal product of capital equals the average product of capital which is equal to A. If the labor force grows at a constant rate n and the depreciation of capital is zero, the basic differential equation would be of the form:

$$\frac{k(t)}{k} = s \cdot \frac{f(k)}{k} - n$$

but $\frac{f(k)}{k} = A$. So the equation becomes:

$$\frac{k(t)}{k} = s \cdot A - n$$

3.5. Discussion

The theory of endogenous growth views economic growth as the result of endogenous factors, rather than exogenous unexplained technological progress. Investment in knowledge, innovation and human capital are all considered as important shapers of the growth process. In an economy that is based on knowledge there are spillover effects as well as positive externalities which enhance economic growth. Therefore, the long run economic growth of an economy is dependent on various policies, such as policies that support education, training, R&D and innovation.

The first two groups of models discussed overcome diminishing returns to scale, while the last group eliminates them. It should be noted that, in a different context, Arrow (1962) had proposed a model that also eliminates diminishing returns to capital. He suggests that the creation of knowledge is a side product of investment. When a firm invests in physical capital, it becomes more efficient. In this model, learning-by-doing is combined with the knowledge spillovers assumption.

Fine (2000) discusses some main issues of the endogenous growth theory. His ideas can be resumed in the following distinct points. The first point, is that despite the fact that endogenous growth theory it is a partial microfounded theory, it is used to explain extensive macroeconomic problems. Secondly, the policy implications of the endogenous growth theory are ambiguous and imprecise. Thirdly, Fine recognizes that the endogenous growth theory has gradually incorporated more complicated mathematical and statistical methods. The shortcoming of this is that the theory is subject to methodological individualism, as authors depart from basic assumptions, making its content arbitrary. Fine claims that the theory should be built on common methodological principles. Finally, the author states that the endogenous theory is able to explain some of the basic facts about growth, such as patterns of divergence and convergence and Kaldor's stylized facts. It is also able to incorporate several elements such as endogenous productivity, money and financial institutions, monopoly, business cycles, institutions, inequality, conflict and more. Fine therefore concludes that it will continue to evolve become an important “holistic” growth theory.

As noted in the previous section, neoclassical theory implies convergence across economies, both in income level and growth rates. Endogenous growth theory, in contrast to neoclassical growth theory, allows for the existence of sustained differences in growth rates and levels of national income. Due to the productivity gains or the externalities resulting from research, there are no diminishing returns to physical or human capital and thus, convergence may not occur.

4. Convergence

4.1. Definition of convergence

Economic convergence can be defined in various ways, such as the convergence of GDP per capita, structural convergence and more. In this review we focus on the former type of convergence, i.e. the real convergence in GDP per capita. From a theoretical point of view, convergence can fall into the following categories: absolute (or unconditional) convergence, conditional convergence and club convergence.

To begin with, absolute convergence occurs when economies converge to a common steady state. Less wealthy economies catch-up with the wealthier ones and disparities are eliminated. However, several reasons can cause divergence between economies. Conditional convergence is observed when economies with similar structural characteristics converge to a common steady state (Sala-i-Martin, 1996), while economies with different respective characteristics will not converge automatically. Finally, club convergence occurs when economies with similar initial conditions converge to the same steady state (Galor, 1996).

The aforementioned types of convergence can be combined (Durlauf et al., 2004)

$$\lim_{t\to\infty} E(logy_{i,t} - logy_{j,t} | \rho_{i,0}, \theta_{i,0}, \rho_{j,0}, \theta_{j,0}) = 0$$

when $\theta_{i,t} = \theta_{j,t(1)}$

where i is the economy, t denotes the period, y is the GDP per capita, ρ denotes the initial conditions and θ the structural variables.

When this equation holds, economies with identical structural variables converge to the same steady state, given their initial conditions.

4.2. Measuring convergence

The speed, as well as the existence of convergence, has been thoroughly investigated in both the theoretical and empirical literature of economic growth. It is already obvious that convergence depends on the characteristics of the economies, the time span studied, the models and the data that are used. It is, therefore, important to analyze the different ways it is measured. There is a distributional approach, a time series approach and the approach of beta-convergence.

The most commonly used distributional approach is the sigma-convergence indicator. This indicator measures the standard deviation of the log GDP per capita. When sigma diminishes across time, disparities between the economies also diminish and, hence, there is sigma-convergence. The beta-convergence approach claims that less wealthy countries in terms of GDP per capita, grow at a higher rate than the wealthy ones. This approach can be accommodated in both cross sectional and panel models, with the later providing more comprehensive results. Finally, the time series approach is based mainly on stochastic approaches such as cointegration. Divergence occurs when there is a unit root in the differences of time series. These approaches measure different types of convergence and may therefore deliver different results.

4.3. Theoretical considerations

In this section we analyze the two main types of convergence discussed in the literature of economic growth. The first type, as already mentioned, is known as the beta-convergence (β-convergence), and refers to the situation where a poor country or region grows faster than a rich one so that it catches up in terms of GDP per capita (Barro, 1984; Baumol, 1986; DeLong, 1988; Barro, 1991; Barro and Sala-i-Martin, 1991, 1992a, 1992b; Michelacci and Zaffaroni, 2000; Abreu et al., 2005; Gluschenko, 2012; Próchniak and Witkowski 2013).

The second type, known as sigma-convergence (σ-convergence), responds to the decline of cross- sectional dispersion. This dispersion can be measured in various ways such as the standard deviation of the logarithm of GDP per capita (Easterlin, 1960; Borts and Stein, 1964; Streissler, 1979; Barro, 1984; Baumol, 1986; Dowrick and Nguyen, 1989; Barro and Sala-i-Martin, 1991, 1992a, 1992b; Boldrin and Canova, 2001; Ling and Zestos, 2003; Monfort, 2008; Sperlich and Sperlich, 2012; Mazurek, 2013).

There is a relation between the two concepts of convergence; β-convergence tends to create σ-convergence, but the effect diminishes due to disturbances that raise dispersion. To display this, consider the following equation of a neoclassical model describing the growth of per capita income in country i, between two periods (Barro and Sala-i-Martin, 2004):

$$\log\left(\frac{y_{it}}{y_{i,t-1}}\right) = a_i - \left(1 - e^{-\beta}\right) \cdot \left[\log\left(y_{i,t-1}\right) - x_i \cdot (t-1)\right] + u_{it}$$

where

$$a_i = x_i + \left(1 - e^{-\beta}\right) \cdot \log(\hat{y}_i^*)$$

and

$$u_{it} \sim iid(0, \sigma_{ut}^2)$$

Note that t denotes the year, i the country, $\hat{y}_i^*$ the steady state value of y_i and x_i the rate of technological progress.

Assume now that $a_{it} = a_t$, i.e. it is common among all countries. This implies that $\hat{y}_i^*$, the steady state value of y_i, and the technological progress are also common among all countries. Obviously, this assumption is probably more relevant in the case of different regions of the same country rather than in the case of different countries, as regions are more likely to exhibit this kind of similarities. Given $a_{it} = a_t$, and $\beta > 0$ less wealthy countries grow faster than the wealthier ones. This is an implication of the neoclassical models but in most cases, it is not implied by the exogenous growth model (Barro and Sala-i-Martin, 2004). Note that in this example, the coefficient of $\log\left(y_{i,t-1}\right)$ is less than one and, as a result, the convergence is not able to wipe out the serial correlation. In other words, a country that starts lower than another, will remain lower.

Now assume that σ_t^2 denotes the cross-country variance of $\log\left(y_{i,t}\right)$. Based on the above, variance evolves according to:

$$\sigma_t^2 = e^{-2\beta} \cdot \sigma_{t-1}^2 + \sigma_{ut}^2$$

Suppose that the variance of the disturbance does not change over time, i.e. $\sigma_{ut}^2 = \sigma_u^2$. In this case, it can be shown that β-convergence constitutes a necessary condition for σ-convergence, but it is not sufficient. Shocks that have a similar effect on groups of countries violate the condition of cross-country independence of the disturbance term. The cross-country variance of $\log\left(y_{i,t}\right)$ is very responsive to this kind of shocks. In case they are omitted from the regression, the estimates of β will be biased.

There are two types of datasets that can be used for the estimation of the speed of convergence; general and regional datasets. Obviously, it is more likely to observe convergence in the regional data. Regions within the same country tend to have similar institutions, technologies and preferences, while this holds less between different countries that have their own governments and legal systems. The result is that absolute convergence will occur with a higher probability across regions than across countries.

4.4. Empirical Findings

4.4.1 Regional Convergence

Barro and Sala-i-Martin (1991) study the convergence of 90 regions in 8 European countries. These include 21 regions in France, 20 regions in Italy, 17 regions in Spain, 11 regions in the United Kingdom, 11 regions in (West) Germany, 4 regions in the Netherlands, 3 regions in Denmark and 3 regions in Belgium during the period 1950- 1990. The joint estimate of β for the first four decades is positive and significant (0.019). The estimates for each decade are quite stable and range between 0.010 in the eighties to 0.023 in the sixties. Moving to the regional level, the growth rate of GDP per capita between 1950 and 1990, has a negative relation with the log of GDP per capita GDP in 1950. Note that both the level and the growth of GDP per capita are measured in relation to the mean of each country. The results support the existence of β-convergence in the regions within each country in the sample. The negative relation between the log of initial GDP per capita and the growth rate is similar to the one detected in the U.S. states and the prefectures in Japan found in Barro and Sala-i-Martin (1992a and 2004).

Then they shift the focus of their analysis to five European countries, namely (West) Germany, the United Kingdom, Italy, France and Spain. In terms of σ-convergence, these countries can be ranked from the one with the highest dispersion to the one with the lowest. Italy comes first, followed by Spain, Germany, France and finally the United Kingdom. All countries reveal a descending pattern in their dispersion across time. The lowest change is observed in the United Kingdom and Germany since 1970. The increase that occurred in the 1980s in the United Kingdom, probably reflects the influence of the oil shocks, as the country was the sole oil producer in the sample. In 1990s σ-convergence ranges between the lowest value of 0.12 (United Kingdom) and the highest value of 0.27 (Italy).

Barro and Sala-i-Martin (1992b) explore the speed of convergence of income per capita among 47 Japanese prefectures during the period 1930-1990. The presence of β-convergence is confirmed by the negative correlation between the log of income per capita in 1930 and the growth rate between 1930 and 1990 across the prefectures. They find that the speed of convergence across prefectures does not differ much from that across districts. Moreover, they break the sample into two sub-periods, namely 1930-1955 and 1955-1990. They report that the speed of convergence in the first period was higher than in the second one. Following this, they focus their study on the analysis of the second period and break it into five-year sub-periods. They find that the convergence is significant and positive in three of the sub-periods, specifically in 1960-1965, 1970-1975 and 1975-1980. They experiment with various specifications and identify two sources of instability. The first one, is the fact that Tokyo is an outlier during the eighties, being the richest prefecture with the highest growth. The second one, is the lack of stability between 1970 and 1975. This can be possibly explained by the existence the of oil shock that took place in 1973 and had a tremendous effect especially on the rich industrial prefectures.

Lastly, they explore the σ-convergence across the whole sample. The standard deviation of the log of income per capita increases from 1930 to 1940. A possible reason for this is the extended military spending that took place in those years. Agricultural prefectures revealed a negative average growth rate, while industrial sectors had a positive rate. The dispersion saw a sharp fall after World War II, hitting a low point in 1987 and staying relatively constant thereafter.

The work of Sala-i-Martin (1996) confirms that the estimated speeds of convergence are inarguably similar across the three data sets, i.e. the U.S. states (1880-1990), the Japanese prefectures (1955-1990) and the European regional data (1950-1990). The speed of convergence tends to reach a rate of 2% per annum. Furthermore, in all countries the inter-regional distribution of income per capita declined over time. The one-sector neoclassical growth model combined with the hypothesis of technological diffusion are in line with the findings of this work.

Barro and Sala-i-Martin (2004) use U.S. data on income per capita during an extended period (1880- 2000) and estimate the speed of β convergence between the states. They estimate a linear regression between the growth rate of income and the logarithm of initial income. They find that the longer the time period over which the growth rate is averaged, the smaller the coefficient is predicted to be. This happens because the growth rate decreases as income rises. Therefore, when the growth rate is computed over a longer time period, the initially higher growth rates are combined with more of the lower future growth rates. Consequently, when the time span is larger, the initial position affects less the average growth rate. The growth rate depends on the steady-state level of income as well as on its initial level. Specifically, after conditioning on the steady state value, it depends on the initial level negatively. More specifically, they find that the U.S. states tend to converge at a speed of approximately 2 percent annually. They use data from four regional censuses and find that the average convergence rate of each region is similar to that of the states included in this region.

One issue that has been thoroughly discussed in the literature is the possible presence of measurement error in the income data. This can cause an upward bias in the estimation of the speed of convergence, i.e. it can introduce a higher value of β than the “true” one. One factor that may cause measurement error is that the deflator used for the state national income is the national price index, as a deflator specific to each region is not available. A possible solution to this is the use of past lag values of the log of income as instrumental variables. In the absence of serial correlation in the error term, past lags are suitable instruments for the log of income in the beginning of the period. In the case of Barro and Sala-i-Martin (2004), measurement error is not likely to pose a threat to the estimation process.

Turning now to the σ-convergence, the dispersion in standard deviation declined between 1800 and 1920. From 1920 until 1930 the deviation rises, reflecting the shock witnessed in the agricultural sector during this period. Poor states that based their economy on agriculture were deeply harmed by the reduction in agricultural prices. The dispersion reaches its highest point in 1932 and continuously falls until 1976, where it reaches its lowest point. Following this, there is an increase until 1988 and a decrease in the early nineties, after which no important changes are found.

4.4.2 Convergence in Unions

The first studies focusing on European integration are cross-country studies. They deal with the comparison of countries that are not members of the European Union to the EU members. The countries that have not joined the EU are mostly in the same stage of development to those compared with. The question of interest is whether a benefit in terms of economic growth exists for countries who have joint the EU. In most cases, the outcome is that such a comparative advantage does not exist (see, for example, Landau, 1996).

Ling et al. (2003) examine the existence of real GDP per capita converge in the EU economies for the period 1960-1995. They report that there is both beta and sigma convergence, except for the sub-period 1980-1985 where there is weak divergence.

Canova (2004) suggests that economies are separated in rich and poor (North and South), during the period 1980-1992, implying convergence clubs. He uses a predictive density approach on a NUTS2 regional level in western European countries. In line with these findings, Corrado, Martin and Weeks (2005) do not find evidence of convergence between the EU-15 and Norway NUTS1 regions during the period 1955-1999. They apply time series methods to reconfirm that geographical location and various social and demographic characteristics are significant in forming convergence clubs before the foundation of the EMU.

In their extended work, Kutan and Yigit (2004, 2005, 2007) and Brada, Kutan, and Zhou (2005) explore various definitions of convergence for the EU-15 economies, as well as the ten countries that became members of the EU in 2004. Kutan and Yigit (2004, 2005) show that there is a significant real convergence of per capita GDP for almost all of the new members during the time period 1993-2003.

Furthermore, Brada et al. (2005) present mixed results on real convergence of the CEEC to the countries of the euro area during 1980-2000 and find that the benefits of the EMU membership are limited. On the other hand, Kutan and Yigit (2007) find that the membership is beneficial for both the new and the founding members of the EU. They find support of real convergence of per capital GDP across 1980-2004

Another strand of the literature focuses on the aggregate macroeconomic data and the results still remain inconclusive. For example, Carvalho and Harvey (2005) use a multivariate structural time series model and apply it on a sample of eleven euro area countries during the time period 1950 to 1997. They separate their sample into a wealthy group of countries, including 5 core countries Finland and Austria and a less-wealthy group that includes Greece, Portugal and Spain. They find evidence of relative club convergence but also find that Ireland follows its own path, diverging from the rest of the countries.

Cunado and Perez de Gracia (2006) use a time series approach to assess the convergence of 5 central and east European countries towards both the US and the German economies during 1950 and 2003. They find no support of overall convergence for the whole sample period. After allowing for structural breaks, they find evidence of convergence of three economies, namely Czech Republic, Hungary and Poland to the German economy and just Poland to the US, during the period 1990-2003.

Crespo Cuaresma et al. (2008) use data from the EU-15 countries during the period 1960-1998 to explore the beta- converge in terms of GDP per capita. They use panel data methods to study the significance of European integration on long-term growth rates for the EU members. They find that the length of the membership plays a positive and significant role on growth rates. It is interesting that the effect is found to be higher for the less wealthy countries. Despite the fact that past studies have found that regional integration has no positive growth implications, the authors claim that there is indeed a convergence-stimulating, asymmetric effect of the membership on the long-term growth rates. The authors finds evidence that poorer countries benefit more from the technological diffusion resulting from EU membership.

Ramajo et al. (2008) estimate the speed of convergence of 163 EU regions between 1981-1996. They use spatial econometric techniques to find further evidence of separate spatial convergence clubs. Specifically, regions that belong to the group of Spain, Greece, Ireland and Portugal converge at a higher rate than the regions of the rest of the countries.

Cavenaile and Dubois (2011) show that there is conditional beta- convergence for the EU-27 countries during the period 1990-2007. However, they report significantly different rates of convergence of the new members from Eastern and Central Europe to those of the fifteen western economies, revealing once more the existence of club convergence.

Additionally, Fritsche and Kuzin (2011) use a factor model initially proposed by Phillips and Sul (2007). They assess different types of convergence for twelve economies of the euro area, Sweden, the United Kingdom and Denmark from 1960 to 2006. They find support for club convergence, and show that differences in economic development as well as geographic distance can play an important role in the formation of the club groups.

Bartkowska and Riedl (2012) also use the aforementioned model to study the real convergence in per capita GDP in a sample of 206 regions in 17 Western European economies during the period 1990-2002. They identify 6 different regional clubs and find that the initial conditions, constitute significant factors of the club membership of each region. On the other hand, structural characteristics do not seem to play an important role.

Monfort et al. (2013) use data from 23 European countries to study β-convergence in productivity terms. The data are available for the period 1980-2009 for the western countries and for the period 1990-2009 for the eastern countries. They identify two distinct convergence clubs in the European Union, not related to the fact that some of the countries belong to the eurozone.

Borsi and Metiu (2015) use the same model in a sample of 27 EU economies across the period 1970 to 2010, in a non-linear latent factor setup and analyze their transitional behavior. They find no evidence of overall real convergence, but using an iterative testing procedure they prove the existence of separate groups that converge to a different steady state. Furthermore, they show that regional spillover effects can be significant in formatting convergence clubs. They conclude that in the long run there is a clear distinction between the old and the new European Union members.

Pasimeni (2014) uses data from the period 1999-2012 for all the EMU countries. He reports that the existence of large economic shocks, such as the one of the recent economic crisis, combined with the non-existence of appropriate adjustment mechanisms, have enhanced tremendously the socio-economic divergence among the countries of the European Monetary Union.

Lopez-Tamayo et al. (2014) uses a dataset of the EU member countries that covers the period 1995-2003 to study the potential impact of the recent recession on convergence. They use a composite indicator consisting of various soft and hard indicators to estimate several convergence equations for each country. They find limited support for absolute convergence among the EU member countries, while the conditional convergence appears more robust.

Marelli and Signorelli (2017), find that there is real convergence among the EU-28 economies between 1999 and 2014, following an absolute β-convergence method. This is most likely explained by the catching- up by the New Member States (NMS). On the contrary, no overall convergence was found for the initial 11 countries of the euro area. Moreover, limited convergence was detected among the nineteen members of the enlarged euro area in the period 2009-2017. When an extended β-convergence method is used, i.e. one assuming that each economy converges to its own steady- state, similar results were found.

Franks et al. (2018) study different dimensions of economic convergence of the euro area economies between 1971 and 2015. They find no support of overall real convergence of per capita GDP among these countries since the adoption of the common currency. While the convergence stayed relatively stable during the first years of the euro, the result was reversed with the arrival of the economic crisis. On the contrary, the new countries that adopted the common currency show real convergence in per capita income. Their business cycles are more synchronized and the magnitude of the cycles declined. The same was the case for their financial cycles. Again there was a synchronization over time, with a declining rate of their magnitude. They conclude that real convergence demands reforms that enhance productivity growth in the less wealthy countries.

4.4.3 Global Convergence

Barro (1991) studied a sample of 98 countries during the period 1960- 1985 and found that the growth rate of real GDP per capita is inversely related to its initial level but is positively related to the initial level of human capital, which is proxied by school enrollment rates. He also finds that economic growth is negatively related to government consumption (as a share of GDP) and market distortions, while the opposite holds for political stability.

Rodrik (2011) uses a large worldwide dataset that covers the period 1950-2008. He claims that the economic growth in developing economies depends on the disparities between their productivity levels and those of the advanced economies. Convergence does not happen automatically and requires continuous structural changes in modern services, manufacturing and other tradables. These policies, such as industrial policies and currency undervaluation, are not easy to be implemented and it is very likely that many economies will struggle with persistent high unemployment. Rodrik concludes that there is unconditional convergence, but this is between industries rather than entire economies.

Barro (2015) uses a country panel sample starting in 1960 and estimates that, conditional on several time varying regressors, the annual convergence rate of GDP is equal to 1.7%. When he adds country fixed effects, the estimate become misleadingly high. When the sample starts in 1870 the estimate equals 2.6%. Next, the author combines the two estimated convergence rates to find a rate very close to the "iron law", i.e. the rate of 2%.

Barro (2016) reports that since 1990, the conditional convergence of the growth rate of real per capita GDP in China has been relatively high. He predicts that the per capita growth rate will fall from roughly 8% to around 3.4%. China's middle income convergence story is very similar to those of Thailand, Indonesia, Costa Rica, Uruguay and Peru. Moreover, upper income convergence story is related to Hong Kong, Malaysia, Chile, Poland, Ireland, Taiwan, South Korea and Singapore. For a group of 25 countries, he reports that the cross- country dispersion of the log of real GDP per capita does not reveal a trend since 1870. India and China, are not included in this group. Finally, for a sample of 34 countries starting in 1896, he finds support for decreasing dispersion starting roughly around the eighties, reflecting the inclusion of India and China in the worldwide economy.

4.5. Discussion

The empirical findings on regional convergence between the EU countries, as well as the states of the US and the Japanese prefectures are close to a figure that became known as the "iron law", i.e. a convergence rate close to 2% per annum. It has been shown that the relationship between the initial level of GDP and its growth rate is negative.

The results on whether the European integration has served as a bonus to the associated economies are mixed. There have been several papers that report a positive and significant bonus, while other authors do not find support for this view. Those in favor of the bonus, find that the poorer countries benefit more due to the diffusion of new technologies that flow toward them and the financial support received.

Most of the literature reports no evidence of total convergence in the European Monetary Union, but rather supports the presence of convergence clubs. The two main clubs are the north and the south economies- the more and the less wealthy countries respectively. The occurrence of a large economic shock, specifically the recent economic crisis, has led into economic divergence in the EMU.

At the global level, most studies conclude that since the 1980s convergence is observed between developed and developing countries, while efficient economic policies may accelerate the rate of convergence. These policies include political stability, minimization of market distortions and low government consumption. As before, there have been reports of club convergence, for example among the middle income and the high income economies. In the long run, there is evidence that the initial level of real per capita GDP is inversely associated with the growth rate and the “iron law” is satisfied.

5. Indicators of economic growth

5.1. Introduction

To be consistent with theory, the appropriate proxy of economic growth for the empirical investigation of the convergence hypothesis should have been the growth rate in output per hour worked. Nevertheless, due to data limitations, most studies examine convergence between countries and/or regions in terms of growth in Gross Domestic Product (GDP) per capita. GDP per capita is a very popular indicator of a country's or a region's level of economic development and has been used as such in countless studies. However, in recent years, an increasing number of authors question its appropriateness for such purposes. Some of the criticisms are particularly relevant in the context of testing the convergence hypothesis.

5.2. GDP per capita

GDP is a flow variable. It measures the total output produced in a given time period (usually, a year) in a certain economy. Therefore, GDP is a measure of production and, ceteris paribus, increases in GDP per capita denote that, on average, an expanded set of goods and services is available to the citizens of the economy under examination. Taking into account that GDP as well as population data are readily available, since such data are regularly collected and published by the national statistical agencies of all countries, further enhanced the popularity of GDP per capita as an indicator of a country's level of economic development. Nevertheless, a number of handicaps are associated with GDP per capita as development indicator.

For a start, usually, GDP measures market activities. As a result, it leaves out or measures inadequately a considerable proportion of the output that households consume without resorting to market activities, namely consumption of own production. For some items of consumption of own production, such as imputed rents or consumption of own farm production, efforts are made to impute relevant values in National Accounts. These efforts may be more or less successful. However, no imputations are included for the consumption of services produced and consumed by the households themselves (Sen, 1979; Stiglitz, Sen and

Fitoussi, 2010). For example, if child minding is performed by a professional child minder the cost of the relevant service is included in the concept of GDP. However, if the same services are provided by the parents or free of charge by the grandparents, other relatives or friends they are not included. This omission may have serious consequences in the context of empirical investigations of convergence since higher levels of development are normally associated with higher levels of marketization. Therefore, part of the observed convergence may be simply attributed to the transfer of a number of items from unrecorded consumption of own production to the recorded consumption of market services.

Taken to extreme, the above argument also applies in the case of leisure. Even though economists may agree that the wage rate is the shadow price of leisure, they normally hesitate to include the value of leisure in the relevant calculations. However, enjoying on average the same basket of goods and services (GDP per capita) as the average person in another country while working fewer hours must surely have welfare implications. This point is directly related to the choice between GDP per capita and output per hour worked mentioned earlier and has implications for the results of empirical studies of the convergence hypothesis. Relative cross-country differences using GDP per capita and output per hour worked can be non-negligible (OECD, 2009). Furthermore, since during the long-run course of economic development, usually the average number of annual hours worked per worker declines, sometimes considerably, the recorded GDP per capita growth rates may underestimate the "true" growth rates of the economy.

In addition to the above, GDP is a "gross" indicator; in other words, it does not account for depreciation and the depletion of resources involved in the production of output, while it includes a number of activities producing "bads" rather than "goods" (Arrow et al, 2004; Heal and Kriström, 2005). For example, while there is inevitable pollution associated with almost all production processes, National Accounts do not record (negatively) the costs associated with the damage occurred while they record (positively) as output attempts dealing with the cleaning of pollution. Several attempts have been made to adjust GDP for such factors but none of them has been widely accepted (Morse, 2003).

An additional drawback of GDP per capita as indicator of the standard of living in empirical convergence studies of panels of countries has to do with the fact that as the economy grows, the basket of commodities produced and consumed becomes more sophisticated. GDP deflators by construction do not take into account changes in the quality of commodities. As a consequence, using GDP per capita risks translating improvements in the quality of these commodities as higher prices, thus leading to an underestimation of the true improvements in the living standards of the population (Deaton and Heston, 2010).

Finally, a major drawback of GDP per capita as a welfare indicator is its lack of sensitivity to the distribution of resources. At the extreme, think of two societies with the same population size and the same level of GDP per capita; in the first society income is equally distributed across all citizens while in the second it accrues to a single individual while the rest of the population members have zero incomes. Even under the simplest additive Social Welfare Function with diminishing utility of income, the first society enjoys a higher level of welfare than the second, but this is not reflected in the ranking implied by GDP per capita. A number of attempts can be found in the literature aiming to adjust for this deficiency. In their simplest form they use as indicator of welfare GDP per capita multiplied by one minus the value of an inequality index taking values in the domain [0, 1] (Atkinson, 1970; de Graaf, 1977). However, they have not been widely accepted, perhaps because behind each index of inequality lies a different Social Welfare Function and preferences over social welfare functions vary widely. Naturally, this deficiency can have implications for the empirical investigation of the convergence hypothesis if growth is associated with substantial changes in the distribution of income - especially if the former is interpreted as convergence is the living standards of the representative population members of the various units (countries or regions).[5]

5.3. GDP per capita in Purchasing Power Parities (PPP)

In the earlier empirical studies of the convergence hypothesis researchers were using as indicator of each country's level of economic development the country's GDP per capita converted in a common currency (usually US dollars) using nominal exchange rates. However, nominal exchange rates are determined primarily by the flows of traded commodities across

[5] See, for example, Klasen (1994). This handicap is even more serious if broader definitions of income are employed, that include the value of services provided by the welfare state. These services vary both across countries and across time but their effect is almost always strongly inequality-reducing (Paulus, Sutherland and Tsakloglou, 2010). Distributionally weighted growth rates have been used in project or program evaluation studies. In a number of instances equal weights are assigned to the growth rates of the incomes of all population members ("population weights"), while in extremis and especially in the evaluation of projects aiming at poverty alleviation only the growth rates of the incomes of the poor member so of the population are taken into consideration (Brent, 1984; Little and Mirrlees, 1990).

countries while a very considerable proportion of the commodities consumed, especially services, are not traded across borders. To the extent that trade barriers are not exorbitantly high, the prices of traded commodities tend to converge. However, this is not the case for non-traded commodities, whose prices are usually closely associated with the country's nominal income per capita.

To make sensible comparisons of welfare levels across countries, common prices for all commodities, traded and non-traded alike, are needed. In other words, we need to make our comparisons using PPP exchange rates. The computation of such rates is not an easy task, both theoretically and, particularly, empirically. Several long-running research projects have devoted their efforts to producing PPP exchange rates (Summers and Heston, 1991; World Bank, 2013). Series of PPP exchange rates are calculated and published by a number of international organizations. The methodologies employed are not identical and, hence, the corresponding estimates of GDP per capita are not identical either, but the cross-country differences are not considerable across methodologies. Most empirical studies use series produced by the World Bank. Irrespective of the specific methodology utilized for the calculation of PPP exchange rates, the gap between rich and poor countries is substantially smaller when using PPP exchange rates than when using nominal exchange rates. In other words, if poor countries grow faster than rich ones, their prices tend to converge to those of rich countries and, ceteris paribus, their recorded growth rates using nominal exchange rates tend to decline. Therefore, the use of growth rates when GDP per capita has been converted using nominal exchange rates in empirical convergence studies tends to mix changes in quantities (that are of interest) with changes in prices (that are not) and result in misleading estimates. This is the reason that nowadays virtually all empirical studies investigating the convergence hypothesis across countries rely on estimates of GDP per capita derived using PPP exchange rates.

Nevertheless, the use of GDP per capita in PPP exchange rates is not problem-free. Apart from using the "right" prices, this indicator suffers from all the other drawbacks associated with GDP per capita that were outlined above. Moreover, by construction, PPP exchange rates reflect the prices of the average basket of commodities consumed globally. Hence, by implication, they reflect primarily the prices of commodities consumed in developed countries (Thomas et al, 2013). This might have implications for the study of the convergence hypothesis, as the structure of consumption changes during the course of economic growth (it tends to bias upwards the GDP estimates of poor countries that consume a different basket of goods than rich countries). Finally, it is not entirely clear whether corrections for regional price differentials should be used when the convergence hypothesis is tested at the regional level within a country. Such differentials do exist, but they often reflect differences in quality of particular commodities that would better remain intact in the corresponding calculations.

5.4. Composite indicators

Taking the above into consideration, there was a growing dissatisfaction with GDP per capita (hereafter, the term denotes “GDP per capita in PPP exchange rates”) as an indicator of development. A consensus emerged that growth in GDP per capita is a necessary but not sufficient condition for improving the living standards of the population and GDP per capita may not be the best indicator of a country’s level of economic development. After all, income is a means to an end and not an end itself. Hence, the search for alternative indicators grew. Since the very nature of “development” is multidimensional, it is not surprising that the indicators suggested in the literature as alternatives to GDP per capita were composite (multidimensional) rather than unidimensional.

To a considerable extent, the relevant literature is based on Sen’s theory of “functionings and capabilities” (Sen, 1985; 1987).[6] According to Sen, the aim of economic development is to increase the capabilities of the members of a population to improve and expand their sets of functionings. Functionings may be either elementary (for example, being adequately nourished) or complex (for example, being able to participate in the life of the community). Income is one of a number of factors that enhances individual capabilities. Sen’s theory was operationalized through the construction of the Human Development Index that was adopted by the United Nations (UNDP). The precise formulation of the index has changed over time, but its main reasoning remained unchanged (Nussbaum, 2011). The index combines three dimensions of well-being: standard of living (approximated by the logarithm of Gross National Income per capita[7]), health (approximated by life expectancy at birth) and education (approximated by mean and expected years of schooling). The calculation of the specific sub-indices is a little

[6] Efforts at constructing multidimensional indices of economic development predate Sen’s work; see, for example Morris (1979) and Hicks and Streeten (1979).
[7] Gross National Income is used instead of Gross Domestic Product, so that the standard of living of the country’s residents is approximated better. The two concepts are closely but not perfectly correlated.

complicated, based on the ratio of the difference of the actual country mean from a theoretical minimum value over the difference between a theoretical maximum and a theoretical minimum value. Then, the three sub-indices are multiplied and the value of the index is the cubic root of the product.

Like all multidimensional indices in the field, the Human Development Index has two main potential drawbacks: selection and aggregation (Kelley, 1991; Ravallion, 2012). Selection is related to the dimensions represented in the index; for example, it has been criticized for omitting important dimensions of human welfare such as freedom. In terms of aggregation it was questioned whether equal weights should be given to all dimensions involved. Related to the later it is also the question of the degree of substitution between dimensions; for example, should lower scores in education be allowed to be compensated by higher scores in health and if so by how much?

The debate about the appropriate indicator of development continues unabated in recent years. In fact, the most influential of the corresponding studies (Stiglitz, Sen and Fitoussi, 2010; Stiglitz, Fitoussi, and Durand, 2028a, 2018b) support the idea of expanding the set of dimensions of well-being, although it is not always clear whether they also support the idea of aggregating all dimensions in a single indicator or relying on the use of the dominance criterion (and, graphically, radar charts). Moreover, they support the idea of looking beyond the average value to the variable under consideration, taking into account its distribution across population members. Finally, another branch of the literature tries to exploit subjective evaluations of well-being and construct “happiness” indicators (Frey and Stutzer, 2002; Layard, 2011) arguing that since happiness is the ultimate goal of the growth process, it would be preferable to look directly at it rather than at surrogate variables.[8]

Empirically, the Human Development Index is strongly positively correlated with (the logarithm of) GDP per capita. Likewise, happiness is also correlated with income per capita, although the corresponding correlation is far less strong. Although in the literature there are studies investigating convergence across countries in terms of the Human Development Index, their theoretical foundations are not always very strong. Even accepting the logic of the index, it may be preferable to use structural estimation of the determinants of each component

[8] Note that this debate revived an old literature questioning whether growth per is desirable (Nordhaus and Tobin, 1973) as well as whether growth increases happiness, the so called “Easterlin paradox” (Easterlin, 1974). Contemporary empirical studies do not see, to confirm the “Easterlin paradox”, but they do point out that ceteris paribus, the marginal utility of income at high income levels is positive but strongly diminishing.

(dimension) of the index rather than rely on reduced form estimation of the aggregate index. Moreover, the current version of the Human Development Index is based on relative distances from theoretical values and, hence, it is even more questionable whether convergence can be studied within such a framework.

5.5. Discussion

The literature on the appropriate indicator of a country's or a region's level of economic development and, consequently, its growth rate has expanded considerably in recent years. The most popular indicator in empirical studies is, by far, GDP per capita in PPP exchange rates. However, this choice is not problem-free. GDP per capita is an output indicator, insensitive to the distribution of resources among the citizens and the damage done to the environment in order to produce output, while it does not take into account non-pecuniary dimensions of human welfare.

This is the reason that in recent years several attempts have been made to construct composite indicators encompassing more dimensions of the standard of living. This is an ambitious effort but encounters two serious problems: selection (that is, which are the most important dimensions of the standard of living to be included in the composite index) and aggregation (that is, what weights should be attached to each dimension and to what extent substitution should be allowed between dimensions). The most well-known of these indicators is the UNDP's Human Development Index. It relies on three dimensions of the standard of living: income per capita, education and health. The Human Development Index as well as most other composite indices suggested in the literature are positively and, usually, strongly correlated with GDP per capita in PPP exchange rates.

In the specific context of the present research project, for the study of convergence across countries and/or regions, it is probably far too ambitious to use composite indicators for a number of reasons. First, such indicators are usually calculated at the national level and in most cases no disaggregated information is readily available at the sub-national level. Second, and most important, it is far from clear that performing reduced form estimation of the determinants of composite indicators, as some empirical studies do, is appropriate. Instead, careful structural estimation is required of the determinants of each particular sub-component of the index and then the derived estimates should be aggregated into a single index. This is a cumbersome process that becomes questionable in the current context of the Human Development Index that relies on relative distances from arbitrary theoretical values.

To be consistent with traditional growth theory that examines only outcomes in terms of quantities of goods and services produced, would require the use of the growth rate of output per hour worked as indicator of a country's or a region's growth rate. However, in many countries such information is not readily available at the national level or the sub-national level for the long time series that are needed for the study of convergence and, even when such series can be found, the quality of the information on hours worked is questionable. Therefore, it seems logical to use GDP per capita in PPP exchange rates despite its deficiencies, especially since it is correlated with composite welfare indicators.

6. Conclusions

The survey covered four areas: models of economic growth and their predictions about convergence, measures of convergence, empirical studies of convergence and growth indicators.

The early neoclassical growth models with exogenous technology predicted that in the long run an economy will converge to its steady state equilibrium. If factors such as savings rates and population growth rates are similar across countries and there are no barriers to technology transfers, poor economies are expected to grow faster and, eventually, converge with the rich ones. Otherwise, each country will converge to its own steady state. In other words, convergence will be "conditional".

On the contrary, endogenous growth models assume that economic growth is the outcome of endogenous factors, rather than exogenous unexplained technological progress. In such modles, investment in human capital, innovation, R&D and knowledge influence decisively the process of economic growth. They entail significant spillover effects as well as positive externalities that can enhance the growth process. These factors can lead to increasing returns to physical or human capital and, hence, unlike the predictions of the neoclassical models, in endogenous growth models converge – even "conditional convergence" – may not be observed.

Three main approaches to the measurement of convergence can be found in the literature. The first, "sigma convergence", focuses on the standard deviation of the variable of interest (usually logarithm of the GDP per capita of the countries or regions in the sample). If over time the standard deviation declines, then convergence occurs. The second, "beta convergence", looks at the initial level of GDP per capita. If, ceteris paribus, there is convergence and poorer countries grow faster than richer ones, the coefficient of the initial level of GDP per capita should be negative and statistically significant. The third approach is based on cointegration techniques. Convergence occurs when there is no unit root in the difference of time series

At the empirical front, studies looking at regional convergence in countries such as the US or Japan usually come to the conclusion that convergence does occur and poorer regions grow faster than richer ones. At the level of the member-states of the European Union, the results are mixed, with several studies pointing out that we can observe “club convergence” (when economies with similar initial conditions converge to the same steady state) and that certainly the situation was aggravated during the recent economic crisis, when significant divergence was recorded. Finally, at the global level earlier studies could not find convergence between developing and developed countries and, in fact, in the first postwar decades developed countries were growing faster than developing countries. The picture changed since the late 1980s and most recent studies report convergence while they also point out that policies promoting political stability, minimization of market distortions and low government consumption tend to enhance growth.

By far the most popular indicator of a country’s or a region’s level of economic development or standard of living in empirical convergence studies is GDP per capita in PPP exchange rates. In recent years there is a growing dissatisfaction with this index since it is insensitive to the distribution of resources among the population members, does not take into account the damage to the environment in the process of production and, particularly, it does not take into account non-pecuniary dimensions of human welfare. Several attempts have been made in recent decades to construct composite indicators encompassing more dimensions of the standard of living, the most well-known of which is the Human Development Index. It is doubtful whether such indicators are the appropriate metrics for empirical converge studies, although in the future, a shift from GDP per capita in PPP exchange rates to output per hour worked (also in PPP exchange rates) that will be consistent with growth models might be desirable.

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