Output convergence in the Central and Eastern European member countries

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Abstract

This thesis is concerned with the question of whether recently joining member countries are converging on European Union norms for per capita GDP. In particular, we focus on the "convergence debate" that has developed within growth theory.

In order to find an answer, we look for a testing framework that is coherent with mainstream theoretical models and we investgate why such convergence may have happened. Firstly, we employ a variety of approaches to test whether economies actually reach a steady state as a consequence of catching-up and we argue that, if this condition is not satisfied, convergence may not happen at all in the long run[1]*. Secondly, we investigate the role of trade openness, motivated by the failure of early theoretical models to recognize its effects on growth. Again, we give particular attention to the the long-run and the supply-side of our economies.*

Empirical results suggest that there is evidence of catching up in the period under investigation, but no conclusive indication of long-run convergence. We also observe little signs the latter was caused by intra-EU trade openness which, in turn, helped growth.

These findings are evidence that EU policies were effective in the short-run. Therefore, the EU should continue its long-run effort of guiding new members' convergence towards a common steady state. In particular, targeting foreign direct investments, as suggested by the existing literature, may be more effective than focusing on the integration of the EU goods market.

Finally, the Solow-Swan growth theory proved a reasonable tool to understand convergence in the enlarged EU, with no compelling need to open the model to trade or endogenize technological progress.

[1] *This conclusion would invalidate the predictions of the neoclassical growth model.*

Contents

List of Figures

List of Tables

Acronyms

A&R	Arrow and Romer growth model
ADF	Augmented Dickey and Fuller statistic
CADF	Cross sectionally augmented ADF statistic
CIPS	Cross sectionally augmented Im Pesaran Shin statistic
CZSO	Czech Statistical Office
DF	Dickey and Fuller statistic
DVAR	VAR in differences
ELG	Exports-led Growth
ERM	Exchange Rates Mechanism
EU	European Union
FADF	Fourier augmented ADF statistic
FDI	Foreign Direct Investments
FPE	Factor prices equalization theorem – Samuelson (1964)
FUR	Fixed Unit Root

GDP	Gross Domestic Product
ILG	Imports-led Growth
IMF	International Monetary Fund
KPSS	Kim Pesaran Shin Smith statistic
NMS	New member states
OPN	Trade Openness
PPP	Purchasing power parity
PPS	Purchasing power standard
S&S	Solow and Swan growth model
STUR	Stochastic Unit Root
TFP	Total factors productivity
UN	United Nations
USSR	Union of Soviet Socialist Republics
VAR	Vector Auto Regressive
VECM	Vector Error Correction Model

Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Copyright

Dedication

To my family.

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Publications

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Journal article:

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Conference papers:

- 4th European Trade Study Group annual conference, Warsaw, Poland, 2008.
- 8th INFER workshop on International Economics, Cluj-Napoca, Romania, 2008.
- 10th European Economic and Finance Society annual meeting, Sofia, Bulgaria, 2007
- 5th INFER workshop on International Economics, Trade Factor Movements and Convergence In Transition Economies, Kingston-Upon-Thames, United Kingdom 2006.

Chapter 1

Introduction

Do poor countries grow faster than rich countries? This is a natural and important question but, as evidenced by a large and still expanding literature, not one for which a single convincing answer has yet achieved consensus. Theory has tried to address it in many different ways by reference to the main determinants that have been postulated for growth. For example, *Abramovitz* (1986), *Baumol* (1986) see catching-up in terms of adopting some leader's technology; for *Barro* (1991), *Mankiw et al.* (1992) it is a matter of diminishing returns on factors of production; *Klenow and Rodriguez-Clare* (1997) or *Easterly and Levine* (2002) look into differences in productivity. In some cases, economists rejected the opportunity of asking the question in the first place. For example, removing the assumption of decreasing returns on the factors of production, as in the *Romer* (1986) endogenous growth model, makes catching-up no longer inevitable in economies starting from different initial levels of per capita output. Given the lack of a predominant theoretical framework, the contribution of empirical research is particularly valuable, though not particularly easy. Translating theoretical questions into testable models has proved a statistical challenge in many occasions. Early investigations based on the neoclassical model have been heavily criticised[1], prompting the development of a less theory-dependent testing framework. The 1990s fortunately saw not only a resurrection of growth theory, but also the popularization of non-stationary time-series econometrics and the development of a literature on time-series (or stochastic) convergence. This was also a period of transition in Eastern European economies: many gained independence, abandoned a centrally planned system and slowly prepared for a political union with a group of countries sharing considerably higher levels of national income. This might be seen as a natural environment for observing catching-up, yet the amount of research produced on converegence within the the EU enalrgement, has been relatively small until very recently. This is perhaps not surprising, given the considerations noted above. Economic theory is largely undecided on whether such behaviour should at all be expected and, if so what are its determinants. Empirical research on the other hand, struggles on the methodological side, especially when information about the past is insufficient or unreliable. However, as much as such information becomes slowly available, the exercise seems more realistic. At present, almost two decades have passed after the transition to a free market has begun and twelve new countries are already members of the European Union, so we feel it is a good time for us to aim exactly at this kind of investigation. In particular, our principal objective is twofold: firstly we seek to

[1]See for example *Quah* (1993b) and references therein.

assess the extent to which time-series methods show evidence that the accession countries (now new members) have been catching-up with the incumbent EU member countries. Secondly, we use such methods to investigate whether one of the relatively unexplored potential vehicles for catching-up - namely trade liberalisation - has actually played a part in the case of those countries . On the empirical side, we give more weight to time-series techniques, so that we can afford to be theory-independent at first and then look for policy predictions in compatible models. In this context, our reference framework is the econometrics of non-stationary series, so we see long-run convergence as a stationary difference between the per-capita output of a given country and a reference output level[2]. Statistically, we test several variations of this definition using the concepts of unit roots and cointegration. This allows for a richer investigation, with more widely applicable conclusions than research that presumes the relevance of the neoclassical model, which in the case of the EU enlargement has often used the more traditional beta regressions.

The other problem is that answering our initial question, naturally brings an additional consideration. Namely, not only it is interesting to understand "if" poor countries grow fast compared to rich countries but also "why". This second issue can be explored from many different angles in the case of the Eastern members of the EU, and to find our way we should dig deeper into the individual characteristics of these economies rather than simply thinking in terms of a political union. An easy approach also compatible with standard growth models, is assuming diminishing

[2]either with reference to a steady-state or a benchmark county. See chapter 4 for more details.

returns to capital. If capital is scarce in low income countries, its rate of return is higher than in richer economies. If this is the case, we should expect stronger investments therefore a faster accumulation in capital stock, then a higher per-capita output and national income. If we allow foreign investments, these will flow into poor countries accelerating the process. This mechanism is very easy to accommodate within the neoclassical model and probably explains the popularity of the literature on foreign direct investments[3]. In particular, focusing on intra-EU direct investments. it is easy to get an appealing representation of what may have happened in the new members. An alternative possibility is to assume that convergence is driven by total factor productivity (TFP). The question then is whether an increase in TFP is the consequence of correcting the production inefficiencies usually associated with centrally planned economies and how long it would last. If the effect is strong enough, it may have the power of pushing the new members to the same steady state shared by the old members[4]. Both approaches however, are mostly concerned with the supply side, essentially proposing some variations in production functions. Our contribution in this field goes in another direction: we look at potentially under-explored determinants of convergence. With this target in mind, it is interesting to note that one of the weak sides of the convergence literature (at present largely founded on the neoclassic model) is its scarce consideration of the trade sector. Yet, it is reasonable to think of trade integration as a veichle to facilitate innovation spillovers, inducing technological progress and therefore

[3]In a slightly broader context, see *Mallick and Moore* (2008).
[4]See for example *Arratibel et al.* (2007), or *Borys et al.* (2008)

a channel to asymmetrically stimulate growth. As we are going to see in chapter 6 however, even at a more general level the consensus is not perfect in this context, and there is a general lack of theoretical models able to explain the mechanism. The major difficulty, is establishing a strong direction in causality, so as to understand whether it really is trade that enhances growth and not the other way around. For this reason, we are going to use model-free time-series techniques. If we get evidence that trade is a key component of the convergence process, the clear implication is that a better theoretical framework is needed to understand the mechanism[5]. On the other hand, if we obtain the opposite result[6] we should be in the position of advocating the primary role of investments and productivity as determinants of convergence, already suggested by the existing literature.

The rest of the thesis is organised as follows: **chapter 2** describes the theoretical concept of convergence with reference to the models it originated in; **chapter 3** introduces the framework we will use for empirical research; in **chapter 4 and 5** we test the convergence hypothesis and some stochastic variants; **chapter 6** investigates the explanatory power of international trade based on the evidence from chapter 4,5 and finally **chapter 7** concludes.

[5]A way to go could be following from endogenous growth as in Grossman & Helpmann or extending the neoclassical model as in Ben-David and Loewy, 2003.

[6]i.e. trade is not relevant to convergence.

Chapter 2

Foundations of the convergence hypothesis

THE question of the existence of convergence does not have a unique answer. This chapter presents alternative theories of growth that form the mainstream literature and are the theoretical background to understanding the meaning of the convergence hypothesis in the EU enlargement. These are often based on some restrictive assumptions but their fundamental intuitions are key to introduce the topic and give a foundation to stochastic techniques used in the empirical investigation proposed in chapter 4. Although some of the issues discussed in the next sections can be traced back to early economic thought, modern economists typically refer them back to the neoclassical model developed in the late 1950s. We follow this convention to simplify the exposition.

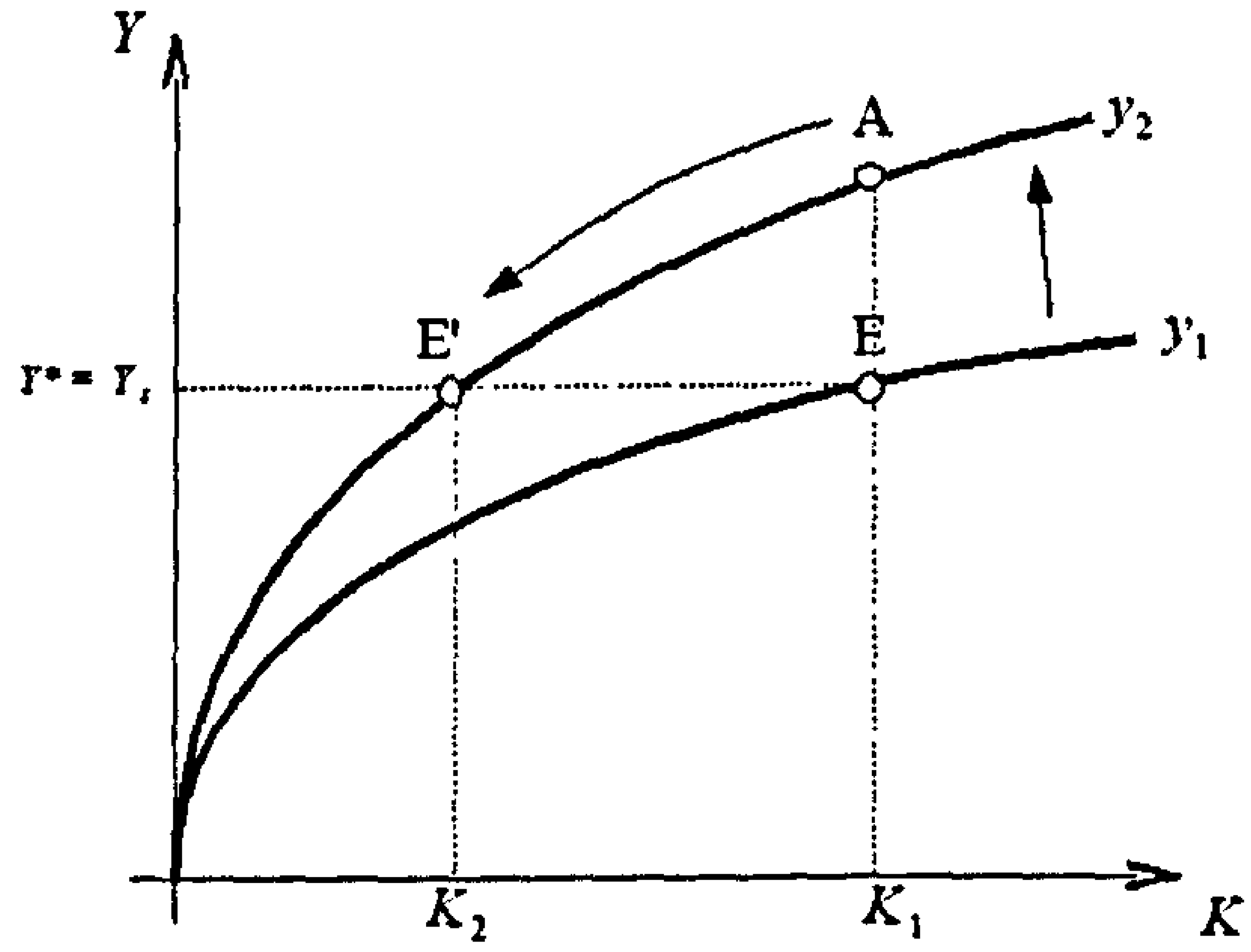
2.1 Output growth

A preliminary exercise to understanding growth differentials in economies with different initial characteristics, is exploring the potential determinants of growth themselves. In this section we survey the mainstream contributions in this area, so we can then consider if and why any of those theories also postulates output convergence.

2.1.1 The exogenous growth model

The model was contemporaneously but independently developed by *Solow* (1956) and *Swan* (1956) as an extension of *Harrod* (1939) incorporating labour and technology as factors of production. The neoclassical approach differs from the classical growth theory (the major theorists being Malthus, Adam Smith and Ricardo) mainly on the question of population growth. In the classical model population growth is endogenous in the sense that population will shrink or expand to bring about a steady-state in which per-capita income is at an exogenously given subsistence level. In other words, a condition of improved growth cannot last in the long run because it will induce a population explosion. In Figure (2.1), a shift in production from y_1 to y_2 translates equilibrium from E to E'. Capital moves from K_1 to K_2 whilst output stays fixed at the subsistence level $Y* = Y_S$. The automatic transition from A to E' is determined only by variations in the population size. Neoclassical economists expanded this idea, arguing that population growth is not the only relevant factor to economic growth.

Figure 2.1: The Classical Model



The neoclassical approach

Differently from the classical model, in Solow-Swan (S&S), output is determined by the following production function, including exogenous technology:

$$Y_t = F(K_t; A_t L_t) \tag{2.1}$$

where production (Y_t) is function of capital (K_t), labour (L_t) and technology (A_t). Technological progress is purely labour augmenting in order to be Harrod-neutral[1]. The production function exhibits diminishing marginal productivity of both factors[2] and constant returns to scale[3] . For convenience, we can reformulate (2.1) as follows:

[1]for more details, see (Harrod 1937) or a comprehensive overview in *Valdes* (2000)

[2]Formally, $MPK_t > 0$, $MP(AL_t) > 0$ and $\frac{\partial^2 Y_t}{\partial K_t^2} < 0$, $\frac{\partial^2 Y_t}{\partial (AL_t)_t^2} < 0$.

[3]$F(\lambda K_t, \lambda L_t) = \lambda Y_t$with λ constant. Adding the assumption of smooth technological progress, growing at a rate "g" (i.e. $A_t = A_0(1+g)^t$) and consequence of diminishing marginal productivity, we observe that $MPL_t > 0$ hence $F[\lambda K_t, A_t(\lambda L_t)] = \lambda Y_t$.

$$y = f(k) \tag{2.2}$$

where $y = \frac{Y_t}{AL_t}$ and $k = \frac{K_t}{AL_t}$ respectively[4] , $f(k) = F(k, 1)$ and $f'(k) > 0$, $f''(k) < 0$ i.e. diminishing returns on capital.

Considering the demand side of the model and assuming n is the population growth rate, d the share of capital constituting depreciation and s the share of income reserved to savings, equilibrium is determined, in steady state, by a condition of equivalence between savings and investments (i.e. $i = (n + \delta)k = sy$).

This conclusion is easily obtained algebraically. Aggregate demand is computed as the sum of consumption (C_t), investments (I_t), government expenditures (G_t) and net exports (NX_t). Formally:

$$Y_t^D = C_t + I_t + G_t + NX_t$$

In the long run, classical full-employment equilibrium must hold, ($Y_t^D = Y_t$) hence, removing for simplicity the time subscript t:

$$Y = C + I + G + NX$$

Subtracting taxation on both sides:

$$Y - T = C + I + (G - T) + NX$$

[4]both variables are now expressed in labour-efficiency units.

Rearranging and assuming budget and trade deficits are not sustainable in the long-run ($G - T = 0$; $NX = 0$) we have:

$$C + S = C + I$$

when disposable income is either consumed or saved ($Y - T = C + S$).

Finally, assuming in the long run savings are endogenously determined as a fraction of income ($S = sY$; with $s \in [0, 1]$), we conclude:

$$I = sY \tag{2.3}$$

In order to get a formulation compatible with (2.2) express (2.3) in terms of labour-efficiency units. Dividing both sides by AL we have:

$$\frac{I}{AL} = s\frac{Y}{AL}$$

Or:

$$i = sy = sf(k) \tag{2.4}$$

Net investments, adding each year to the stock of capital, provide a connection between the supply (production function) and the demand side (aggregate demand) .

In order to make the model more realistic, assume capital depreciates every year at a rate the rate δ, so that:

$$\frac{\partial K}{\partial t} = I - \delta K \tag{2.5}$$

or in labour-efficiency units ($1/AL$):

$$\frac{\partial k}{\partial t} = \frac{\partial K}{\partial t}\frac{1}{AL} - \frac{\partial A}{\partial t}k - \frac{\partial L}{\partial t}k$$

substituting (2.5):

$$\frac{I - dK}{AL} - \frac{\partial A}{\partial t}k - \frac{\partial L}{\partial t}k = \frac{I}{AL} - \delta k - \frac{\partial A}{\partial t}k - \frac{\partial L}{\partial t}k = i - \left(\delta + \frac{\partial A}{\partial t} + \frac{\partial L}{\partial t}\right)k$$

where $i = \frac{I}{AL}$ is (gross) investments in labour-efficiency units and $k = \frac{K}{AL}$.

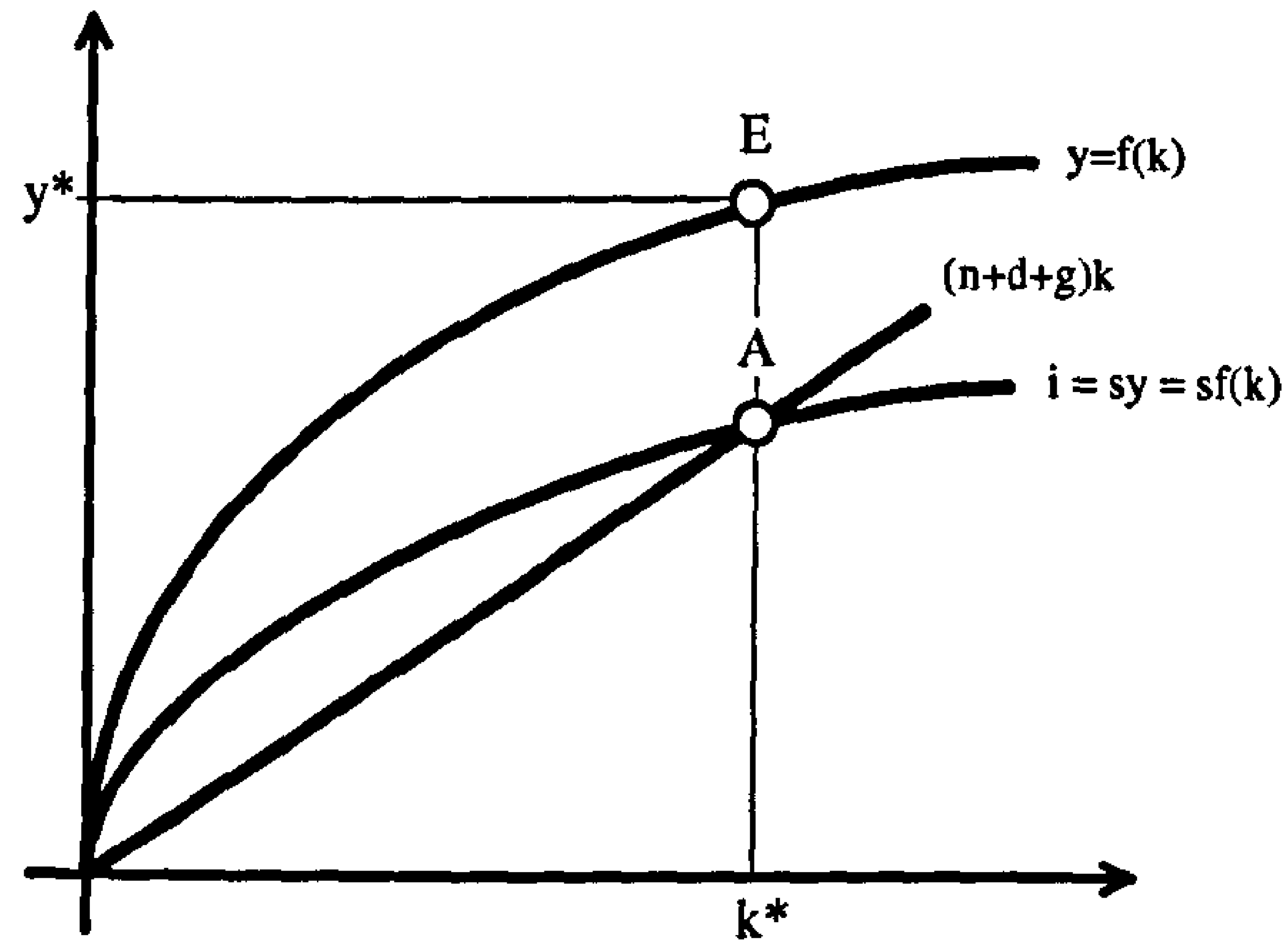
Using the equilibrium relation (2.4) we can rewrite the above as:

$$\frac{\partial k}{\partial t} = sf(k) - \left(\delta + \frac{\partial A}{\partial t} + \frac{\partial L}{\partial t}\right)k$$

or, assuming technical progress is taking place at a fixed, exogenous rate $\frac{\partial A}{\partial t} = g$ and similarly population growing at a fixed rate $\frac{\partial L}{\partial t} = n$[5], we can write:

[5]both are strong assumptions that the S&S model is forced to introduce because it lacks a theory to explain endogenously the technological progress and the population growth. Further, the size of the population coincides with the work-force.

Figure 2.2: Equilibrium in the Solow growth model



$$\frac{\partial k}{\partial t} = sy - (\delta + g + n)k \tag{2.6}$$

the latter is the fundamental growth equation and summarizes the dynamics of the model . The equilibrium corresponds to a steady state condition where $\frac{\partial k}{\partial t} = 0$ as in the graph (2.2). Any level of capital $k \neq k*$ generates a short run unbalance between sy and $(\delta + g + n)k$ while in the long-run the economy re-adjusts to A.

For example, consider an economy for which at the time period t:

$$k_t < k^* \Rightarrow sy_t > (\delta + g + n)k_t \Rightarrow \frac{\partial k}{\partial t} > 0 \Rightarrow k_{t+1} > k_t$$

or:

$$k_t > k^* \Rightarrow sy_t < (\delta + g + n)k_t \Rightarrow \frac{\partial k}{\partial t} < 0 \Rightarrow k_{t+1} < k_t$$

In the first case, gross investments $i_t = sy_t$ exceed the depreciation of capital $(\delta + g + n)k_t$ making net investments positive today and therefore k higher ($k_{t+1} > k_t$). The mechanism is inverted for $k_t > k*$ and in both cases it persists up to the steady state equilibrium, where:

$$k_t = k* \Rightarrow \frac{\partial k}{\partial t} = 0 \tag{2.7}$$

(See Figure 2.2). A series of additional considerations are possible, within this basic framework. The most immediate is understanding the consequences of relaxing part of the assumptions we have used so far. For example, endogeneising technological progress, population growth or looking at a world where the first does not play a significant role (i.e. $g = 0$). As a preliminary exercise however, it is worth looking into the main policy implications of the model as it stands. We will look at in detail:

- A shock in savings rates (s).
- A shock in the rate of population growth (n).

The first exercise is interesting since it can form the basis[6] for understanding the consequence of a shock in investments (i) and in particular in foreign investments (i_f) if we assume i.e. $i = i_d + i_f$ with i_d domestic investments. The second exercise links to classical theory. In terms of the EU8, it is also interesting to note that in many eastern countries population is decreasing, yet growth rates of total GDP are strong. Further, a decrease in the population growth rate can have an impact on per-capita variables.

[6]recall the model predicts $i = sy$.

Policy and model predictions

This section looks into the dynamics of the Solow-Swan (S&S) model to analyse its policy predictions, with particular reference to:

- A shock in the savings rate
- A shock in the population growth

At first, assume the level of savings in the economy is raised from s_0 to s_1 so that:

$$i_0 = s_0 f(k) < s_1 f(k) = i_1$$

This is sufficient for moving the economy towards a new steady state $k*_1$ since at the old level $k*_0$ gross investments, as determined by the new investment function $i_1 = s_1 f(k)$, would be greater than depreciation thus resulting in positive $\frac{\partial k}{\partial t} > 0$ allowing for an higher labour efficient capital stock in the next period. The new equilibrium implies:

$$(k*_1, y*_1) > (k*, y*)$$

Here, the prediction of the model, is that countries with higher rates of savings (a link with investments is also possible through equation 2.3) should have a higher level of per capita income.

In the second case, we assume an increase in the population so that n_0 goes to n_1 , therefore:

$$(n_0 + \delta + g)k < (n_1 + \delta + g)k$$

maintaining gross investments fixed at $i = sf(k)$, now we face a value of investments lower than "depreciation" ($i = sf(k) < (n_1 + \delta + g)k$) around the old steady state, therefore negative net investments $\frac{\partial k}{\partial t} < 0$ and a lower level of capital ($k*_1 < k$) in the next period. The new steady state shifts to:

$$(k*_1, y*_1) < (k*, y*)$$

The prediction of the model in this case is that countries with a higher n should expect lower levels of per capita income.

Finally, a last important prediction of the neoclassical model relates to the ability of increasing capital relative to labour to create economic growth, due to more productive people, given more capital.

2.1.2 The endogenous growth model

The neoclassical model offers a convenient description of why economic growth occurs in the macro economy and, as we are going to see next[7],

[7]See section 2.2.

it has enough elements to explain how much of it we should expect in countries with heterogeneous initial level of per-capita output. However it has some restrictive assumptions too, in particular in the consideration that technological progress is determined outside the model. Given the importance of technology for growth and convergence emerging from Solow-Swan, we now look at an alternative class of models that generated a large consensus in the literature: the endogenous growth models. Unlike the exogenous growth model, *Romer* (1992) abandon the hypothesis of augmenting technology introducing the idea of a stock of knowledge. Technological progress is divided into two components: discoveries and know-how, the first acquired from research and development (R&D) the second - based on the preliminary work of *Arrow* (1962), through job practice. Furthermore, once a firm introduces a new technology, not only does it learn slowly how to use it (know how) but it also acquires the skills to modify and improve it (learning-by-doing). The concept of learning by doing itself has a "learning side" and an "inventing side". People are learning the new technology by using it and at the same time they are able to improve it. The message is that capital accumulation brings two separate effects: higher mechanization (higher capital-labour ratio: e.g. $\frac{K_t}{L_t}$) and increase in the stock of knowledge ($A_{i,t}$). Formally, given the stock of knowledge of the firm i at time t, $A_{i,t}$, its percentage change (in stock of knowledge) following an increase in mechanization, is (in logs for convenience):

$$\frac{\partial log A_{i,t}}{\partial log(K_{i,t}/L_{i,t})} = \theta$$

where $\theta > 0$.

Rearranging and solving for $A_{i,t}$ in levels, we obtain[8] :

$$A_{i,t} = \xi \left(\frac{K_{i,t}}{L_{i,t}} \right)^{\theta}, \theta > 0 \tag{2.8}$$

The idea of learning-by-doing brings the concept of spillovers. Whilst in the real world, a successful new technology is very likely to be copied by other firms, the process is neither fast or without cost. However, the *Romer* (1986) approach, whose contribution is to add spillovers to *Arrow* (1962)'s theory, is to simplify the model by assuming that these are also instantaneous and all firms can use them for free.

This consideration has the following implications:

1) Everyone knows everything. At a given time t, the level of knowledge is the same for all firms ($A_{i,t} = A_t, \forall i$).

2) The capital-labour ratio is the same for all firms. This is a direct consequence of the previous statement. Using (2.8) and given $A_{i,t} = A_t, \forall i$, we obtain:

$$\frac{K_{i,t}}{L_{i,t}} = \left(\frac{A_t}{\xi} \right)^{1/\theta} = \zeta_t$$

3) Knowledge (A_t) is given for the firms (spillovers).

[8] see section 4.5 for details.

The Arrow-Romer model

The concepts introduced in the previous section, were formalised by *Romer* (1986) in the model we are going to refer to as Arrow-Romer (A&R), which also assumes profit maximizing firms, having individual labour augmenting production functions of the generic form:

$$Y_{i,t} = F(K_{i,t}, A_t L_{i,t})$$

With $i = 1, 2, ..., N$ and:

- No market power (firms are price-takers).
- Free and learning-by-doing determined technological knowledge.
- Constant returns to scale, positive marginal productivity of capital (MPK) and labour (MPL) and $F''(...) < 0$.

Using a Cobb-Dougls function for convenience:

$$Y_{i,t} = K_{i,t}^{\alpha} (A_t L_{i,t})^{1-\alpha} \tag{2.9}$$

Profits for the individual firm are given by:

$$\pi_{i,t} = Y_{i,t} - \rho_t K_{i,t} - \omega_t L_{i,t}$$

where ρ_t is the interest rate and ω_t wages at time t. Assuming optimizing firms:

$$\max_{K,L} \left[K_{i,t}^{\alpha}, (A_t L_{i,t})^{1-\alpha} - \rho_t K_{i,t} - \omega_t L_{i,t}\right]$$

First order conditions:

$$\begin{array}{c} \frac{\partial \pi_{i,t}}{\partial K_{i,t}} = 0 \Rightarrow \alpha A_t^{1-\alpha} \left(\frac{K_{i,t}}{L_{i,t}}\right)^{\alpha-1} = \rho_t \\ \frac{\partial \pi_{i,t}}{\partial L_{i,t}} = 0 \Rightarrow (1-\alpha) A_t^{1-\alpha} \left(\frac{K_{i,t}}{L_{i,t}}\right)^{\alpha} = \omega_t \end{array} \tag{2.10}$$

Aggregating across the industry, we can rewrite the production function (2.9) as:

$$\sum_{i=1}^{N} Y_{i,t} = A^{1-\alpha} \sum_{i=1}^{N} \left(\frac{K_{i,t}}{L_{i,t}}\right)^{\alpha} L_{i,t}$$

which, as a consequence of learning-by-doing[9] can be arranged as:

$$Y_t = K_t^{\alpha}(A_t L_t)^{1-\alpha} \tag{2.11}$$

The solution of the model depends on the same production function as in S&S, except for A_t. Instead of growing at a constant (exogenous) rate, technology is endogeneised in the model through equation (??). Of course if, despite its endogenous nature, A_t manages to grow at a constant rate,

[9] See point (2).

the A&R model coincides with S&S. Formally, using the sign ^ for labour ratios ($1/L_t$) and $\sim$ for growth rates[10], we can write:

$$\hat{k}_t = \frac{K_t}{L_t} \Rightarrow \frac{\partial \hat{k}_t}{\partial t} = sy - (\delta + n)\hat{k}_t \tag{2.12}$$

From (??), we can derive a measure for the growth rate of A_t as following:

$$\tilde{A}_t = \frac{\partial A_t / \partial t}{A_t} = \frac{\dot{A}_t}{A_t} = \theta \left(\frac{\tilde{K}_t}{L_t} \right) = \theta \tilde{\hat{k}}_t$$

where: $\tilde{\hat{k}}_t = \frac{\partial \hat{k}_t / \partial t}{\hat{k}_t} = \frac{\dot{\hat{k}}_t}{\hat{k}_t}$ and $\dot{A}_t = \frac{\partial A_t}{\partial t}$.

Using the aggregate production function (2.11) and the aggregate technology in equation (??) :

$$y_t = a\hat{k}_t^{\alpha + \theta(1-\alpha)}$$

11

with $a = \xi^{1-\alpha}$:

Which we can substitute in (2.12) to get:

$$\frac{\partial \hat{k}_t}{\partial t} = sa\hat{k}_t^{\alpha + \theta(1-\alpha)} - (\delta + n)\hat{k}_t$$

[10] For example, for the generic variable y, in the continuous time, we define: $\dot{y} = \frac{\partial y}{\partial t}$ and $\tilde{y} = \frac{\dot{y}}{y} = \frac{\partial y / \partial t}{y}$.

[11] See section 4.5 for details.

and therefore:

$$\tilde{\hat{k}}_t = \frac{\tilde{A}_t}{\theta} = sa\hat{k}_t^{\alpha+\theta(1-\alpha)} - (\delta + n)$$

From the latter we can conclude that the growth rate of the capital labour ratio (and technological knowledge) are constant only when $\theta = 1$ (elasticity of learning-by-doing equal to unity). In this case the economy has a steady state (like in the neoclassical model), however the aggregate production function is reduced to:

$$Y_t = aK_t$$

The model thus obtained (usually called the "AK" model) satisfies four conditions which, as we are going to see in section (2.3), can challenge the way we deal with convergence. These are:

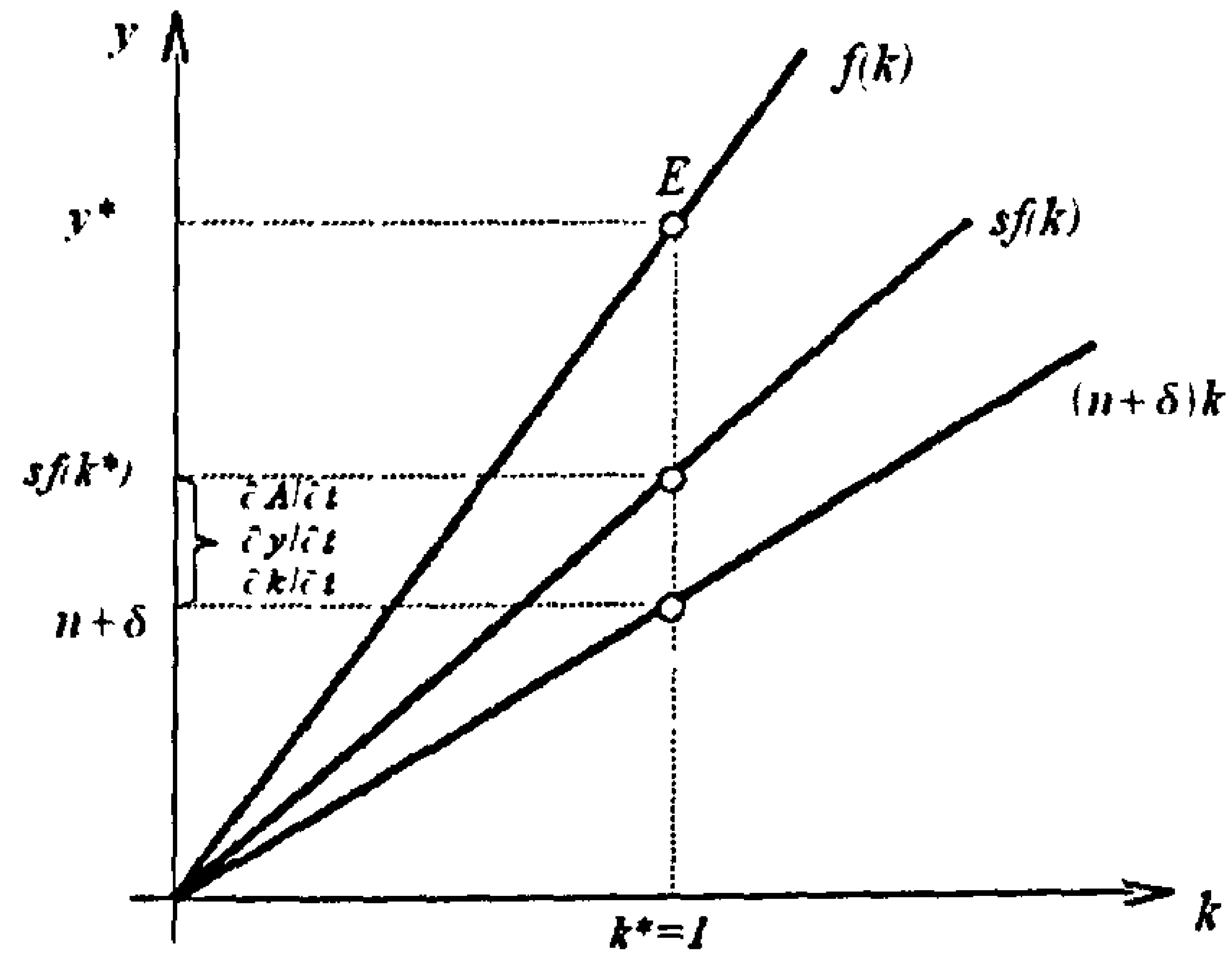
1) When $\theta = 1$ we have $\hat{y}_t = \tilde{\hat{k}}_t = sa - (\delta + n) > 0$ meaning in the long run per capita output grows at a positive, non diminishing, rate.

2) Using the first order condition derived above - see eq. (2.10) - the expression for aggregate technology (??) and the condition $\theta = 1$, we have $\rho_t = \alpha a$ so that the return to physical capital is constant in the long run.

3) Since $\hat{y}_t = \tilde{\hat{k}}_t$ therefore the capital-output ratio (K_t/Y_t) is also constant.

4) Since $\tilde{y}_t = sa - (\delta + n)$ and there is usually high heterogeneity in s, a, δ, n across countries, it is easy to expect substantial differences in their rates of growth.

Figure 2.3: The Arrow-Romer model



This four conditions where firstly examined by *Kaldor* (1961) referring to them as "stylized facts of economic growth". In steady state we can add a further condition:

$$i = sy \Rightarrow \tilde{i} = \tilde{y}$$
$$c = y - i = (1 - s)y \Rightarrow \tilde{c} = \tilde{y}$$

Summarizing:

$$\tilde{y} = \tilde{\tilde{k}} = \tilde{i} = \tilde{c} = sa - (\delta + n) \qquad (2.13)$$

which is also true for variables in levels, where growth is equal to the per capita case plus the population rate. Figure (2.3) shows the equilibrium level of output ($y*$) when $k* = 1$.

In order to put the model in context we can also summarize its main predictions and compare them with the neoclassical (S&S) approach.

1) From the last set of considerations, it easy to see how in the long run per capita income ($\tilde{y}_t$) grows at the rate $sa - (\delta + n)$ and the total income ($\tilde{Y}_t$) at the rate $sa - \delta$. Different levels of this parameters can explain different growth rates.

2) As in the S&S model, $\tilde{y}_t$ is a positive function of savings (s). Unlike the S&S model the effect is permanent and not limited to the transition period only. In the long run, countries with higher levels of savings will tend to grow faster.

3) As in the S&S model, $\tilde{y}_t$ is a negative function of n, δ . Unlike the S&S model the effect is permanent and not limited to the transition period only. In the long run, countries with higher rates of population growth or capital depreciation will tend to grow slower.

4) Economic integration raise the economic growth of the area permanently (movements of people and capitals, firms competition and spillovers). In the S&S model the effect is temporary. The reason lays in the different MPK in the two models:

$$MPK_{S\&S} = \alpha \frac{K_t}{Y_t} < MPK_{A\&R} = a = \frac{K_t}{Y_t} \tag{2.14}$$

with $\alpha \in (0, 1]$. A decreasing MPK means that the initial benefit of integration will slowly disappear in the S&S model. In economic terms, the A&R model add an "invisible" benefit (externality) to any additional unit of capital through learning-by-doing and subsequent spillovers. This is sufficient for eliminating the tendency of capital to diminish and to make the benefits of integration permanent for the economy. This point may assume relevance in the case of the European enlargement, even though if the benefits of integration are equally spread among the member states it does not necessarily imply convergence between old and new members[12].

5) The first order conditions introduced in eq. (2.10) give an indication on the dynamics of real wages in the model ($\theta = 1$):

$$\omega_t = a(1-\alpha)\left(\frac{K_t}{L_t}\right)$$

Countries with higher capital to labour ratio (K_t/L_t) have higher real wages. The above can also contribute to explain why labour tend to migrate to rich countries, even though we are not going to investigate this point further in this research.

In general, an extensive investigation of every potential determinant of growth[13] - except for trade[14] that is discussed in chapter 6, is outside the scope of our research[15], so we will also concentrate on a process of convergence, that can be explained within the exogenous and endogenous growth models described above. This is illustrated in the next section.

---

[12]See next section

[13]particularly the last point mentioned above - i.e. see alternative models of migration, for example *Harris and Todaro* (1970) or *Ghatak and Daly* (2001); *Ghatak et al.* (2009, 2001) for an application to Eastern European countries.

[14]Note that both Solow-Swan or Arrow-Romer exclude trade in their models and therefore it is not discussed in this chapter.

[15]See Chapter 1.

2.2 Output convergence

The convergence question, emerges naturally from the growth literature; it asks to explain whether countries with different starting levels in per capita income will reduce this gap in the long run. Different models of economic growth, carry different predictions of convergence.

Take the generic production function (2.2) in efficiency units:

$$y = f(k)$$

and assume a Cobb-Douglas production function $f(k) = k^\alpha$ so that:

$$y = k^\alpha$$

In terms of growth rates, this means that:

$$\frac{\dot{y}}{y} = \alpha \frac{\dot{k}}{k} \tag{2.15}$$

where $\dot{y} = \frac{\partial y}{\partial t}$ and $\dot{k} = \frac{\partial k}{\partial t}$

The fundamental Solow equation (2.6), without technological progress ($g = 0$) is given by:

$$\frac{\partial k}{\partial t} = \dot{k} = sy - (\delta + n)k$$

and, dividing by k gives:

$$\frac{\dot{k}}{k} = \frac{f(k)}{k}s - (\delta + n) \tag{2.16}$$

Substituting (2.16) into (2.15):

$$\frac{\dot{y}}{y} = \alpha \left[\frac{sf(k) - (\delta + n)k}{k} \right] = \alpha \left[\frac{f(k)}{k}s - (\delta + n) \right]$$

A graphical representation is given in figure (2.4).

The growth rate $\dot{k}/k$ diminishes as far as $k_1$approaches its steady state value k^*. If we consider two countries with similar structural characteristics we can redraw figure (2.4) as follows (see figure 2.5):

Note that, since:

$$\frac{\dot{y}_1}{y_1} = \alpha_1 \frac{\dot{k}_1}{k_1}, \ \frac{\dot{y}_2}{y_2} = \alpha_2 \frac{\dot{k}_2}{k_2}$$

if $\alpha_1 = \alpha_2$:

$$k_1 < k_2 \Rightarrow \frac{\dot{y}_1}{y_1} > \frac{\dot{y}_2}{y_2}$$

That is, the growth rate of output for the poor country is greater than the rich country.

Figure 2.4: Transition dynamics

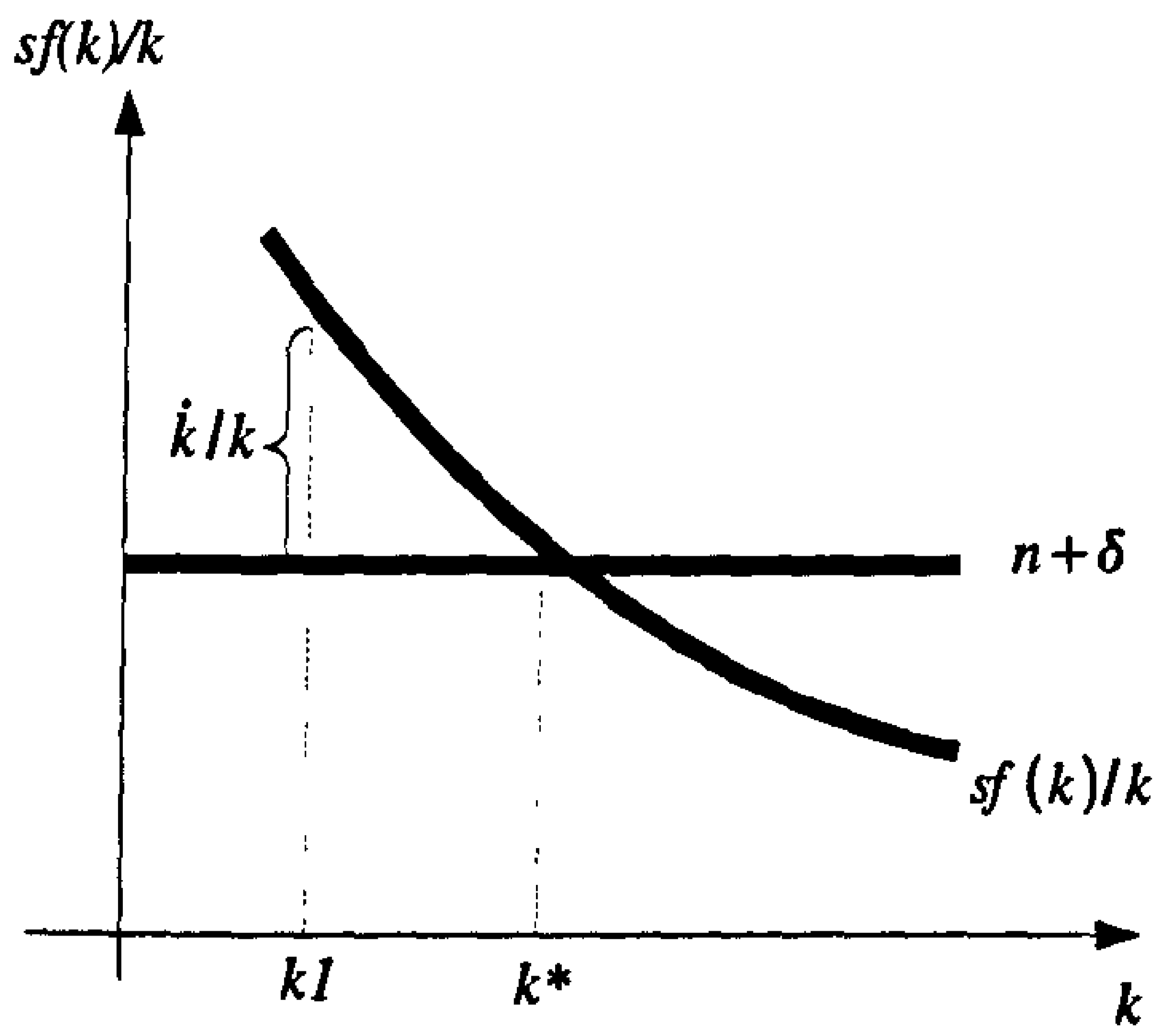


Figure 2.5: Absolute convergence

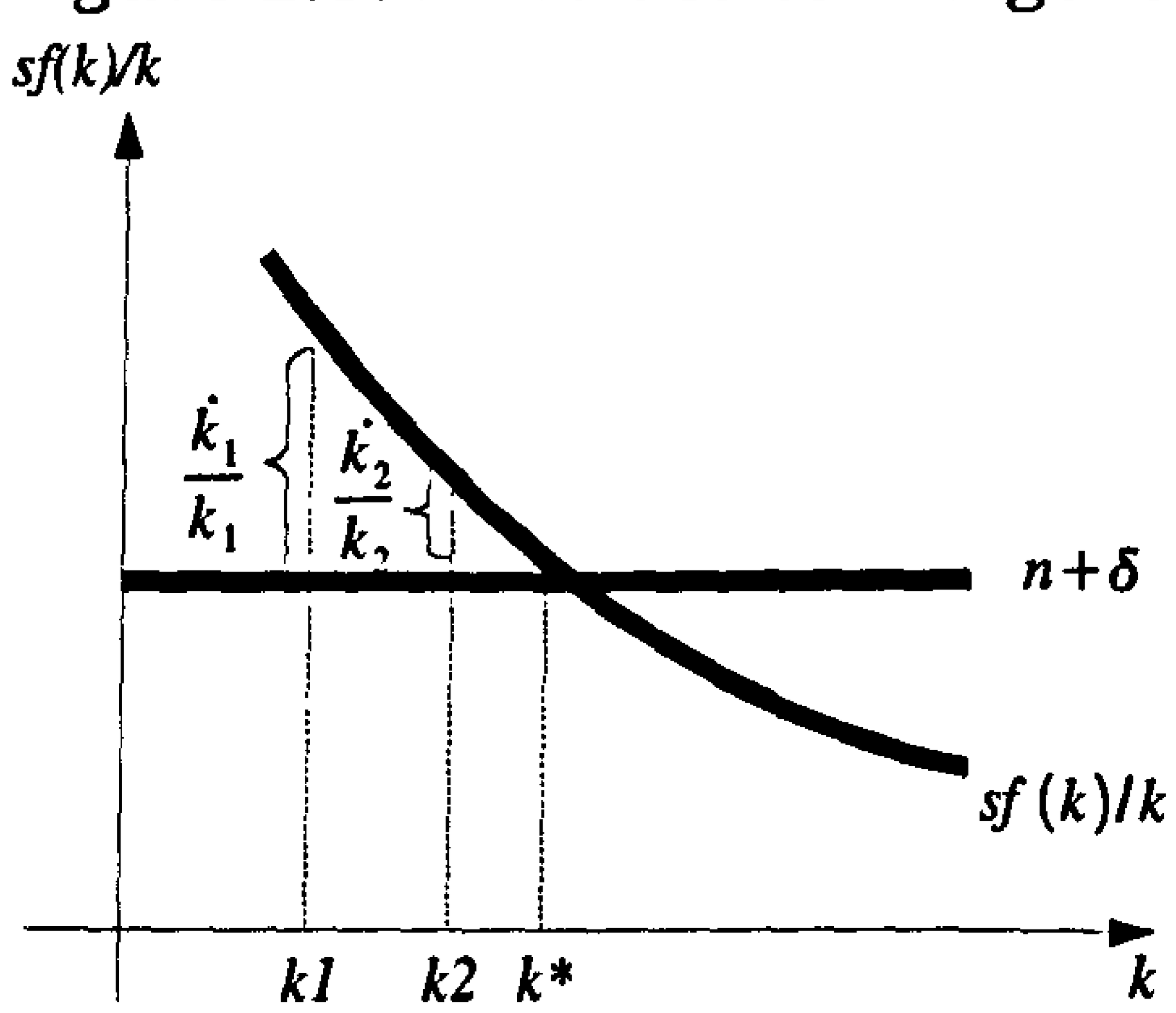
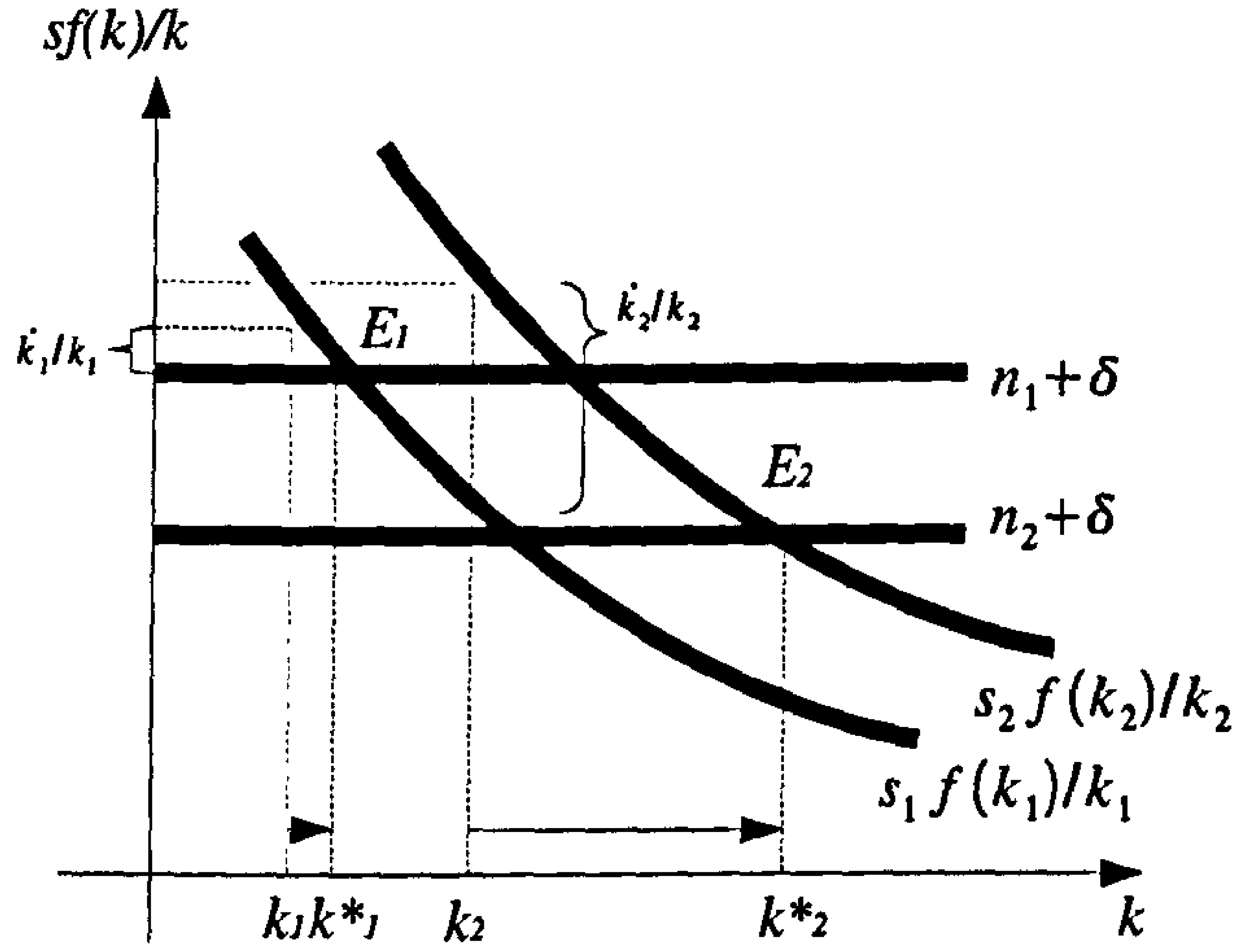


Figure 2.6: Conditional convergence



This condition however is rarely encountered in practice[16], since it assumes two economies identical in their fundamentals. If we allow different structural characteristics then the economies diverge in absolute terms or converge to different steady states. In this case we talk of conditional convergence. Figure (2.6) illustrates.

Note how the poor country has a faster population growth ($n_1 > n_2$) and a lower savings rate ($s_1 < s_2$). The steady state level of capital for the poor country is therefore lower than in the rich country ($k_1^* < k_2^*$) so that the growth of capital is slower in the poor country ($\frac{\dot{k}_1}{k_1} < \frac{\dot{k}_2}{k_2}$). The rich country is diverging from the poor country but both are converging to their own steady states. This mechanism is frequently observed in empirical analysis and it is described among others by *Barro* (1991) and Mankiw (1985)

.

Both absolute and conditional convergence have a stochastic equivalent that is described in chapter 5.

[16]See a for example *King and Rebelo* (1993) or *Durlauf et al.* (2004).

We can also reformulate the problem as a linear approximation around the steady state[17]. Using the fundamental growth equation (2.6), Mankiw and Weil (1992) express the per capita output growth rate $\tilde{y}_t$ in terms of the speed of convergence (λ) and the deviation from the steady state at time t:

$$\tilde{y}_t = g + \lambda(\log y_t - \log y^*)$$
$$\lambda = (\alpha - 1)(\delta + n + g)$$

with y^* : per capita income at steady state.

According to the distance from steady state, we can expect either a constant growth rate equal to the rate of technology g ($\log y_t - \log y^* = 0 \Rightarrow \tilde{y}_t = g$) or a faster/lower rate above/below the long-run path (either $\log y_t - \log y^* > 0 \Rightarrow \tilde{y}_t > g$ or $\log y_t - \log y^* < 0 \Rightarrow \tilde{y}_t < g$).

The same mechanism can be extended to two countries (i, j) sharing the same steady states (y^*) and goes under the name of absolute convergence. Formally:

$$\begin{aligned} \tilde{y}_{i,t} &= g + \lambda(\log y_{i,t} - \log y^*) \\ \tilde{y}_{j,t} &= g + \lambda(\log y_{j,t} - \log y^*) \end{aligned} \tag{2.17}$$

at the initial time $t = 0$, if:

$$y^* > y_{i,0} > y_{j,0} \Rightarrow \tilde{y}_j > \tilde{y}_i > g$$

[17]See appendix for a discussion

In other words, country j is catching-up with i and both are moving (converging) towards the same steady state.

Starting from a Cobb-Douglas, labour augmenting production function of the form $Y = K^{\alpha}(AL)^{1-\alpha}$, it can be demonstrated that, in steady state y_t depends[18] positively on A_t and s and negatively on $(n + g + \delta)$.

As detailed above, this approach to convergence is compatible only with economies sharing the same values for these variables. The popular test for absolute convergence proposed by *Barro* (1991), is based on this framework and assumes a unique steady state and requires the same s, n, δ, g for all economies under investigation.

For economies sharing different steady states, S&S cannot predict convergence. For example, extending our two-countries model (2.17):

$$\begin{aligned} y_{i,t} &= g_i + \lambda(\log y_{i,t} - \log y_i^*) \\ y_{j,t} &= g_j + \lambda(\log y_{j,t} - \log y_j^*) \end{aligned} \tag{2.18}$$

This time, to find out the relation between $\tilde{y}_{i,t}, \tilde{y}_{j,t}$ we should be able to consider not only the two different steady states y_i^* and y_j^* but also the different rates of technical progress g_j, g_i . Whether this might be possible empirically (for individual cases), it is very difficult to generalize and formalize in theory. A possibility is using conditional convergence, modifying the original "Barro' regression" - *Barro* (1991) - which constitutes the basis for β-convergence testing and controlling different steady states. On the empirical side, new methodology to test the convergence

[18] $\log y_t^* = logA_t + \frac{\alpha}{1-\alpha}\log s - \frac{\alpha}{1-\alpha}\log(n + g + \delta)$.

hypothesis have been proposed using time series. The most notable example is *Bernard and Durlauf* (1995) where convergence is defined in terms of the joint statistical properties of GDP per capita series[19] . Although this approach might help to overcome some objective statistical difficulties[20], it contributes only to the quantitative side of the problem but it gives no input to the theoretical debate other than helping with the empirical validation of the models we are analyzing. Some interesting surveys of this approach can be found in *Islam* (2003) , *Durlauf et al.* (2004) and *Cavusoglu and Tebaldi* (2006).

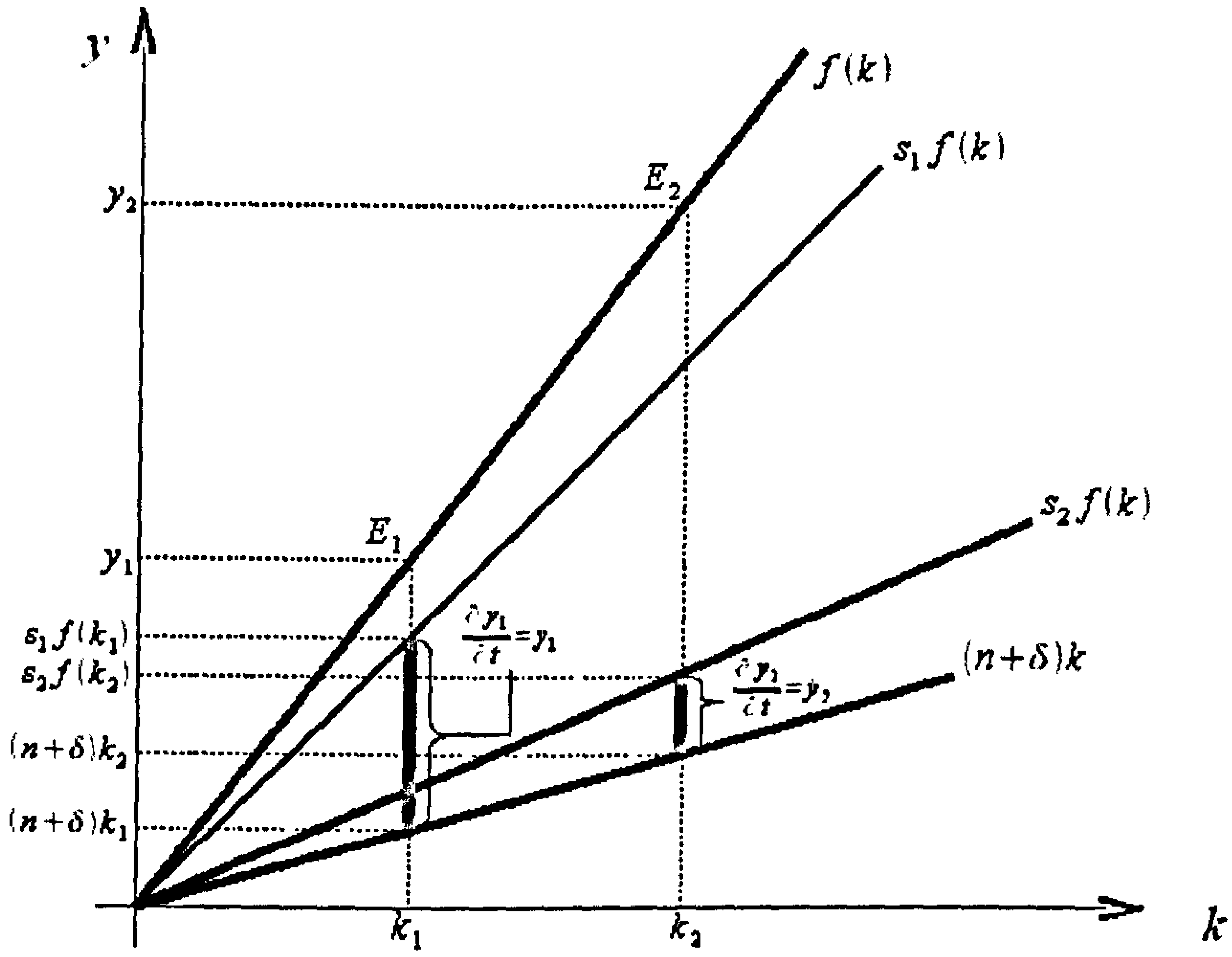
In endogenous growth models, the convergence hypothesis assumes a different meaning. Using the already mentioned Arrow-Romer (AK) model we can arrive at the conclusion that being $\tilde{y}_t$ independent from y_t ; there is no relation between the future growth rates and current per capita income. Since the model assumes constant returns on capital, it lacks the key mechanism through which different economies reduce the gap between different starting levels of per capita income (there is no adjustment to steady state: the economy is indefinitely in steady state - see Figure 2.3). However, a difference in the structural parameters s or n is still able to induce output convergence even in the absence of decreasing returns on capital[21] as explained next. Equilibrium in the AK model, is determined by profit maximisation and the production function is not concave as in Solow as shown in Figure (2.3) with reference to an opti-

[19]Convergence exists when, for a set of countries $i = 1, 2, ..., N$ and for a period of time $t = 1, 2, ..., T$ it is true that $\lim_{p \to \infty} E(y_{1,t+p} - y_{i,t+p} | I_t) = 0$. Where $y_{i,t}$is the GDP per capita of country i at time t.

[20]See for example *Quah* (1995).

[21]A good example is using the permanent benefits coming from integration to achieve convergence targets.

Figure 2.7: Saving rates in the AK model



mal level of $k*$, $y*$. This formulation does not allow poor countries with a lower starting level of capital (in labour units) to grow faster then rich countries[22] unless the structure of their economies is different. For example, if a country has a lower initial level of capital ($k_1 < k_2$) but an higher saving rate ($s_1 > s_2$) their respective equilibria are determined as in figure (2.7).

For the poor country:

$$k_1 < k_2$$

[22]Increases in output are a linear function of increases in capita - i.e. there is no steady state.

$$\frac{\partial y_1}{\partial t} > \frac{\partial y_2}{\partial t} \tag{2.19}$$

even though $y_2 > y_1$.

Note that, accordinig to equation (2.13) and (2.12):

$$\dot{y} = \frac{\partial y}{\partial t} = \frac{\partial k}{\partial t} = \dot{k}$$

$$\frac{\partial k}{\partial t} = sy - (n + \delta)k = sf(k) - (n + \delta)k$$

$$\dot{y} = sf(k) - (n + \delta)k$$

Equation (2.19) compares output first differences, growth rates can be calculated as follows:

$$\frac{\partial y/\partial t}{y} = \frac{\dot{y}}{y}$$

With reference to the economies introduced above, we know that:

$$\dot{y}_1 > \dot{y}_2, \; y_1 < y_2$$

and:

$$y_1 > \dot{y}_1\,,\, y_2 > \dot{y}_2$$

therefore:

$$\frac{\dot{y}_1}{y_1} > \frac{\dot{y}_2}{y_2}$$

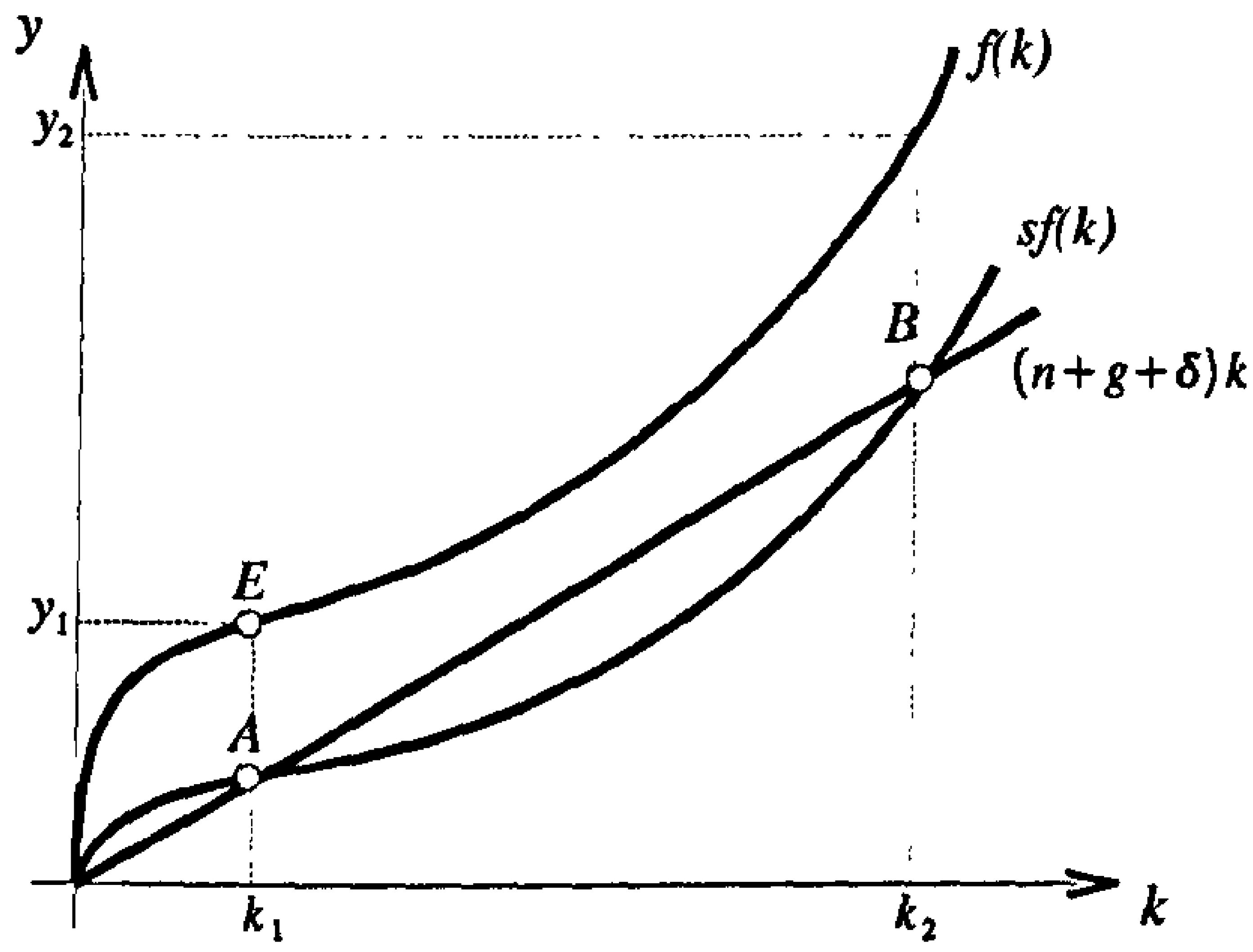
since in the first ratio $\dot{y}_1$ is marginally smaller than y_1, and for the second $\dot{y}_2$ is considerably smaller than y_2.

Growth is faster in the poor country so more capital is accumulated at every round up to the point where as $k_2 = k_1$ for which the production of the second country will be exactly the same as the first. In this sense the poor country is catching-up. The point however is that, because there are no diminishing returns to capital and the saving rate is higher the once poor country will continue to grow faster than the other country leaving it behind[23] in the long run. Notice how the same result can be obtained with different population rates as the size of n determines the slope of the function $(n + \delta)k$.

More recently, new endogenous growth models have been developed in order to support the convergence hypothesis even in economies with the same structural characteristics. The key element consist in relaxing the constant MPK assumption (replacing diminishing returns) therefore being able to rely on transitional dynamics. The first formalization of this

[23]Notice that this country will not be able to compensate because the acceleration is driven by - exogenous - savings and, as such, is independent from the level of capital - i.e. it is not the fact of being poor but having a higher propensity to savings.

Figure 2.8: A mixed production function



idea can be found in *Jones and Manuelli* (1990). Their aggregate production function incorporate some neoclassical elements through the following formulation:

$$Y_t = F(K_t, L_t) = A_t K_t + \Omega(K_t L_t)$$

where $\Omega(K_t L_t)$ exhibit positive and diminishing marginal products and constant returns to scale while $A_t K_t$ is the endogenous part. Figure (2.8) illustrates.

2.3 The new members' perspective

Since one of the likely consequences of the 5th European enlargement is an higher level of integration between its old and new member states, at the end of this chapter we briefly discuss the implication of integration for growth and convergence as emerging from the theoretical models we introduced in section 2.1. The Solow-Swan model and Arrow-Romer reach opposite conclusions[24] when considering economic integration. In the exogenous (S&S) view, economic growth does not benefit from integration in any particular way, whilst this conclusion is challenged by the endogenous perspective. *Cuaresma et al.* (2008) effectively summarize the meaning of the two approaches in the context of EU integration. Although in that case the focus is restricted to the EU15 country members, we can safely extend it to the enlarged EU25. In Solow-Swan the population growth rate is assumed constant and growth is generated only through the exogenous rate of technological change (g). In such conditions, economic policy is completely ineffective in the long run and so is any hypothetical integration. The reallocation of resources is only temporary (technology is common to all countries), while the economy expands over its steady state growth path. If we ask the question of whether economic growth in Europe is integration-enhanced, the answer of the neoclassical model is negative, though we must expect perfect convergence in per-capita income in levels. Such a conclusion is contested by the endogenous growth model. In fact, the assumption of exogenous technology is relaxed and it is now subject to the decision making process of individual firms although knowledge spillovers prevent the full[25] accumulation of monopoly rents[26] resulting from new inventions. In other words, the

[24]It does not appear sensible, at least at this stage, to go back to classical theories, which pose the basis but is largely encompassed in many of its conclusions by the neoclassical theory. The only sensible argument in favor of a classical analysis, seems to disaggregate the effect of land among the factors of production, which can make limited sense when considering rural economies.

[25]The effect is only temporary but at the same time is the stimulus for firms to new research activity.

[26]The idea of firms profiting from short term monopoly rents is introduced here for the first time, with little concern about potential losses in the clarity of exposition, as it

technological progress depends on individual research activities. In this sense, a larger, integrated bloc, has positive effects on growth. A larger population means a larger market and increased monopoly rents which, although not lasting in the long run, give the opportunity to firms to invest in new research at no extra cost[27] . At the same time, the increased research activity generates higher spillovers (accommodated by the positive effect of new infrastructures) in the integrated economies, contributing to increased capital accumulation. The result is that the long-run growth rate in an individual country strongly benefits from the integration and enlargement processes[28] . The same conclusion applies to the European Union: the larger its size, the greater the incentive towards new research and development (R&D), and the higher its growth rate in the long run. On the empirical side, studies exist to validate the predictions of both models. *Ben-David and Papell* (1995) propose a distinction between neoclassical and endogenous economic growth models settled in terms of the stochastic properties of the output. The influential study of *Mankiw et al.* (1992) focus on S&S and it largely agrees on its conclusions. At the same time *Mankiw et al.* (1992) proposes an augmented version of the neoclassical model[29] which accommodates a not-so-realistic capital share of factor income. The advantage is that, empirically, the validation methodology can be extended to different growth models - see *Bernanke and Gurkaynak* (2001) on endogenous growth. However, the

appears a natural consequence of the framework described in section 2.1.2.

[27]We assume the cost of new research is not dependent on population

[28]The same conclusion, marking the difference between S&S and A&R, is expressed in a formal way in chapter 2.1 through equation (2.14)

[29]The major contribution being the inclusion of human capital alongside phisical captial.

theoretical predictions do not change. Other studies examine specifically the benefit of EU integration and as such, refer to the endogenous growth model[30]. An exception is *Vanhoudt* (1999) testing the S&S hypothesis of no long-term influence of integration on growth. Comparing with a set of countries outside the EU and using panel data techniques, he reaches the conclusion that the neoclassical hypothesis cannot be rejected for the current member states[31] .

In this situation of general lack of empirical consensus and objective difficulty of understanding whether or not integration is asymmetrically growth enanching[32] , we note a series of further open matters. We believe these make sense in the theoretical framework we have analyzed above and are particularly relevant for the practitioners when dealing specifically with the EU enlargement:

Time. One of the major difficulties when analyzing enlargement related issues is time. The neoclassical growth is able to capture transition dynamics, so it can be more informative to interpret empirical results.

Spillovers. Arrow and Romer (AK) assume free spillovers. It can be a very restrictive assumption for accession countries[33].

Labour mobility. Countries with lower capital (K/L) tend to have lower

[30]See for example Landau (1995)

[31]Being a pre-enlargement study the focus here is on EU15 with no consideration of accession countries if not as foreign economies.

[32]i.e. more beneficial for poor countries so that they grow faster than (or converge to) rich countries.

[33]One of the hypothesis we try to address in this research is whether trade can be an important vector for growth in the new members of the European Union - see chapter 5. If this is the case it may be reasonable to think that the increased volume of transactions motivated the occurence of spillovers.

wages stimulating people to move from one country to another. Considering the effect of migration can be sensible for accession countries (especially if substantial differences in capital exist) and, eventually, have an impact on long run convergence through n and the determination of the steady state.

Integration. The Arrow-Romer (AK) model, does not allow for convergence, other than through integration. Other than referring to a modified theoretical model it can be very important to assess the determinants of a successful integration process. Infrastructures can play a significant role.

Steady state. In the neoclassical perspective, it can be interesting to establish whether accession countries are near steady state or dominated by transition dynamics. This is usually done by assuming that a fast speed of convergence[34] is a sign of proximity to steady state. Furthermore, in a multicountry analysis it can be important to establish whether they are sharing the same steady state. In the presence of different conditions on n, g, δ the answer appears negative.

2.4 Conclusion

This chapter investigated the theoretical foundations of the convergence hypothesis. We have seen how alternative growth models have different answers to the question of whether economies with different initial level

[34] Both the "Barro' regressions" - see *Barro and Sala-I-Martin* (1992), and tests for cointegration - see *Bernard and Durlauf* (1995), allow to compute it empirically.

of output will reduce their gap in the long-run. In the case of economies sharing the same structural characteristics, the neoclassical hypothesis of diminishing returns to the factors of production alone, is sufficient to explain this process. Once technology is endogenized, learning by doing and spillover effects induce constant returns making it impossible for economies sharing the same structural characteristics to catch-up if starting from different levels of output[35]. For this reason, empirical tests of the convergence hypothesis are traditionally founded on the Solow-Swan model. This is a convenient choice in practice, but not exhaustive in a policy environment. During the chapter we assessed the strength and weakness of both model. In particular we noted two critical areas that motivate the remaining of our analysis: the existence of steady states & short/long-run catching-up dynamics, the effects of trade & integration on growth. With these considerations in mind, we have a look at the institutional background of the EU enlargement (chapter 3) so that we can then progress to to our empirical investigation of convergence in chapter 4.

2.5 Appendix

This section, written as an appendix to the framework developed within the chapter, formalises the concepts of learning by doing and per-capita output in the Arrow-Romer model and the derivation of the speed of con-

[35]We have also analyzed the case of dissimilar economies in terms of n, δ, g, noting that in this particular circumstances catching up is possible even within the Arrow-Romer model.

vergence in the neoclassical model.

Learning by doing

Given the stock of knowledge of the firm i at time t, $A_{i,t}$:

$$\theta = \frac{\partial \log A_{i,t}}{\partial \log(K_t/L_t)}, \theta > 0$$

Rearranging, in levels:

$$\int \partial \log A_{i,t} = \theta \int d \log \left(\frac{K_t}{L_t} \right)$$

hence:

$$\log A_{i,t} + \log \mu = \theta \log \left(\frac{K_t}{L_t} \right) + \log \eta$$

where the integration constants $\log \mu$ and $\log \eta$ are expressed in logarithms for convenience.

$$\log A_{i,t} = \theta \log \left(\frac{K_t}{L_t} \right) + \log(\mu/\eta)$$

$$A_{i,t} = \xi \log \left(\frac{K_t}{L_t} \right)^{\theta}, \theta > 0$$

where $\xi = \mu/\eta$.

Per-capita output in the A&R model

Given the aggregate, Cobb-Douglas, production function:

$$Y_t = K_t^{\alpha}(A_t L_t)^{1-\alpha}$$

we define:

$$y_t = \frac{Y_t}{L_t} = \frac{K_t^{\alpha}(A_t L_t)^{1-\alpha}}{L_t} = K_t^{\alpha} A_t^{1-\alpha} L^{-\alpha} = \left(\frac{K_t}{L_t}\right)^{\alpha} A_t^{1-\alpha}$$

Given that:

$$A_t = \xi \left(\frac{K_t}{L_t}\right)^{\theta}$$

Substituting:

$$y_t = \left(\frac{K_t}{L_t}\right)^{\alpha} \left[\xi \left(\frac{K_t}{L_t}\right)^{\theta}\right]^{1-\alpha} = \left(\frac{K_t}{L_t}\right)^{\alpha} \xi^{1-\alpha} \left(\frac{K_t}{L_t}\right)^{\theta(1-\alpha)} =$$

$$= \xi^{1-\alpha} \left(\frac{K_t}{L_t}\right)^{\alpha+\theta(1-\alpha)} = a\hat{k}_t^{\alpha+\theta(1-\alpha)}$$

where $a = \xi^{1-\alpha}$and $\hat{k}_t = \frac{K_t}{L_t}$.

Deriving the speed of convergence[36]

The Taylor expansion of a generic function $h(k) = g(e^k)$ around $\ln(k*)$ is given by:

$$h(k) \sim h[\ln(k*)] + h'[k - \ln(k*)]$$

Therefore, if we define:

$$\bar{k} = \ln(k) - \ln(k*)$$

then:

$$g(k) = h[\ln(k)] \sim g(k*) + k * g'(k*)\bar{k}$$

or by substitution:

$$g(k) \sim g(k*) + k * g'(k*) \ln(k/k*) \tag{2.20}$$

Now, from equation (2.6) we know that:

$$\dot{k} = \frac{\partial k}{\partial t} = sf(k) - (\delta + n + g)$$

[36]For simplicity, we remove the time subscript to all variables in this section.

dividing by k:

$$g(k) = \frac{\dot{k}}{k} = s\frac{f(k)}{k} - (\delta + n + g) \tag{2.21}$$

Our target is to approximate equation (2.21) around the steady state where we know from equation (2.7) it is zero:

$$\frac{\partial k}{\partial t} = 0 \Rightarrow \frac{\partial k/\partial t}{k} = 0 \tag{2.22}$$

Using a Cobb-Douglas production function such as $f(k) = k^{\alpha}$ and substituting into (2.21):

$$\frac{\dot{k}}{k} = \frac{s\dot{k}^{\alpha}}{k} - (\delta + n + g)$$

$$\frac{\dot{k}}{k} = sk^{\alpha}k^{-1} - (\delta + n + g)$$

$$g(k) = \frac{\dot{k}}{k} = sk^{\alpha-1} - (\delta + n + g) \tag{2.23}$$

Therefore:

$$g'(k) = (\alpha - 1)sk^{\alpha-2}$$

At steady state:

$$g'(k*) = (\alpha - 1)sk*^{\alpha-2}$$

Multiplying by $k*$:

$$k * g'(k*) = (\alpha - 1)sk *^{\alpha-2} k*$$

$$k * g'(k*) = (\alpha - 1)sk*^{\alpha-1} \quad (2.24)$$

At $k*$ we also know from (2.22) that:

$$g(k*) = \frac{\dot{k}}{k} = \frac{\partial k * /\partial t}{k} = 0 \quad (2.25)$$

so using (2.23):

$$sk^{\alpha-1} - (\delta + n + g) = 0$$

$$sk^{\alpha-1} = (\delta + n + g) \quad (2.26)$$

which we can substitute into (2.24) to get:

$$k * g'(k*) = (\alpha - 1)(\delta + n + g) \quad (2.27)$$

Finally, substituting (2.25) and (2.27) into (2.20):

$$g(k) = \frac{\dot{k}}{k} \sim 0 + (\alpha - 1)(\delta + n + g)\ln(k/k*)$$

For Cobb-Douglas production functions, we also know from (2.14):

$$\frac{\dot{y}}{y} = \alpha\frac{\dot{k}}{k} \Rightarrow \frac{\dot{y}}{y} = \alpha g(k)$$

$$\frac{\dot{y}}{y} = \alpha(\alpha - 1)(\delta + n + g)\ln(k/k*) = (\alpha - 1)(\delta + n + g)\ln\left[(y/y*)^{\frac{1}{\alpha}}\right]$$

$$\frac{\dot{y}}{y} = \frac{\alpha(\alpha - 1)}{\alpha}(\delta + n + g)\ln(y/y*)$$

$$\frac{\dot{y}}{y} = (\alpha - 1)(\delta + n + g)\ln(y/y*)$$

which we can rewrite as:

$$\frac{\dot{y}}{y} = \lambda\left[\ln(y) - \ln(y*)\right] \qquad (2.28)$$

with:

$$\lambda = (\alpha - 1)(\delta + n + g)$$

We call λ the speed of convergence. Note also that the model is expressed in continuos time but it safely approximable to a discrete time equivalent when s and g are small[37].

[37]This is usually the case in practice.

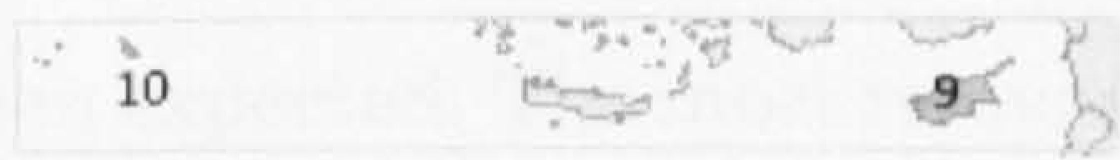
Chapter 3

Data sources and institutional background

THE convergence hypothesis has been tested extensively, sometimes across world economies and sometimes within selected national economies (e.g. the United States). Recent political events have introduced a need for exploring it more carefully in Europe. Specific policies have been already implemented to actively stimulate convergence, so it is important that we have a better perception of their effectiveness so far. This chapter looks into what has been done on the institutional side and what can potentially make the assessment of these policies a particularly challenging exercise.

Figure 3.1: Country codes

Country	PWT	Eurostat
1	EST	EE
2	LVA	LV
3	LTU	LT
4	POL	PL
5	CZE	CZ
6	SVK	SK
7	HUN	HU
8	SVN	SI
9	CYP	CY
10	MLT	MT



Notes: PWT, Penn World Tables 6.2

3.1 Historical background

It is not easy to build a clear picture of the criteria and policies imposed to guide the convergence between the block of current EU members (EU15) and the first group of countries involved in the so called "eastern enlargement" (NMS10[1]) [2].

On the institutional side, the European Council, supported by the European Commission is responsible for taking decisions on the relevant policies. Convergence criteria, in relation to enlargement, were set at the Copenhagen European Council 1993 (Copenhagen Criteria[3]) and rati-

[1]We are concerned with the countries involved in the 5th enlargement, joining the European Union on May 2004: Lithuania, Latvia, Estonia, Slovakia, Czech Republic, Poland, Hungary, Slovenia, Cyprus and Malta.

[2]These are represented in figure (3.1) together with the country codes we are going to use in this thesis. Note that Eurostat developed its own Nomenclature of Territorial Units for Statistics (NUTS) classification in 1988 and adopted it in 2003 - see e.g. Regulation (EC) No 1059/2003 of the European Parliament and of the Council. Penn World Tables uses different three-digit codes, given the large number of countries included in their database.

[3]Stability of institutions guaranteeing democracy, the rule of law, human rights and

fied during the Madrid Council, 1995. Unlike the detail of the Maastricht treaty, the definition was loose, causing not a little criticism. *Inotai* (1994) stated that the only formal criteria to be applied as requisite for accession was the very fact of being a "European" country[4] (art. 237, Treaty of Rome). In practice, part of the requirements were set in the four enlargements leading to EU15[5] from the union's foundation (1952). The central argument remained that previous phases were decided purely on a political basis. From that point onward, the path toward convergence developed easier than might have been expected. The most relevant steps follow: White Paper for the transition economies (1995) - see European *European Commission* (1995)[6] , Agenda 2000 (Luxembourg, 1997[7]) up to the final ratifcation of the Accession Treaty 2003 (Luxembourg, 2003) and Accession Treaty 2005. The NMS10 joined the EU on May 2004 and 1st January 2007 became the official date for the accession of Romania and Bulgaria. The central economic criteria for enlargement, as emerging from the documents above, can be summarized by the following targets::

respect for and protection of minorities; The existence of a functioning market economy as well as the capacity to cope with competitive pressure and market forces within the Union; The ability to take on the obligations of membership including adherence to the aims of political, economic & monetary union. See (European Council 1993).

[4]Plus the exercise of tracing the geographical eastern European boarder was considered a very subjective political decision once again.

[5]In chronological order: 1973 EU6; 1981 EU9; 1986 EU12; 1995 EU15.

[6]Examined by the European Parliament 17/4/1996

[7]The European Council meeting in Luxemburg (1997) pushed the process of "accession and negotiation" throughout the denition of "Accession partnerships" and an "Increased pre-accession aid" program. Furthermore, it set the guidelines of individual accession strate- gies and launched Agenda 2000. The latter was intended as a six-years plan concerning the development of the EUs policies and its future nancial framework. The specic target was to ensure that the EU15 were in a sound position to cope with the upcoming enlargement.

- Price stability.
- Sustainable government finance.
- Stable exchange rates.
- Convergence of long-run interest rates.

Instead of relying exclusively on a centralised policy, the easiest way to promote convergence, seemed to let new member states implement national policies to achieve the targets listed above. However, the ambition was also partially supported at the aggregate level by the development of CEFTA (Central European Free Trade Area). CZ, SK, HU, PL were among the first group of countries joining in 1993 (soon after CZ/SK independence) followed by Slovenia in 1996 and all the remaining new members. We note however, that most of these policies were used to guide nominal rather than real convergence. As such, in our research and the framework introduced in chapter 2, output is sensible only to a subset of these enlargement criteria and - for example - we will take for granted the stability of prices and exchange rates[8].

Moreover, there was not and still is no broad consensus as to what the optimal policies for targeting the convergence criteria should be. Some countries felt that letting the market economy work without any external intervention would run the risk of not integrating the eastern block with the rest of Europe[9]. Looking at the future, it is even likely that

[8]In chapter 4 we will calculate output at constant prices and exchange rates. For a discussion of the the empirical relevance of real convergence on the process of nominal convergence see *Lein et al.* (2008).

[9]We will see later how convergence within the eastern block appears slightly stronger than with the rest of EU15.

new directions will be explored to accommodate what, now is a strong implication of the EU enlargement for its new member states: joining the European Monetary Union (EMU). Until recently, the most natural possibility - although not formally expressed in the Accession Treaties - was the adoption of the Maastricht criteria. At present this prospect seems unlikely and an alternative strategy may be necessary, in a more complex world, with stronger regional differences. Understanding convergence in the post-soviet era has become crucial and, apart from the strong influence the EU may have had on the accession countries, there are strong national questions to be addressed too. In this context, the lack of strict criteria is not necessarily seen as a weakness but makes it interesting to see if economic convergence between old and new members followed the political enlargement. This is precisely the point of view of this research: verify the final[10] effect of the european policies implemented up to this point regardless of their original objective. Time series techniques, which we will discuss in detail later, prove particularly suited for the task. Policies with a high degree of subjectiveness can be difficult to relate to a specic theoretical framework. The risk of mis-specifying a potential model is therefore high, especially when data sources are not fully reliable[11] too.

[10]i.e. in terms of real growth differential among countries.
[11]See section 3.3.

3.2 The state of convergence in the European Union

The first[12] and second[13] stage of the 5th EU enlargement finally took place in 2004 and 2007, more than a decade after the first agreements were signed with most of the new members, as detailed by Table (3.1).

Some of the new EU states are currently in a situation where in many cases a plan for introducing the Euro is in place and a preliminary date for joining the Euro area has been set. A decision on whether or not to join will be required in a few years time. But staying inside the EU and in particular the Euro area requires a certain level of convergence among the member states[14]. A likely possibility is that the countries in question will be assessed by EU authorities as to whether they meet the determined criteria for entering the next stage of the economic and monetary union (EMU). An analysis of the development in nominal and real convergence of economies including comparison is therefore highly relevant and necessary. Figure (3.2) gives a preliminary sense of the dynamics of GDP per capita[15] in eight[16] new members.

[12]See countries in Figure (3.1).

[13]Bulgaria and Romania. The first enlargement was in 1973 (Denmark, Ireland and United Kingdom). The reunification of Germany is understood as an enlargement sui generis.

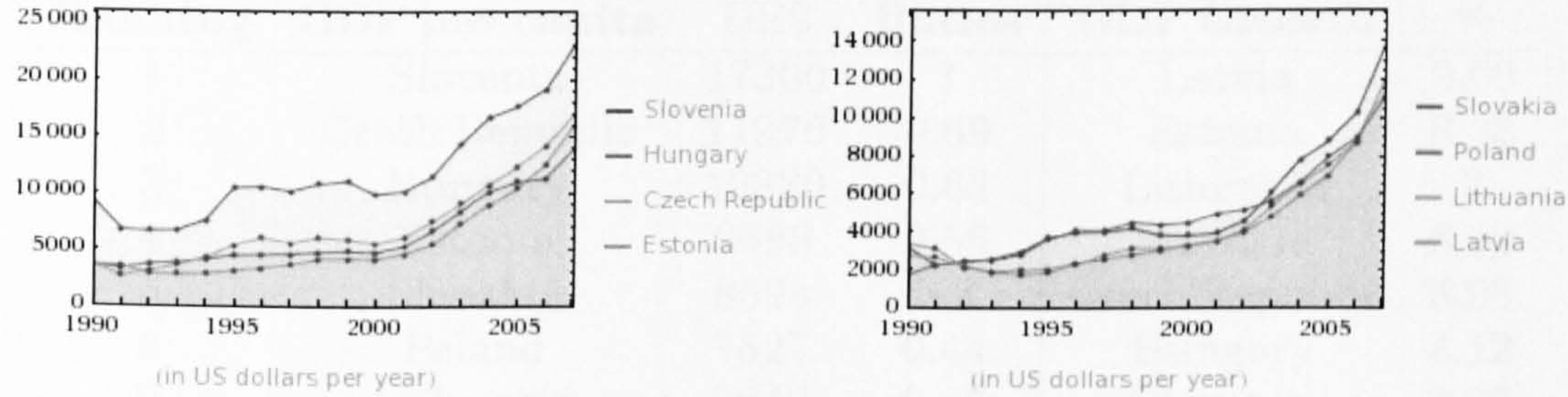
[14]Slovenia has just adopted the common currency and it is 13th member of the Euro area (there has been twelve member states prior 2007).

[15]At this stage the value of GDP is calculated at market prices, we are going to correct

Table 3.1: EU Enlargement Chronology

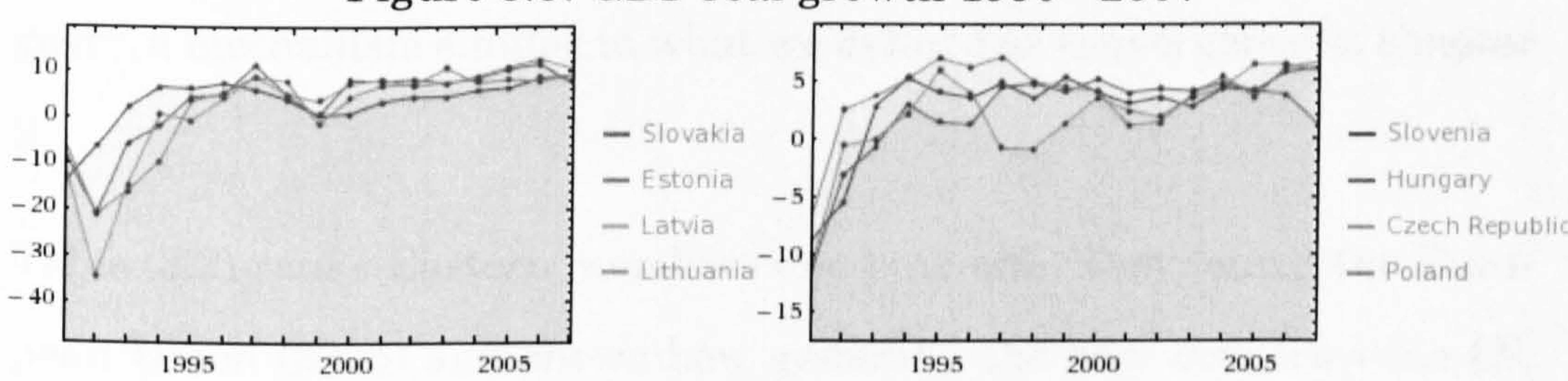
	Agreement signed	**Came into force**	**Application**	**Joined**
Bulgaria	March 1993	February 1995	December 1995	January 2007
Czech Republic	October 1993	February 1995	January 1996	May 2004
Estonia	June 1995	February 1998	November 1995	May 2004
Hungary	December 1991	February 1994	March 1994	May 2004
Latvia	June 1995	February 1998	October 1995	May 2004
Lithuania	June 1995	February 1998	December 1995	May 2004
Poland	December 1991	February 1994	April 1994	May 2004
Romania	February 1993	February 1995	June 1995	January 2007
Slovakia	October 1993	February 1995	June 1995	May 2004
Slovenia	June 1996	February 1999	June 1996	May 2004
	Agreement signed	**Came into force**	**Application**	**Joined**
Turkey	September 1963	December 1964	April 1987	-
Malta	December 1970	April 1971	July 1990	May 2004
Cyprus	December 1972	June 1973	July 1990	May 2004

Figure 3.2: GDP per capita 1990 - 2007



Source: Wolfram, Country Data 2009

Figure 3.3: GDP real growth 1990 - 2007



Source: Wolfram, Country Data 2009, % change from previous year.

Looking at growth rates, gives a sense of the effect of market liberalisations in the early 90s and the strong acceleration from 1995 to 2007. This makes the period 1990 - 1995 less representative[17] of the transition path towards the old EU members and it will be excluded from our analysis. Figure (3.3) illustrates[18].

Ranking the countries by GDP per capita and growth rates seems to sug-

this issue later in our analysis.

[16]In this chapter we discuss only the eight new EU member states since the mediterranean countries Cyprus and Malta are somewhat different both in terms of economic indicators (structural characteristic of their economies) and past political experiences. The newcomers Bulgaria and Romania are not included in our analysis due to data problems.

[17]It is often seen as a short-run fluctuation following a radical change in the structure of most of the ex-soviet economies.

[18]Note here we are representing total GDP rather than per capita, so that the growth reates are not inflated by the general decline in population that affects eastern european countries.

Table 3.2: Rankings (GDP per capita & growth)

Ranking	GDP per capita	US$	Ratios	GDP Growth	%
1	Slovenia	17300	1	Latvia	9.09
2	Czech Republic	11970	0.69	Estonia	8.38
3	Hungary	10820	0.63	Lithuania	7
4	Estonia	9598	0.56	Slovakia	6.12
5	Slovakia	8594	0.5	Czech Republic	5.95
6	Poland	7527	0.44	Hungary	4.12
7	Lithuania	7247	0.42	Slovenia	3.87
8	Latvia	6608	0.38	Poland	3.24

Source: Wolfram, Country Data 2009, *Values one year after joining the EU* (2005 per capita, 2004/05 % change).

gest[19] a mechanism similar to what we defined as convergence in chapter 2.

Table (3.2) ranks Eastern members one year after they joined the European Union (2005) and shows how generally the poor countries (i.e LV, LT etc...) were growing faster than the rich (i.e. SL, HU etc..) .

As detailed in the previous chapter, a number of new approaches explaining this convergence phenomena have been presented over the last two decades. Modern concepts of the endogenous growth theory have been developed to reflect a range of additional up to now neglected factors, such as education of the population, institutional quality, etc. One permanent status for otherwise identical economies cannot exist due to these dissimilar qualities. These models can provide a theoretical description of empirically documented development of economies with a broader gap in the economic level that grow faster than others. Some countries grow faster than others in spite of the achieved higher economic standard, while others may continue to lag behind - see e.g. *Barro and Sala-i Martin* (1992). There has also been a significant amount of applied research examining

[19]Rank correlation is -0.84 excluding Poland, -0.52 otherwise.

the real convergence in both developed and developing countries - for review see e.g. *Matkowsky and Prochniak* (2004). The most recent ones are e.g. *Kocenda et al.* (2006) or *Dobrinsky et al.* (2006). We can identify three main strands in the recent literature focusing on real convergence in Central and Eastern European economies.

The first strand works with long-term GDP series employing either standard measures of sigma and beta convergence - e.g. *Matkowski and Prochniak* (2007) - or the time-series approach – e.g. *Bruggemann and Trenkler* (2005). Such studies utilise data for the post-war period or longer.

The second stream takes a broader prospective, testing convergence of several economic indicators - such as industrial production in *Kutan and Yigit* (2004) or *Kocenda* (2001) - and usually employs time series analysis.

The third group of studies specifically looks at eastern european countries in the post-liberalization period. *Dobrinsky* (2003) and *Matkowsky and Prochniak* (2004) focus on the new member states of the European Union while *Kocenda et al.* (2006) on the NMS8 against the core or periphery of the EU. A comprehensive review is available in the last paper or in *Matkowski and Prochniak* (2007).

The conclusions reached by different authors within the three groups identified above are mixed. *Matkowsky and Prochniak* (2004) found a relatively fast convergence process in the NMS8 countries during the period 1993-2004 and for the sub-periods 1993-1998 and 1998-2004 with a speed of convergence varying within the narrow band 1.7 % - 2.7 %.

For the NMS8 and EU15 regions, the band is found to be even narrower at 2.2% - 2.5%. A potential problem may be the inclusion of the early years of the transition (1993-1994) which may bias the results mentioned above, in particular reducing the speed of convergence.

Kocenda et al. (2006) focused on real and nominal convergence in NMS8 in relation to the average GDP per capita in the core (Austria, Belgium, France, Germany and the Netherlands) and periphery of EU (Greece, Portugal and Spain). They used quarterly GDP both in national currency and in Euros (1996-2005). The best performance in terms of speed of convergence is associated with the Baltic states which however does not appear strong enough to shrink the GDP gap in Euro terms.

Kutan and Yigit (2004) tested real and monetary stochastic convergence[20] for selected transition countries over the period 1993-2001. They used industrial production (monthly time series) as a proxy of real convergence in order to capture both potential supply and demand shocks. Their findings do not confirm the existence of real convergence between the new and old EU members. Our research differs in the choice of target variables[21], sample size, data frequency and time-series tests for convergence.

Kocenda (2001) has a very similar approach including real and nominal convergence, industrial production and monthly time series covering the period 1991-1998. The conclusion is in favour of a strong decline in output during the first part of the sample and then surprisingly high growth

[20]For a definition, see chapter 4.

[21]We look at per-capita output and use the EU average instead of Germany as a benchmark - see chapter 4.

rates in the second. We suspect this behaviour to be biased by the inclusion of the beginning of transformation process (early 90s).

Dobrinsky (2003) studied real and nominal convergence and the linkages between them. Real convergence is measured in GDP per capita (PPP) with the help of growth accounting (Solow residual), for the period 1990-2003. The major conclusion of the paper is that the robust real convergence in CEE and CIS countries is supported by strong growth in total factor productivity.

Summarising, the process of real convergence is seen by these authors as an important issue which should be discussed in greater detail than has been done so far, and we will follow up this conclusion in the next chapters.

3.3 On data sources and their reliability

The lack of consistent sources and the questionable quality of data for Eastern European transition countries is a well known[22] fact[23] . On a closer analysis, difficulties do not arise from strong methodological deficiencies or organisation problem at the institutional level, rather, questions concerning data reliability are a consequence of the particular political history of these economies. The countries we consider each have their

[22]See for example *Powers* (1992) surveying the U.S. Bureau of Labor Statistics/Eurostat Conference on Economic Statistics for Economies in Transition: Eastern Europe in the 1990's.

[23]This is also the main reason, why it is highly questionable, whether one should try to analyse development in EU-8 countries prior 1990.

individual historical experience and institutional detail but, for an initial consideration of data issues, we can usefully distinguish five groups:

- Baltic republics/former USSR: Estonia, Lithuania, Latvia.
- Former Czechoslovakia: Czech republic, Slovakia.
- Former Yugoslavia: Slovenia
- Islands: Malta, Cyprus
- Others/ex soviet influence: Poland, Hungary, Bulgaria, Romania

Except for the last two groups, most of the nations considered gained independence in recent times (mostly in the early 90s) and were to various degrees connected with the Soviet regime. From a statistical perspective, this means that before this date data collection was centralized and regional data not always easily available. A few relevant examples include, the USSR (Goskomstat of USSR[24]) in or the Federal office of statistics for Yugoslavia and the Federal Statistical Office[25] in Slovenia.

In the specific case of the USSR, the low availability and high statistical discrepancies lead these data to be widely considered to be of poor quality. See for example *Nakamura* (1998) and *Basdevant* (2000). The post independence years saw the birth of several new national institutions responsible for managing economic statistics allowing for a degree of precision once available on regional basis. This new change in "focus" however

[24]Goskomstat of USSR 1991 - 1987, Central Statistical Board before 1987
[25]Federal Statistical Office 1969 - 1993, State Statistical Office before 1969

came at a cost. The implications of this period of institutional transition, other than an objective difficulty in obtaining old datasets from no-longer-existing ex-soviet institutions, can be grouped into two categories: "very frequent revisions of available datasets" and "shifts/breaks in time".

To give a sense of the problem, we look at international and national statistical institutions dealing with eastern european EU members. United Nations (UN), The International Monetary Fund (IMF) and Eurostat provide a wide range of statistics. All databases have strengths and weakness.

The UN Common Database covers a wide selection of countries on annual frequency and offers some of these in the freely available National Account Database. All data are usually accessible in electronic form. Before 1990s aggregated data are provided for former USSR, Yugoslavia and Czechoslovakia, at least up to 1971. Eurostat (former New Cronos, now freely accessible) database is strong with quarterly data up to 1995 for individual central European economies. The period 1989 - 1990 is critical since for some economies national institution were still too young to implement the procedure needed for collecting data at high frequencies. The annual equivalents are available through UN. In 1995 Eurostat adopted a common procedure known as ESA95 making the data comparable across countries[26]. For real GDP this means 10 years of quarterly data for any economy among the 11 involved in the enlargement. These data sets are particularly useful, and well suited to be used with panel

[26]See *Eurostat* (1997).

data techniques[27] or to investigate convergence. Successful examples exist in the literature - see e.g. *Yigit and Kutan* (2004), successfully used quarterly datasets (GDP per capita) for 8 selected accession countries for the period 1993 - 2002. The inclusion of Slovenia and Cyprus shifts the beginning of the sample to 1995 but without compromising the total number of observations, since data up to 2008 are available at present time.

An alternative to the use of international databases is relying on national sources. For the period 1995 - present this is usually not very effective since a strong coordination with Eurostat (in the prospective of EU accession) resulted in almost duplicate databases for a specic set of new accession countries.

The post-communist countries[28] had different experience with their statistical offices. The former statistical offices were an integral part of the former system of governance. It meant that they provided information important for the planning council (agency, bureau) and thus they were secret. When they were published, they were also revised very frequently often in favor of presenting a better assessment of the state of the world rather than a more realistic one. In some cases however, national institutions have the advantage of being the only source for acquiring data during the period 1989 1995 and pre-1989 (often pre-independence). For the nations that had not achieved independence before the date, the institutions of reference are:

[27]The combination of a relatively homogeneous set of countries (N) in the form of a panel is used to compensate for a small number of observation in the individual time series (T).

[28]Some authors use the term "ex-socialist" *Polanec* (2004). The name is also used for the whole group of Central and Eastern European Countries.

- Federal Office of Statistics - Yugoslavia (now: Serbia and Montenegro)
- Goskomstat of USSR/Central Statistical Board - Baltic States (now: Goskomstat of Russia)
- Federal Statistical Office/State Office of Statistics - Czechoslovakia (now: Czech Statistical Office (CZSO) and Slovak Statistical Office)

In general, the main sources for real GDP data are local National offices of Statistics although national central banks or governments (ministries of finance or equivalent) may prove a good alternative.

In addition to this general problem there are two source of concern relating to the low quality data in transition countries. One of them is the process of disaggregation[29]/aggregation[30] which is beyond the scope of our analysis. We believe that this issue is carefully taken into consideration in statistical agencies (e.g. Eurostat). The other issue results from indicators expressed in constant or current prices. There is a large number of methodological and practical problems related to the cross-country comparison of per capita income levels and it was only recently that data sets of acceptable standards and quality were compiled. The Penn World Table by *Heston et al.* (2006) is a potential source, containing GDP per capita for more than 130 countries starting from 1950 - see *Dobrinsky* (2003) - together with data held by The Groningen Growth and Development Centre (GGDC), particularly in its Total Economy Database[31] maintained by

[29]At the national level, in transition economies.
[30]At the European level (Eurostat).
[31]See The Conference Board (2009)

the US not-for-profit organization The Conference Board. The data problems are even more severe when considering the former centrally planned economies of Central and Eastern Europe. The redrawing of national borders in this part of the continent after the start of economic and political transformation has aggravated these problems. The available past estimates for the former centrally planned economies present some basis for longer-term comparative studies - *United Nations Economic Commission for Europe* (2000). However, the explanatory power of these data with respect to our target analysis is limited both by methodological deficiencies in their collection and changes in national boundaries of the countries they refer to. For this reason, comparisons are very problematic[32].

Another significant problem is expressing GDP in the correct currency, for example using real data unadjusted for PPP (or PPS) may create a bias. GDP per capita in the purchasing power parity (PPP) better reflects the country's economic standard in international comparison. When spatial comparison is carried out, volume indexes are expressed in the purchasing power parity to exclude price level differences. This indicator expresses the real 'physical volume' of goods and services available to the relevant economy for consumption and investment (including the balance of foreign trade). It is necessary to distinguish between the PPS unit and PPP of the currency (for example the US dollar) as published by OECD or World Bank (where the US country is taken as the reference country). The European equivalent is "Purchasing power standards" (PPS): This is an artificial unit created by EUROSTAT according to the average price

[32]For additional explanations and estimates of long-term development see e.g. *Dobrinsky et al.* (2006).

level in the EU states (created on the basis of Euro and calculated from the average price levels in member states once EU15, now EU25) and this is why its values vary even within individual EU countries. PPS is also an artificial monetary unit which fulfills the function of a double converter (prices and exchange rate). The relative prices of non-tradable goods and services are likely to be lower in low income countries and the real GDP growth rates correspondingly lower than growth rates of GDP in PPP (PPS). On the other hand, we can obtain GDP in PPP (PPS) in annual frequencies. This does not seem to be enough for modern time series techniques. Most of the data are taken from the Eurostat database.

A final critical issue is data reliability at the beginning of the transformations phase. Some studies have shown that the steep economic decline (measured in real GDP) which is usually associated with this period, could be overestimated. For example, *Dobozi* (1995) shows that if we measure an economic slowdown in terms of energy consumption, the the down-fall of many NMS8 economies appears rather different. Probably the most interesting example is the overestimation of the decline in Czech Republic production - as measured by GDP - at the beginning of the transformation phase[33].

Given all these consideration, at various stages during this research, we used:

Quarterly per capita GDP in euro for individual new EU Member states and for the old members (chain-linked 2000 constant prices and exchange

[33]About -21% between 1989 and 1993 if measured by GDP and about -11 % in the same period if measured by energy consumption, see op. cit.

rates)[34]. The best choice would be the chain-linked time series with prices of the previous year which were not available for the most of NMS8 countries. The population growth is based on the Annex of *Economic Commission, Directorate General Economic and Financial Affairs* (2006) and Eurostat New Chronos database. Our data covered the 13 years period between 1995 and 2007. Aggregation follows internal Eurostat procedures except for a NMS8 average which we constructed it ourselves using GDP per capita valued at PPS, due to non-existence of official figures.[35]

GDP per capita at PPS for individual new EU Member states and for the EU15. The EU-8 countries′ average was made as weighted average of country′s weight in total (EU-8) and the GDP in euro.

3.3.1 Data vintages and population statistics

As detailed above, one of the main difficulties of starting an empirical research on accession countries in the middle of the enlargement was the relative unreliability of the data sources. In practice Eurostat coordinated the process relying on national sources, resulting in frequent revision of its enlargement database. This imposes severe constraints especially when dealing with data vintages of the entire sample opposed to just a few recent observations. Other than this general problem some statistics are of particularly poor quality. Population data are available

[34]We used 2000 constant prices, even though we are conscious of possible bias linked with constant prices in case of transition countries, which is the main reason, why we did not use GDP per capita 1995 current prices.

[35]For a discussion of price bias in case of transition countries, see e.g. *Filer and Hanousek* (2004).

only at annual frequencies and a few NMS8 members have breaks in the series. This problem however is common to several databases (UN, Eurostat, National offices etc...) and it is illustrated in figure (3.4) displaying the total population series for the eight countris, as appearing in all four databases. Data for Poland show the better example of this behaviour, with a potential break between 2001 and 2002.

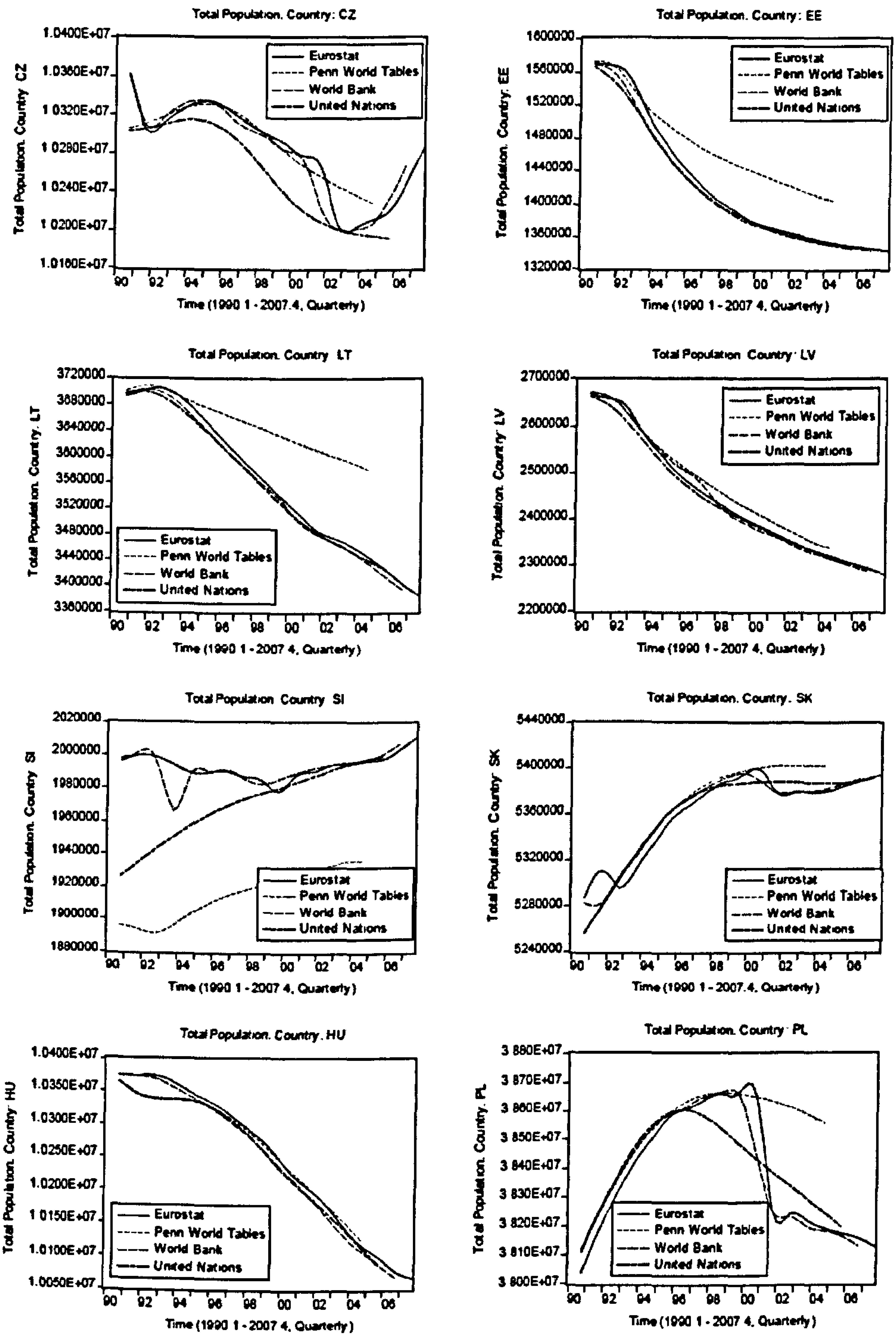
This issue is particularly relevant since we are going to rely on per capita data in many part of our research. This is also the reason why Eurostat consistently approximates its GDP per-capita data in the case of accession countries[36]. Part of the problem is related to changes in statistic statistical methodologies and census in different countries. It is also known in the demographic literature - see e.g. *Matysiak and Nowok* (2007). Under these conditions, we constructed our per capita series ourselves, using cubic spline interpolations to convert from lower to higher frequencies.

3.3.2 Custom datasets and definition of economic variables

Since the quality of data for new member states is generally poor this research uses a range of data sources. The key variable under investigation is GDP per capita at constant prices and it is expressed in dollars (Penn World Tables, UN, IMF), in euros or in PPS (Eurostat). The latter is preferable but it is generally available only for annual data. For quarterly frequencies, dollars have the advantage of facilitating conversions

[36]Note that the approximation is such to make quarterly data not better than annual and therefore un-usable for our exercise

Figure 3.4: NMS8 Total Population by country



from national currencies, especially in the period 1995 - 1999. Anyway, since the Eurostat publishes an estimate of the euro/dollar exchange rate for the few years before the adoption of the single currency, a conversion into euros is possible for the full period.

3.4 Conclusion

This chapter looked into policies targeting real convergence in the enlarged Europe and their effectiveness. We noted how, these being driven by targets set by EU treaties[37] the focus has been primarily on nominal convergence, which per-se does not neglect a spill-over effect on real convergence. We also noted the particular regime under which trade agreements were negotiated and how this makes particularly appealing an assessment of their ability of promoting growth in these economies. We also surveyed the major empirical attempts to test the convergence hypothesis in the context of the recent enlargement and recorded a general tendency in favor of initially disadvantaged new members reducing their output gap during the last decade. However, we argued that the methodologies used by some authors were sometime problematic and not always compatible with the theoretical background introduced in chapter 2. Finally, we stressed the consistent difficulties in collecting good quality data and constructing the relevant output indicators for the NMS10. In this context we propose an alternative empirical investigation of convergence that is described in the next chapter.

[37]and enforced by similarly-shaped institutions.

Chapter 4

Empirical tests for convergence I

HAVING described the core issues in the convergence literature, we now progress to an empirical assessment of convergence with reference to the European enlargement background described in the previous chapter. The neoclassical convergence hypothesis is tested mainly using modern time series techniques which, in this context have been scarcely used if compared to distributional or regression analysis. The target of this chapter is to describe and compare the essential elements of the two approaches. Given the greater flexibility of these tools, we look for potential new results and therefore summarise the existing empirical literature before progressing further.

4.1 The β-convergence approach

The point of interest in the literature on β-convergence is the negative correlation between initial levels of GDP per capita and its yearly average rate of growth (per capita). The possibility of using selected control variables brings the difference between conditional and unconditional β-convergence, adding at the same time the possibility of developing models with a more structured theoretical economics specification (e.g. disaggregation by sector) compared to a purely statistical analysis. In this way we could abandon in part the time-series environment, bringing into play the concept of convergence as direct consequence of the growth literature both in the previously discussed neoclassical *Solow* (1956) model or the endogenous growth model of *Romer* (1986) and *Barro* (1991). For example, given the same rate of savings and population growth in two economies, *Solow* (1956) would predict full convergence in GDP per capita levels. In the case of different rates of savings and population growth the neoclassical prediction is limited to a constant difference between their equilibrium outputs. However, the second is not confirmed by the endogenous growth theory and therefore difficult to test using β-convergence techniques. In principle such an approach could be applied to the EU enlargement, we will see later in our analysis how other methodological and country-specific[1] problems prevent a successful application.

The first formalization of the concept, presented below as appearing in

[1]See *Banerjee et al.* (2005)

Quah (1995), was introduced by *Barro and Sala-i Martin* (1992) as an implication of the neoclassical growth model [2]. As such it is easy to link with the framework introduced in chapter 2. If, other than a closed economy we assume there is no taxation ($T = 0$ so that $S = Y - C$), we can go back to equation (2.4) and re-write it as ($c = C/L$):

$$i = sf(k) = f(k) - c$$

therefore equation (2.6) is now:

$$\dot{k} = \frac{\partial k}{\partial t} = f(k) - c - (n + \delta + g)k \tag{4.1}$$

Barro and Sala-i Martin (1992) assume that houseolds are utility-maximisers[3] so that their optimal consumption is such that:

$$\tilde{c} = \frac{\dot{c}}{c} = \frac{1}{\theta}\left[f'(k) - \delta - \rho\right] \tag{4.2}$$

where θ is a parameter, and the authors assume that $\theta > 0$ to impose constant elasticiy to the marginal utility function[4] in respect to c. ρ is the rate of time preference[5].

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[2]In the specific case, equation (1) is the solution of the *Barro and Sala-i Martin* (1992) log-linearized approximation of the neoclassical growth model (closed economy) with Cobb-Douglas technology. See also chapter 2.

[3]Their infinite-horizon utility function is $U = \int_0^{+\infty} u(c)e^{nt}e^{-\rho t}dt$ with $u(c) = \frac{c^{1-\theta}-1}{1-\theta}$ - see op. cit. Note also how this assumption was not strictly necessary in our exposition in chapter 2.

[4]$u'(c) = c^{-\theta}$

[5]with $\rho > n + (1 - \theta)g$ to satisfy the transversality condition.

Using the familiar[6] log-linearisation of equations (4.1) and (4.2) around the steady state, we get the transitional dynamics:

$$\ln(y_t) = \ln(y_0)e^{-\beta t} + \ln(y^*)(1 - e^{-\beta t}) \tag{4.3}$$

where:

$$2\beta = \left\{\psi^2 + 4\left(\frac{1-\alpha}{\theta}\right)(\rho + \delta + \theta g) \times \left[\frac{\rho + \delta + \theta g}{\alpha} - (n + \delta + g)\right]\right\}^{1/2} - \psi$$

and $\psi = \rho - n - (1 - \theta)\, g > 0$. We can also rewrite equation (2.4) in terms of average growth rates between time zero and T as following:

$$\frac{\ln(y_T/y_0)}{T} = g + \frac{(1 - e^{-\beta t})\ln(y^*/y_0)}{T}$$

For empirical applications *Barro and Sala-i Martin* (1992) propose to adapt the analyisis to the discrete time and *Quah* (1995) reformulates equation (2.4)[7] as follows:

$$\frac{\ln(y_{i,T}) - \ln(y_{i,0})}{T} = \alpha - \frac{1 - e^{-\beta T}}{T}\ln(y_{i,0}) + \varepsilon_{i,T} \tag{4.4}$$

Where y_i is GDP per capita for country "i" while $(\ln y_{i,T} - \ln y_{i,0})/T$ its average annual rate of growth (note the logarithms) between time 0 and

[6]See the appendix to chapter 2.

[7] *Barro and Sala-i Martin* (1992) similarly propose the regression: $\ln(y_{i,t}) - \ln(y_{i,t-1}) = \alpha_i - (1-e^{-\beta})\ln(y_{i,t-1}) + \varepsilon_{i,t}$ with $\alpha_i = \left[1 + (t-1)(1 - e^{-\beta})\right] g_i - (1-e^{-\beta})\ln(y_i^*)$ the only difference being the interest in average growth rates.

time T. This is regressed against a constant and an initial level of output ($\ln y_{i,0}$) across a set of N countries[8].

An estimated coefficient β, is interpreted as a signal of convergence, if $\beta > 0$ and therefore $\left(1 - e^{-\beta T}\right) T^{-1} < 0$. In other terms, countries with lower initial per capita output will grow faster. High values of β are interpreted as a high responsiveness of average growth rates to the initial condition $y_{i,0}$ or a faster convergence toward steady state. In this particular condition the literature uses the term "unconditional" convergence.

To extend the concept, consider a simplified version of equation (4.4), the so called "Barro Regression":

$$\frac{(\ln y_{i,T} - \ln y_{i,0})}{T} = \alpha + b \ln y_{i,0} + \varepsilon_{i,T} \qquad (4.5)$$

Where $b = -(1 - e^{-\beta T})T^{-1}$. As already observed, a negative coefficient (b) on initial levels is seen as a sign of convergence.

Testing for convergence is by definition "conditional" on a set of selected explanatory variables $x_1, x_2, ..., x_m$ when:

$$\frac{(y_{i,T} - y_{i,0})}{T} = \alpha + b y_{i,0} + \sum_{k=1}^{m} (\gamma_k x_k) + \varepsilon_{i,T} \qquad (4.6)$$

The same implications in terms of convergence apply, depending on the estimated $b < 0$. This second definition is usually more interesting in economic terms since it allows us to test whether a set of countries is

[8] $i = 1, 2, ..., N$

converging to a common growth path, with clear implications in terms of persistence in the initial inequality among them.

Testing for *Barro and Sala-i Martin* (1992) β-convergence might have some advantages although - at least in its original meaning - the approach has been widely criticized[9]. Nevertheless, we provide a short application to explain its meaning in the context of EU enlargement and to explain why it is often given for granted within the group of new members. The methodology used by *Crespo-Cuaresma et al.* (2002) in the context of the EU15, which is based on the *Barro and Sala-i Martin* (1992) framework described above, can be extended to NMS10 data. Before progressing further, we have a look at world convergence, using data from more than 180 countries as provided by Penn World Table (see figure 4.1). Annual EU15 and new members (NMS10) GDP per capita are observed over 13 years from 1995 to 2007 (included).

Picture (4.1) shows something that is well established in the literature: absolute convergence is difficult to observe in practice (i.e. there seems to be no relation between the initial condition at the growth rate in a given period of time). This is the reason why early empirical research focused mostly on conditional convergence. If we restrict the analyis to the member of the EU union however, the outcome is remarkably different (see Figure 4.2).

Figure (4.2) adds some preliminary evidence of potential convergence "within" the new members in addition to the *Crespo-Cuaresma et al.* (2002) analysis of EU15. Much stronger evidence, from β-convergence,

[9]See *Quah* (1993b) and chapter 4

Figure 4.1: Absolute converegence (World)

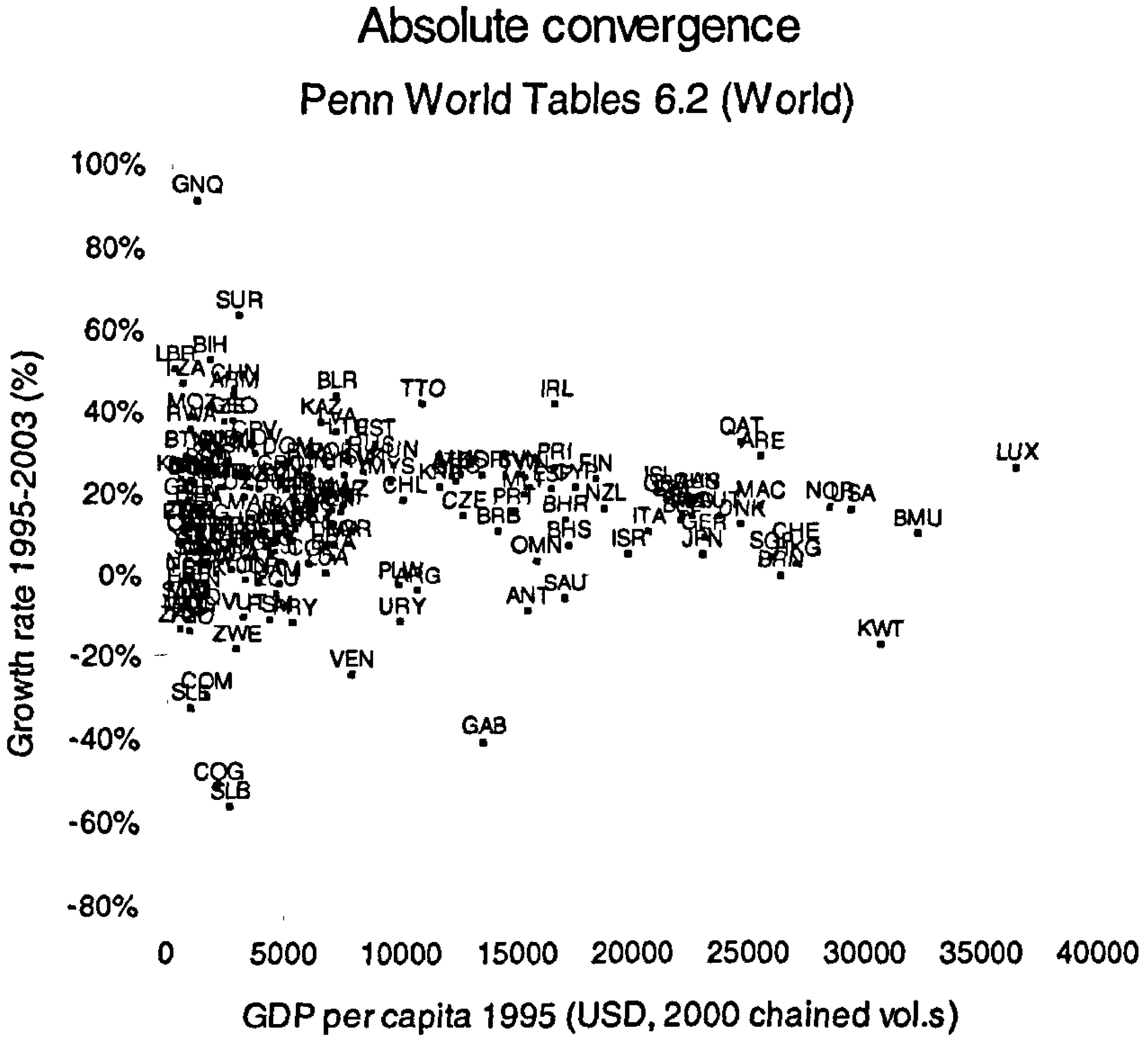
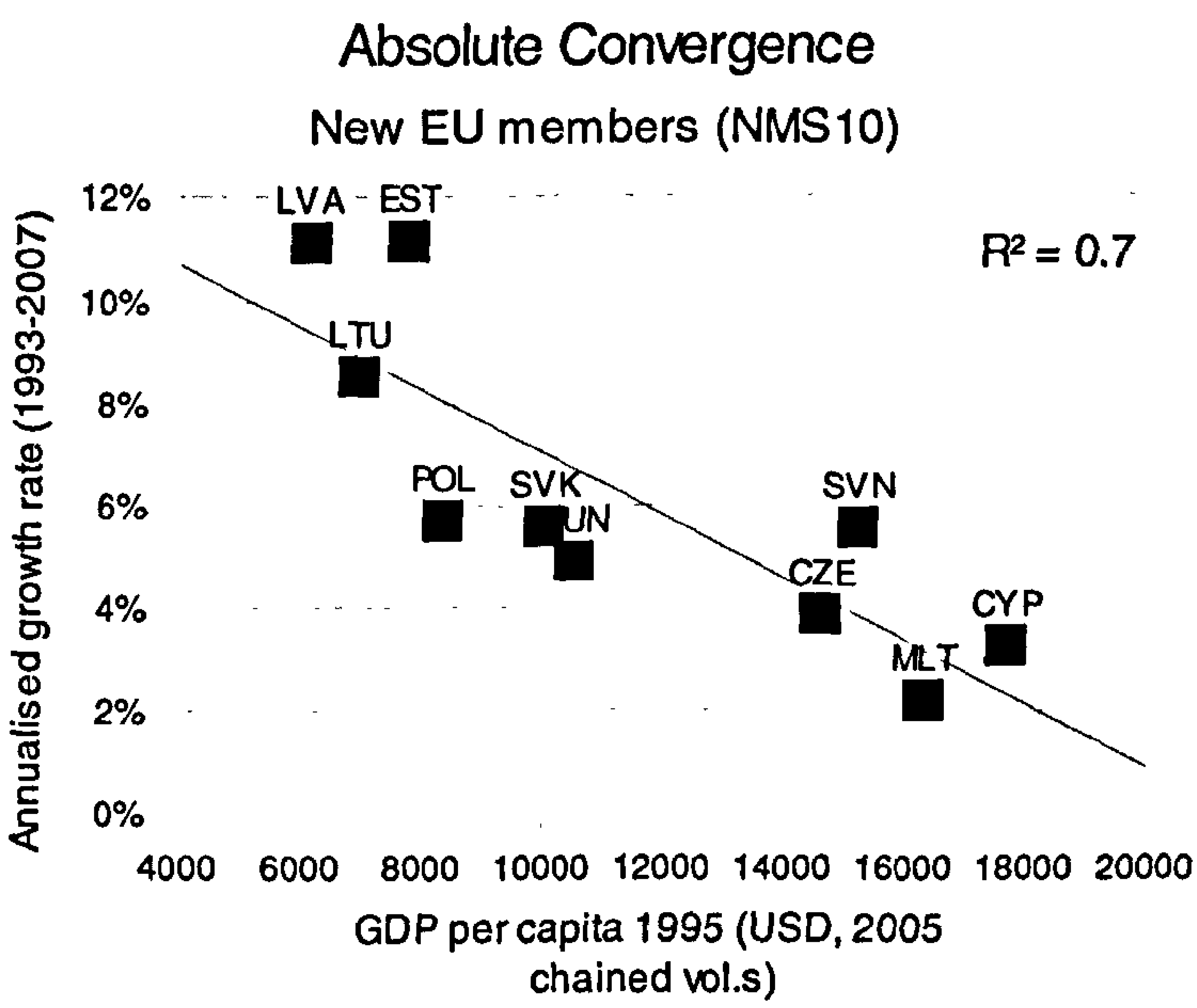
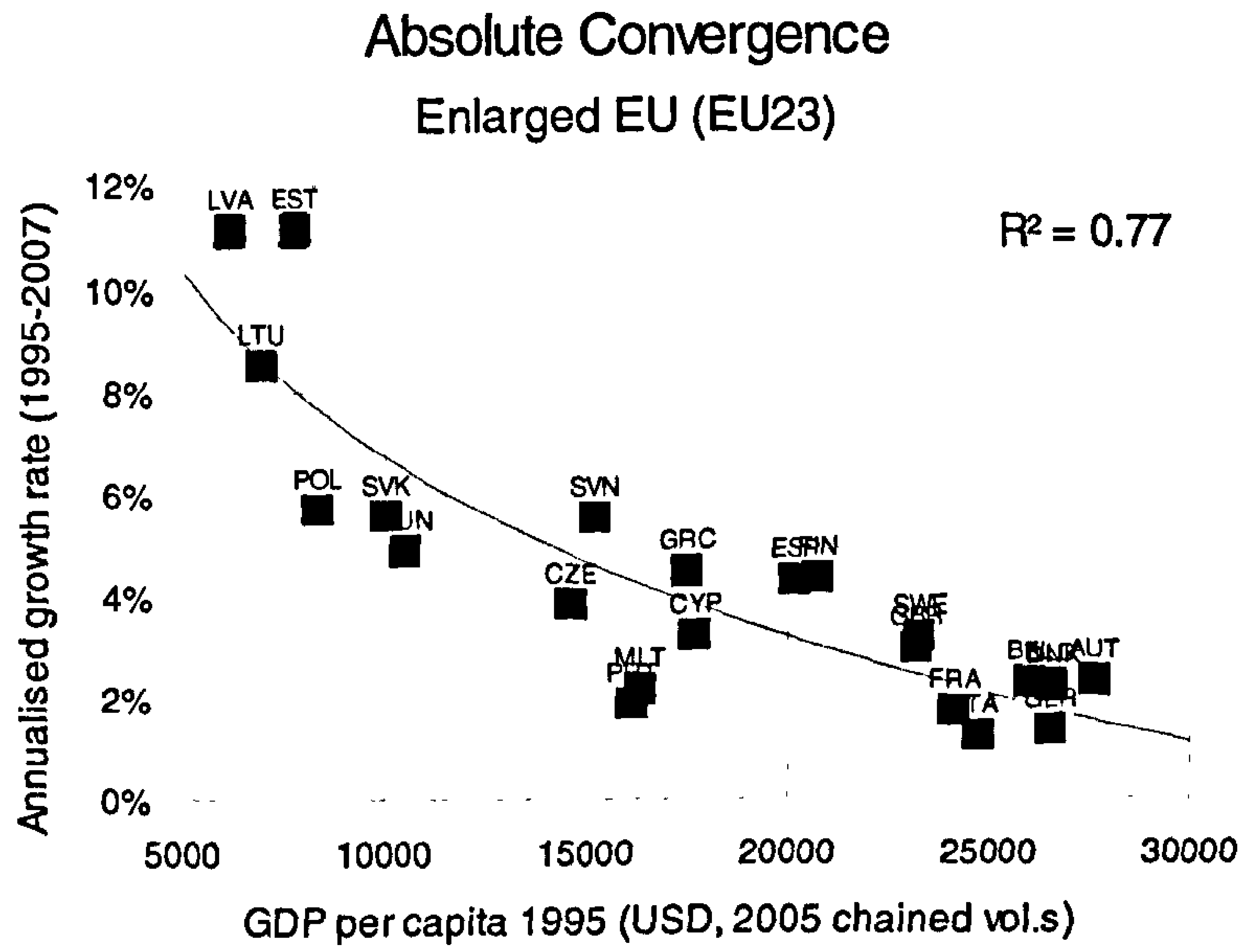


Figure 4.2: Absolute convergence (NMS10)



Source: Penn World Tables 6.3

Figure 4.3: Absolute convergence (EU21)



Source: Penn World Tables 6.3

is presented below although we argue that the most interesting question arises from the comparison of the two blocks, rather than investigating on national basis. The next picture (Figure 4.3) gives a sense of potential absolute convergence in the enlarged Europe.

A negative relation between log level of initial GDP per capita and its annualised growth[10] can be interpreted as unconditional β-convergence in the accession countries in the period 1995 - 2007. This condition holds for all the major EU economies, old and new members.

The policy implication of what we see are potentially strong: even if absolute convergence does not seem to hold in the world economy, it may do

[10]UN National Account Database, Annual data for CY, MA, CZ, SK, EE, LV, LI, HU, SK, PL. GDP at 1995 constant prices

so in a sufficient homogenous set of countries[11]. If this is the case, the convergence criteria set in the accession treaties as discussed in chapter 3 may make sense because they are implemented on an integrating set of economies [12].

4.2 Unit-roots and cointegration tests for convergence

The convergence literature has grown very fast since the *Barro and Sala-i Martin* (1992) seminal paper and since then has developed in at least two different directions. We discussed how the first of these has developed around the concept of beta-convergence, whilst the second has used unit-roots and cointegration techniques to address the question. Both were largely debated at different stages and both recently benefit from the development of more advanced panel data techniques[13] reviving and, in part merging, the literature. *Quah* (1995) centrally questioned what appears to be a "much-heralded uniform two percent rate of convergence" considering it purely unrelated to dynamics of economic growth. Additionally, the criticism of *Quah* (1993a), demonstrating how "Barro Re-

[11]Give this empirical evidence, the prediction of the neoclassical model, is that the countries are similar in terms of n, δ, g (see chapter 2) and it is likely they share a unique steady state.

[12]Note how what apparently is observed on "national" basis assumes a "regional fashion" at the European Union level. We will see later that, looking closer at the performance of the individual economies, it is easier to identify smaller "convergence clubs" than drawing a unique conclusion for the area.

[13]See chapter 5.

gressions" are subject to the classic Galton's fallacy[14] , suggests choosing a different direction for an empirical exercise. Given the high interest in the topic, detailed surveys of the literature emerging as an alternative to beta-convergence, which we will address with the term "stochastic convergence", has been provided in good number. Among those, the most relevant are probably *Durlauf et al.* (2004) and *Islam* (2003). In our particular case, we apply the *Bernard and Durlauf* (1995) approach to convergence to the set of new EU members introduced in chapter 2. Reducing the dependence on a thoretical model, is done at the cost of loosing some explanatory power (especially in a policy prospective). However, this seems the best choice for our research, given the lack of a wide empirical corroboration for a particular growth theory [15] and the methodological issues already discussed, Therefore we reformulate our original hypothesis following *Bernard and Durlauf* (1995). According to the authors "there is convergence between the log GDP per capita of country i, $y_{i,t}$[16], and the log GDP per capita of country j, $y_{j,t}$, if and only if their difference $(y_{i,t} - y_{j,t})$ is stationary with zero mean".

Generalizing this idea and extending it to a set of N countries, we can conclude for convergence if, in each i-th cross-section, the long-run prediction of the per capita output difference conditioned on a set of informations I_t, is stationary:

[14]i.e. the convergence hypothesis is subject to regression toward the mean: if a country is rich (it was growing fast/more than the average in the past) it has a higher chance of growing less than a poor country (growing less than the average in the past).

[15]For a recent survey, see *Cavusoglu and Tebaldi* (2006)

[16]Note the change in notation: from this point we assume y is the log of output.

$$\lim_{p \to \infty} E\left(y_{1,t+p} - y_{j,t+p} | I_t\right) = \mu \qquad (4.7)$$

with: $i = 1, 2, ..., N$ and $y_t = \ln(Y_t)$.

Notice how we now need at least two countries and we use one as a benchmark. In Barro regressions, it is assumed that all the countries share the same steady state so that this distinction is unecessary. Also, note that the condition is imposed over the logarithm of output so that:

$$\lim_{p \to \infty} E\left(Y_{1,t+p} / Y_{j,t+p} | I_t\right) = e^{\mu}$$

Clearely, this formulation is generic enough to allow two types of convergence. In particular, the convergence process is said to be absolute (or convergence in equality) when $\mu = 0$ (therefore the expected value $Y_{1,t+\infty} = Y_{j,t+\infty}$). When $\mu \neq 0$ there is a persistence/long-run difference in the output levels of the two countries (i.e. the expected value $Y_{1,t+\infty} = e^{\mu} Y_{j,t+\infty}$). Since absolute convergence may be difficult to prove empirically, especially for a large number of cross-sections[17], allowing for a broader definition may be useful. Finally notice how $\mu \neq 0$ should be seen as a weak form of convergence and does not imply divergence in the neoclassical sense and even the way we use the terms "absolute" has no connections with the idea of constraining/not constraining the analyisis to a set of explanatory variables (as in Barro regressions).

An interesting special case of definition (4.7) is proposed by *Evans and*

[17]see for example figure 4.1.

Karras (1996) in a panel data environment:

$$\lim_{p \to \infty} E\left(y_{i,t+t} - \bar{y}_{t+p} | I_t\right) = \mu, \forall i$$

where $\bar{y}_t = \sum_{i=1}^{N}(y_{i,t})$.

Absolute convergence requires $\mu = 0$ in the same way as in *Bernard and Durlauf* (1995). An interesting implication of this formulation is that using the average GDP per capita ($\bar{y}_t$) means dealing with the level to which gains of EU member states are assessed, marking the line between net contributors and net debtors. If the enlargement can bring signicant variation on this value, direct effects can be observed on a national basis. *Gaullier et al.* (1999) extended the *Evans and Karras* (1996)'s procedure relying on a non standard distribution derived ad-hoc from monte-carlo simulation.

Finally, following *Daly and Li* (2005) we give special attention to another generalized version of (4.7) - convergence to a common trend - since it can potentially allow convergence in a wider range of cases than strictly predicted by the neoclassical model. Formally:

$$\lim_{p \to \infty} E_t\left(y_{1,t+p} - k_i y_{i,t+p} | I_t\right) = 0 \qquad (4.8)$$

with $i = 1, 2, ..., N$ and k_i a scalar.

Statistically, the definitions of convergence mentioned above are tested looking for stationarity in the output gap between a chosen and a benchmark country or in a cointegration setting, testing for stationary residuals from an estimated linear combination of this two series.

The first approach was introduced by *Carlino and Mills* (1993), the second by *Bernard and Durlauf* (1995) and *Bernard and Durlauf* (1996). Although very similar in principle, they are not the same, with the first imposing some extra restriction compared to the second. Both can also be extended to panels, with the limits descibed below.

The basic problem can be fomulated as follows. Given two countries i and j, define the difference:

$$g_t = \log(y_{i,t}) - \log(y_{j,t})$$

For a set of information I_t , the definition we introduced in section 4.2 implies that this difference tend to a zero or constant value[18] in the long-run:

$$\lim_{t \to \infty} E\left(g_t | I_t\right) = \kappa \tag{4.9}$$

with $\kappa \geq 0$.

In practice, detecting a constant asymptotic expectation proceeds by testing for stationarity and using for example the *Dickey and Fuller* (1979) (DF/ADF) tests. At its simplest, it is a matter of testing for a unit root in the series:

[18]according to the definition of convergence, see above.

$$g_t = \rho g_{t-1} + \mu_t \tag{4.10}$$

the null hypothesis being:

$$H_0 : \rho = 1$$
$$H_1 : \rho < 1$$

Rejecting the unit-root (with a simple t-statistic in eq. 4.10) is a sign of ouput convergence between the chosen and benchmark country.

Note that this is also equivalent to ($\rho - 1 = \alpha$):

$$\Delta g_t = \alpha g_{t-1} + \varepsilon_t \tag{4.11}$$

where a unit root ($\alpha = 0$ then $\rho = 1$), makes (4.11) a non-stationary random walk which should be taken as a sign of output divergence between two selected countries i and j. A unit root can be either pure or stochastic discussed later in this chapter.

Bernard & Durlauf, propose to use co-integration instead of stationarity of the output differential to test the same hypothesis. This, in principle, can be done either following the Engle-Granger or the Johansen approach. The second allows for a better control over the number of cointegrating relations when the number of units is greater than two, and is therefore used by many authors. However, a brief review of the first helps to better understand the nature of the problem, since the *Carlino* *and Mills* (1993) procedure described above deals with only two countries at a time.

Formally, assume we are interested in the long run relation between the output of the two countries introduced above (i.e. $y_{i,t}$ and $y_{j,t}$). The idea behind the Engle-Granger approach is to estimate the long-run relation as a simple linear regression and then tests for stationarity in the regression residuals:

$$\log y_{i,t} = \beta \log y_{j,t} + \varepsilon_t \Rightarrow \hat{\varepsilon}_t = \log y_{i,t} - \hat{\beta} \log y_{j,t} \qquad (4.12)$$

The DF/ADF tests specification is now:

$$\hat{\varepsilon}_t = \rho \hat{\varepsilon}_{t-1} + \mu_t$$

and, as usual the null hypothesis is $H_0 : \rho = 1$.[19] Non stationarity of the residuals is evidence that the fitted regression is "spurious" and not the result of a stable long-run relation between the series[20].

Note that this procedure is a generalisation of the above - *Carlino and Mills* (1993). In fact, if $\hat{\beta} = 1$ then, from equation (4.12):

$$\hat{\varepsilon}_t = \log y_{i,t} - (1) \log y_{j,t} = g_t$$

[19]If the original $y_{i,t}$ and $y_{j,t}$ series are both $I(1)$, this behaviour is not obvious and it is very likely that the white-noise/stationarity assumption on the disturbances $\hat{\varepsilon}_t$ is violated.

[20]i.e. if we need cointegration, we are looking for evidence in favor of reject the null hypothesis.

and $\hat{\varepsilon}_t = \rho\hat{\varepsilon}_{t-1} + \mu_t = g_t = \rho g_{t-1} + \mu_t$, which is exactly the same condition tested in equation (4.10).

In terms of convergence, this does not mean testing for output gap stationarity over time, instead a more general combination of the two. We call this partial difference:

$$g_t^* = \log y_{i,t} - \hat{\beta}\log y_{j,t} \tag{4.13}$$

Now, from equation (4.9), we know that at infinity:

$$\log y_{i,t\to\infty} - \log y_{j,t\to\infty} = \kappa$$

if $\kappa \neq 0$, a permanent difference between the series is mainteined in the long run (convergence to a common trend). In particular:

$$\log y_{i,t\to\infty} = \kappa + \log y_{j,t\to\infty}$$

Using the more generic definition of output-gap introduced by eq. 4.13[21] (the time subscript is removed for simplicity):

$$g_t^* = \log y_i - \hat{\beta}\log y_j = \log y_i - \hat{\beta}(\kappa + \log y_j)$$

the long-run permanent difference will now be:

[21] a partial difference/output-gap.

$$\log y_i = \hat{\beta}(\kappa + \log y_j)$$

Note that, even if we assume $\kappa = 0$ there will be no long-run absolute converegnce in the output levels, since:

$$\log y_i = \hat{\beta}(0 + \log y_j) = \hat{\beta} \log y_j$$

other than in the very special case in which the estimated $\hat{\beta}$ is exactly equal to one ($\hat{\beta} = 1$)[22].

In conclusion, the cointegration approach is more flexible in its specification, but it does not imply absolute convergence, unless appropriate restrictions are imposed *a priori*. Since absolute convergence is a more stringent condition than convergence to a common trend, it is not surprisingly that the *Bernard and Durlauf* (1995) cointegration test tends to confirm convergence more often than *Carlino and Mills* (1993) stationarity usually does. This result, if though in connection with the neoclassical theory, gives more flexibility than the standard regression analysis introduced at the beginning of the chapter and it shows how the new framework is able to capture convergence even in economies that are structurally dissimilar.

[22]Equivalent to restricting the cointegrating vector from $[1, -\beta]$ to $[1, -1]$

4.2.1 An application to the 5th EU enlargement: unit-roots

Since the definitions introduced in this section require an output differential and our aim is to measure convergence between the old and new EU members, we use the EU15 GDP per capita aggregate as a benchmark. The variable g_t denotes the difference between log per-capita output of a generic new eastern european member and the aggregate of all the old western members. Firstly, we test for the existence of a pure[23] unit root using the standard *Dickey and Fuller* (1979) with three alternative specifications: a simple model as in (4.11) and two alternative models with a constant and a trend.

$$\Delta g_t = \alpha g_{t-1} + \gamma + \Sigma_{q=1}^{Q} \beta_q \Delta g_{t-q} + \varepsilon_t$$
$$\Delta g_t = \alpha g_{t-1} + \gamma + \delta t + \Sigma_{q=1}^{Q} \beta_q \Delta g_{t-q} + \varepsilon_t$$

with $q = 1, 2, ..., Q$ selected lag-length (in the example $Q = 0, 1, 2$)

Table 4.1: Stationarity tests (output differentials with EU15)

	lt	lv	ee	cz	sk	pl	hu	si
t-stat	-1.88	2.34	-2.22	0.79	-0.29	-4.45	-4.17	-2.77
stationary?	no**	no*	no**	no*	no*	yes***	yes**	yes**
constant?	yes	yes	yes	yes	yes	yes	yes	yes
trend?	yes	no	yes	no	yes	yes	yes	yes

Source: EUROSTAT (2007) National Accounts, own calculations. Note: critical values in [Dickey and Fuler, 1979]. *,**,*** reliability of the test.

[23]the term "pure root" is used to distinguish from "stochastic root" as detailed in section 4.4 and in the next chapter.

Overall our results seems to suggest weak evidence of convergence in the *Carlino and Mills* (1993) sense (stationary difference series with zero mean). However, the estimation of the coefficients in the test equations is affected by a variety of factors, different from country to country. These range from insignificant coefficients and poor fit to some degree of serial correlation in the disturbances. Augmenting the specification for an appropriate number of lags helps in some cases. In others, residual seasonal components influence the quality of the analysis. In all cases, only one of the three models[24] proposed did not violate any core estimation assumption. In Table () we present test statistics computed only on the basis of non-mispecified models.

For each of the selected specifications, we indicate deterministic components and the reliablity of the esitmates used for computing the statistics employed in testing stationarity. Note also the definition of convergence varies according to the specification used (i.e. level or trend stationarity[25]), however the general conclusion against it, makes the distinction irrelevant in the particular example. It is also noted that, given unit-root tests are generally considered to have low power[26], at this stage we should probably interpret our results with some caution. We are going to address this issue using stochastic unit-root tests in the next chapter.

Further, the empirical results at this stage are quite far from our beta-convergence analysis in section 4.1. This is not totally unexpected, given the theoretical difference between the two approaches. With beta conver-

[24] either including a constant or a constant and a trend.
[25] Note the second is a relaxation of the first and therefore less favorable. See beginning of section 4.2. for a formal discussion.
[26] a low probability of rejecting a false null hypothesis of a unit-root.

gence we can spot economies that show signs of convergence and even speculate on the duration of the catching-up process. Time series techniques capture either short-run fluctuations around the steady-state but also the long-run tendency so that in the neoclassical terminology once the test gives a positive answer, economies have already converged. Furthermore, unit-roots and cointegration can capture easily economies converging to different steady states or to a common trend without choosing the conditioning factors a priori [27].

4.2.2 An application to the 5th EU enlargement: cointegration

In search of more reliable statistical evidence we apply an alternative test for the convergence hypothesis, we follow a restricted version of *Bernard and Durlauf* (1995) itself an application of *Johansen* (1991). In particular, we use the concept of cointegration looking for the number of stationary linear combinations generated by two[28] individually $I(1)$ series. When a unique relation is identified between two countries, we conclude for convergence.

Bruggemann and Trenkler (2004) used a similar procedure with some differences. Similarly, they expressed the *Bernard and Durlauf* (1995) definition in terms of the properties of the cointegrating vector and used

[27] i.e. conditional convergence in beta convergence requires the specification of the relevant explanatory variables, see Barro regression in section 4.1.

[28] *Bernard and Durlauf* (1995) is generic enough to allow for n countries, however at this stage we are interested in the convergence behaviour of each indivdual NMS10.

Johansen (1991) to test for it. However, they restricted the analysis to three accession countries and focused on industrial production rather than GDP per capita. Germany is used as a proxy for EU15, instead of an average/aggregate series. In a later paper, *Bruggemann and Trenkler* (2005) shift the research objective to GDP per capita and catching up. Instead of using recursive[29] cointegration tests based on *Johansen* (1991), they rely on *Lee and Strazicich* (2003). We start from the first methodology which we apply to GDP per capita series of all NMS8 countries.

The *Johansen* (1991) cointegration test is used in the context described at the beginning of this section, as an alternative to Engle-Granger[30].

In particular, given the (unrestricted) VAR(p), expressed in differences as:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + Bx_t + \varepsilon_t$$

where we define $\Pi = \sum_{i=1}^{p} A_i - I$, $\Gamma_i = -\sum_{j=i+1}^{p} A_j$ and $\underset{(1,k)}{y} = [y_1, y_2, ..., y_k]$ with $y_1 \sim ... \sim y_k \sim I(1)$. $\underset{(1,d)}{x} = [x_{1,}, x_2, ..., x_d]$ is a vector of deterministic components, A_j the coefficient for the lagged y_{t-j} and ε_t an innovations vector.

According to the *Engle and Granger* (1987)'s representation theorem if

[29] i.e. repeted pairwise tests for every country in the group of interest.

[30] i.e. we simply restrict the original *Bernard and Durlauf* (1995) context, where *Johansen* (1991) is preferable because of its ability of dealing with multiple cointegrating relations. Even though in our particular case it is not essential, it makes any result easily understandable in a literature using similar tests.

the matrix Π has reduced rank ($\tau < k$), there must exist a α and β of dimenstion ($\tau x k$) such as their rank is equal to τ, the product $\alpha\beta' = \Pi$ and most importantly in our case $\beta' y_t \sim I(0)$. Formally:

$$r(\Pi) = \tau < k \Rightarrow \exists \underset{(k\times\tau)}{\alpha}, \underset{(k\times\tau)}{\beta} | r(\alpha) = r(\beta) = \tau \cap \Pi = \alpha\beta' \cap \beta' y_t \sim I(0)$$

with τ the number of cointegrating relations, β a matrix of cointegrating vectors and α the adjustment factors.

To find the value for $\tau = r(\Pi)$ (the number of cointegrating relations), after imposing the appropriate assumption on the trend, which in the specific case will be (no trend or intercept):

$$\Pi y_{t-1} + Bx_t = \alpha\beta' y_{t-1}$$

or, with no additional exogenous variables. ($Bx_t = 0, \forall t$), simply:

$$\Pi y_{t-1} = \alpha\beta' y_{t-1}$$

Johansen (1991) uses sequentially the trace statistic, in the range of $\tau \in [0, k-1]$, trying for every step to reject the null (H_0):

$$H_0 : r(\Pi) = \tau$$
$$H_1 : r(\Pi) = k$$

(H_0:Π has reduced rank, H_1:Π has full rank) until failure. Critical values are non standard and obtained through montecarlo simulations by *Osterwald-Lenum* (1992). Conflicting results between individual unit roots (e.g. ADF tests) and cointegration tests are usually to be attributed either to low power or misspecification. The first is more frequent in presence of small sample sizes and *Johansen* (2002) introduced a correction factor for these particular cases.

For the logarithms of individual NMS8 countries and EU15 GDP per capita we reach the results summarized in Table (4.2) which now seems to confirm the convergence hypothesis, although a number of limitations make the tests not very powerful. We find quite strong (1 percent significance) evidence of one cointegrating relation between the majority of series concluding for a unique trend in the long run (see Table 4.2 and critical values in Table 4.3). Note that, these results can be compared with previous ADF tests in a few different ways. In terms of statistical power,*Kremers et al.* (1992) suggest using cointegration is a superior choice[31]. On the other hand, assuming both tests are equally reliable means we should concentrate on the hypothesis we test in both cases. As already explained, cointegration offers a less stringent approach to convergence[32] than unit-roots, which can potentially explain different results. However, since most of the models we used for testing stationarity contained a time trend[33], they did not imply absolute convergence, even

[31]Note however, additional issues may arise from the small sample - see *Johansen* (2002)

[32]convergence to a common trend

[33]alternative models without a time-trend suffered from mis-specification problems for almost all countries

in the few cases where we were able to reject the null hypothesis (HU, PL, SI). In this sense, conflicting results should probably be attributed to the statistical nature of the tests.

Table 4.2: Cointegration tests

	LT	LV	EE	CZ
None	20.5383	34.5469	23.4548	35.4818
At most 1	0.13187	0.89765	0.1613	0.90621
Reject: H0 None	1%	1%	1%	1%
Reject: H0 AT1	N.R.	N.R.	N.R.	N.R.
N. coint. rel.s	1	1	1	1
	SK	**PL**	**SI**	**HU**
None	22.1195	19.2495	34.939	33.1737
At most 1	0	0	0	0
Reject: H0 None	1%	1%	1%	1%
Reject: H0 AT1	N.R.	N.R.	N.R.	N.R.
N. coint. rel.s	1	1	1	1

Source: EUROSTAT (2007) National Accounts, own calculations. Note: N.R. not rejected. CVs in Table ().

This conclusion, paired with the beta-convergence evidence in section 4.1 add some preliminary support in favor of stochastic convergence in the *Carlino and Mills* (1993) sense for the EU enlargement case.

Table 4.3: Cointegration tests CVs

Critical Values[34]	5%	1%
None	12.53	16.31
AT1	3.84	6.51

Source: Johansen (1991)

4.3 Conclusions

In this chapter we applied standard beta-convergence and time-series test of the convergence hypothesis to eight new members of the European Union. Beta regressions suggest that, even if absolute convergence is a concept difficult to observe in the world economy, if applied to a subset of these economies can give different results. The neoclassical model suggests that if this is the case then, the economies are sufficiently homogeneous in terms of their fundamentals. We also noted that modern time-series tests give more flexibility and are able to test widely the predictions of our reference theoretical models. A strength of this approach is to easily allow for countries to converge to multiple steady state. The empirical evidence obtained with this new tests at the country level gives a different picture of the state of convergence between new and old members. If we consider catching-up in the long run prospective, we see that what appears a likely prediction for the future in the short-run has not been met over the last decade. Cointegration however gave more encouraging results and motivates us to increase the degree of complexity of our empirical analysis in the direction pointed by the next chapter.

Chapter 5

Empirical tests for convergence II

IN this chapter we test the robustness of our empirical results, against a number of issues that have increasingly gained attention in the unit-roots and cointegration literature and have not been applied extensively to the convergence hypothesis. We start our analysis looking at non-linear unit roots tests that allow for a potentially asymmetric adjustment of output to the steady state. We then look at the relevance of potential structural changes in output for convergence and finally we target an aggregated east/west analysis using panel data.

5.1 Non-linearity and asymmetric adjustment

At least three considerations motivate us to abandon the linear specification we used in various forms in chapter 4. Firstly, the linear ADF tests posed several difficulties demonstrating to have poor performance[1] in our particular case. Other than the problems already mentioned in section 4.2, the possibility is that a linear specification is not enough to capture the asymmetries and time-varying adjustments in some countries (especially SK, CZ). Further, there is positive evidence in the literature that a great number of existing studies (almost half according to *Leybourne et al.* (1996)) failed to reject the null of a unit root mainly because of an inappropriate linear specification.

Secondly *Carlino and Mills* (1993) relaxed the strength of the time-series convergence hypothesis introducing the concept of trend stationarity paired with positive beta-convergence. The authors point out that, stochastic convergence tests the hypothesis that shocks to relative per-capita incomes are temporary whilst beta convergence is concerned with initially poor countries catching up with the rich countries - i.e. the nature of the two tests is different. They conclude that stochastic convergence (statistically a mean reversion) is a necessary but not sufficient condition for per capita income convergence[2] An alternative generalization is to see

[1] Insignificant coefficients, poor fit, serially correlated disturbances etc... See chapter 4, table 4.2.1.

[2] note that following the neoclassical terminology, what is missing in beta convergence is evidence that countires reverted towards their steady state, hence the difference between economies that are converging (and potentially will converge in the long-run) and economies that have already converged.

the problem in terms of stochastic unit roots[3] instead of fixed unit root, maintaining the link with beta-convergence at the same time. This would introduce a definition of stochastic convergence related to stochastic unit roots. In economics terms, the difference between the two concepts is not the common conclusion that deviations from a unique or relative steady state are temporary, but rather the dynamic of the reversion process. In the standard case (fixed root) we assume this is linear, in the stochastic case we allow it to be non-linear. Since in the real world output dynamics are generally non-linear, a generalised specification for our unit-root test is likely to give us a more realistic view of convergence [4]. Before applying these concepts we introduce them formally.

Following *Granger and Swanson* (1997), we reformulate the unit-root problem in section 4.2 starting from the stochastic unit root (STUR) process:

$$g_t = a_t g_{t-1} + \varepsilon_t \tag{5.1}$$

where a_t is now a stationary series such as $a_t \sim iid(1, w^2)$ and $\varepsilon_t \sim iid(0, \sigma^2)$. When $a_t = 1, \forall t$ the STUR process exhibits a pure unit-root (a_t is equivalent to the fixed root $\rho = 1, \alpha = 0$). Whilst the existence of a pure unit-root is usually tested through standard or augmented *Dickey and Fuller* (1979) as in section 4.2, for the stochastic variant *Leybourne et al.* (1996) developed an ad-hoc LM test and derived (simulated) the

[3] See *Granger and Swanson* (1997).

[4] or at least reduce the distortions introduced by assuming that a non-linear process is linear

distribution of the following test statistic based on (5.1), augmented for q lags :

$$\hat{Z}_T = \frac{\sum_{t=q+3}^{T}\left[\left(\sum_{p=q+2}^{t-1}\hat{\varepsilon}_p\right)^2\left(\hat{\varepsilon}_t - \hat{\sigma^2}\right)\right]}{\hat{k}\hat{\sigma}^2\sqrt{T^3}}$$

assuming the residuals component is estimated as:

$$\hat{\varepsilon}_t = \Delta x_t - \hat{\alpha} - \hat{\gamma}t - \sum_{n=1}^{q}\hat{\beta}_n\Delta x_{t-n}$$

and $\hat{\sigma}^2 = T^{-1}\sum_{t=1}^{T}\hat{\varepsilon}_t^2$, $\hat{k}^2 = T^{-1}\sum_{t=1}^{T}\left(\hat{\varepsilon}_t - \hat{\sigma^2}\right)$.

The null hypothesis is set to the pure unit-root[5]

$$H_0 : w^2 = 0$$
$$H_1 : w^2 > 0$$

against a more general STUR process. *Granger and Swanson* (1997) suggest the opposite would be more effective but the cost is a far more complex simulation of the test statistic, which is understandably avoided by *Leybourne et al.* (1996).

Yau and Hung (2007) show how it is possible to use this framework in the context of output convergence. Starting from the process in equation

[5]when $w^2 = 0$, $a_t \sim iid(1, 0)$ is equivalent to $\rho = 1$ i.e. a non stationary random walk in the model (5.1).

(5.1) where $a_t \sim N(1, \omega^2)$ and $\varepsilon_t \sim N(0,1)$, divide both sides for $a_t g_{t-1}$, to get:

$$\frac{g_t}{a_t g_{t-1}} = \frac{a_t g_{t-1}}{a_t g_{t-1}} + \frac{\varepsilon_t}{a_t g_{t-1}}$$

$$\frac{g_t}{a_t g_{t-1}} = 1 + \frac{\varepsilon_t}{a_t g_{t-1}}$$

or:

$$g_t = a_t g_{t-1}(1 + \xi_t), \; \xi_t = \frac{\varepsilon_t}{a_t g_{t-1}}$$

and implies:

$$\ln(g_t) = \ln(a_t g_{t-1}) + \ln(1 + \xi_t)$$

Assuming ε_t and therefore ξ_t are relatively small, allows the approximations:

$$\ln(1 + \xi_t) \approx \xi_t$$

$$\ln(g_t) \approx \ln(a_t g_{t-1}) + \xi_t$$

$$\ln(g_t) \approx \ln(a_t) + \ln(g_{t-1}) + \xi_t$$

Introducing $\beta_t = \ln(a_t)$ leads to:

$$\ln(g_t) \approx E[\beta_t] + \ln(g_{t-1}) + \{(\beta_t + E[\beta_t]) + \xi_t\}$$

Note that $\ln(z)$ is a concave function and according to the Jensen inequality if $f(z)$ is a concave function, $\{z\}$ a range of values for z, and $w\{z\}$an averaging operator, then;

$$f(w\{z\}) \geq w\{f(z)\}$$

Hence, noticing that $E[a_t] = 1$:

$$0 = \ln(E[a_t]) \geq E[\ln(a_t)] = E[\beta_t]$$

The conclusion is that $\ln(g_t)$ is a unit-root process with downward drift. Its asymptotic behaviour is to approach negative infinity, implying that g_t approaches to zero - i.e. convergence:

$$\lim_{t\to\infty} \ln(g_t) = -\infty \Rightarrow \lim_{t\to\infty} g_t = 0$$

5.1.1 Simulations

With reference to the setup introduced above, we use a series of simulations[6] to highlight the difference between pure and stochastic unit roots and give a sense of similarities and differences allowed by this formulation. These are difficult to represent within the thoeretical neoclassical framework[7] introduced in chapter 2 but are relevant to empirical research. Given the restricted number of references on the topic, they should also serve as a guide for interpreting the application to the EU enalrgement proposed in section (5.1.2).

Firstly, we simulate convergence using fixed and stochastic roots processes. We generate a hundred series[8] for which we assume normally distributed disturbances $\varepsilon_t \sim N(0, 0.05)$[9] and 50 observations[10]. Figure (5.1) shows the results.

For the fixed root, if we call $g_t = \ln y_t - \ln y_t^E$ the difference between the logarithms of output a chosen (y_t) and benchmark country (y_t^E), the data are generated from the familiar[11] model:

$$g_t = \rho g_{t-1} + \varepsilon_t$$

under the alternative hypothesis $H_1 : \rho < 1$. In other words, output

[6]All simulations performed in Eviews 5.1.

[7]which, as such, is more interested in "if" and "why" economies should revert to their steady state, rather than "how".

[8]This is close to the graphical capabilities of our software

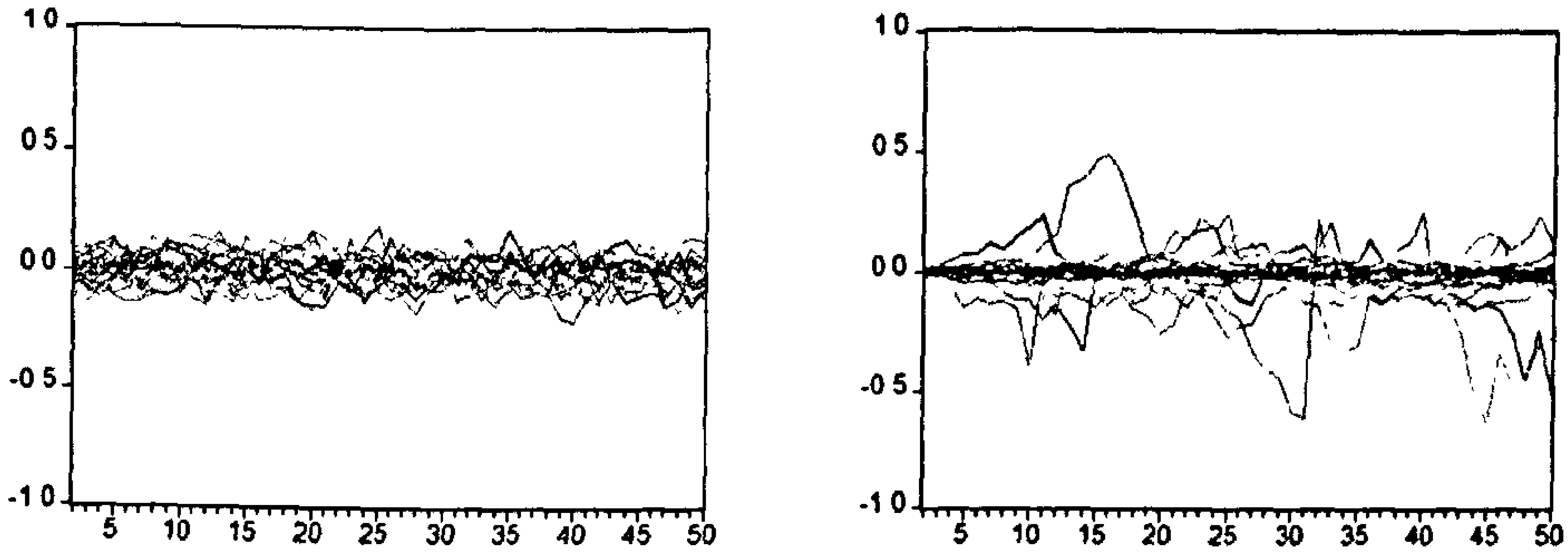
[9]Note the S.E. of our ADF regressions in chapter chapter 4 section (4.2) were in the range of 0.01 to 0.05.

[10]These approximate our typical sample size.

[11]See chapter 4.

Figure 5.1: Convergence: fixed and stochastic roots

i. A fixed fractional root	ii. A stochastic root



Notes: $\rho = 0.5 < 1$ Notes: $a_t \sim N(1, w^2),\ w^2 = 0.6 > 0$

convergence requires that the distance from the steady state is stationary over time, with mean zero[12] .

The second half of Figure (5.1) is obtained transforming the fixed root (ρ) into a random variable $a_t \sim N(1, w^2)$[13] and assuming this has positive variance ($w^2 > 0$). The resulting process reverts to its zero mean, although with different dynamics if compared with the FUR case.

Similarly, in Figure (5.2) we simulate divergence[14]. In this case the we assume $w^2 = 0$ so the STUR and FUR models coincide.

A few considerations emerge from this exercise.

Firstly, even in the linear case, the behavior of the log differences in output is not exactly the same described by Barro when talking of converegence. If we go back to the idea of "poor countries growing faster"[15], con-

[12] Other than small short run variations, the long run tendency is a zero distance from the steady state. Note although this can be relaxed if the mean is positive, the levels of output will still grow together.

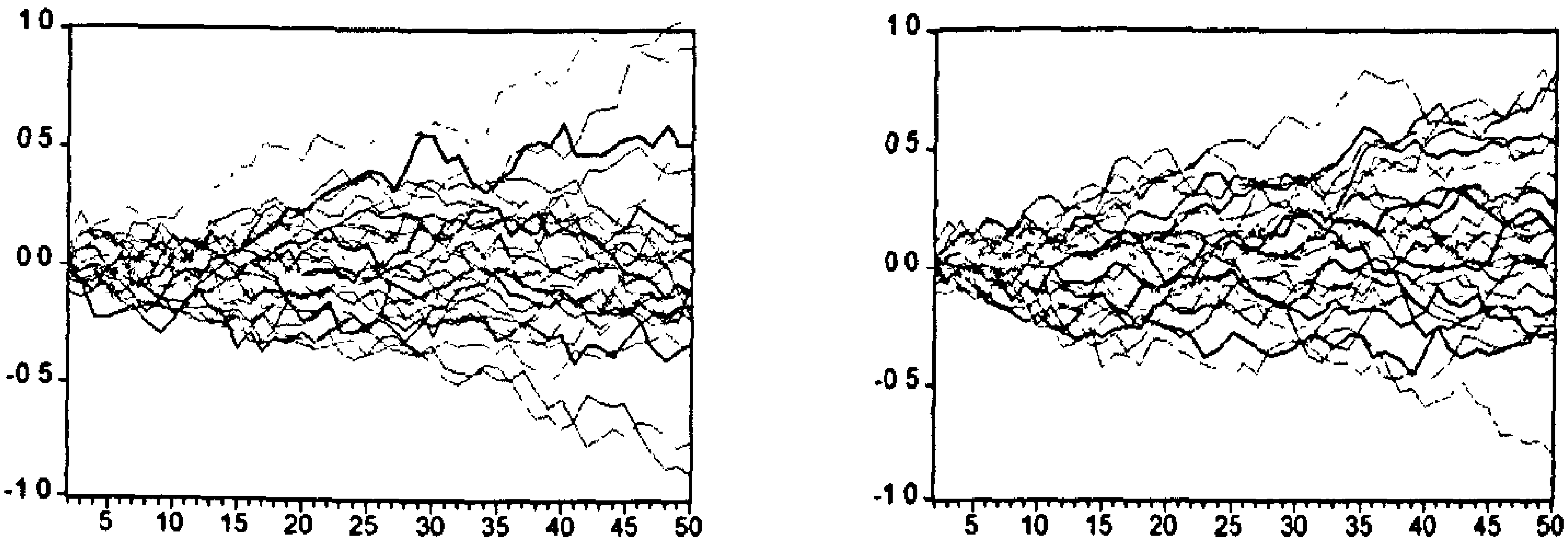
[13] $g_t = a_t g_{t-1} + \varepsilon_t$

[14] Most of the simulated differences in log GDP per capita do not revert to zero.

[15] See chapter 2.

Figure 5.2: Divergence: fixed and stochastic roots

i. A fixed unit root ii. A FUR from the stochastic model



Notes: $\rho = 1$ Notes: $a_t \sim N(1, w^2)$, $w^2 = 0$

vergence here means that economies have converged (we can only choose between $\rho = 1$ and $\rho < 1$, convergence or divergence – we do not know anything about the size of ρ under the alternative). At best there is some short run adjustment/variation around the steady state. Although we test a long-run condition, economies are allowed to catch-up in the short-run. This is the way *Carlino and Mills* (1993) solved the "regression to the mean" problem discussed by *Quah* (1993b) . Instead of looking at two countries we can use cointegration ad look at a group of countries altogether. The theoretical point of view[16] however remains the same.

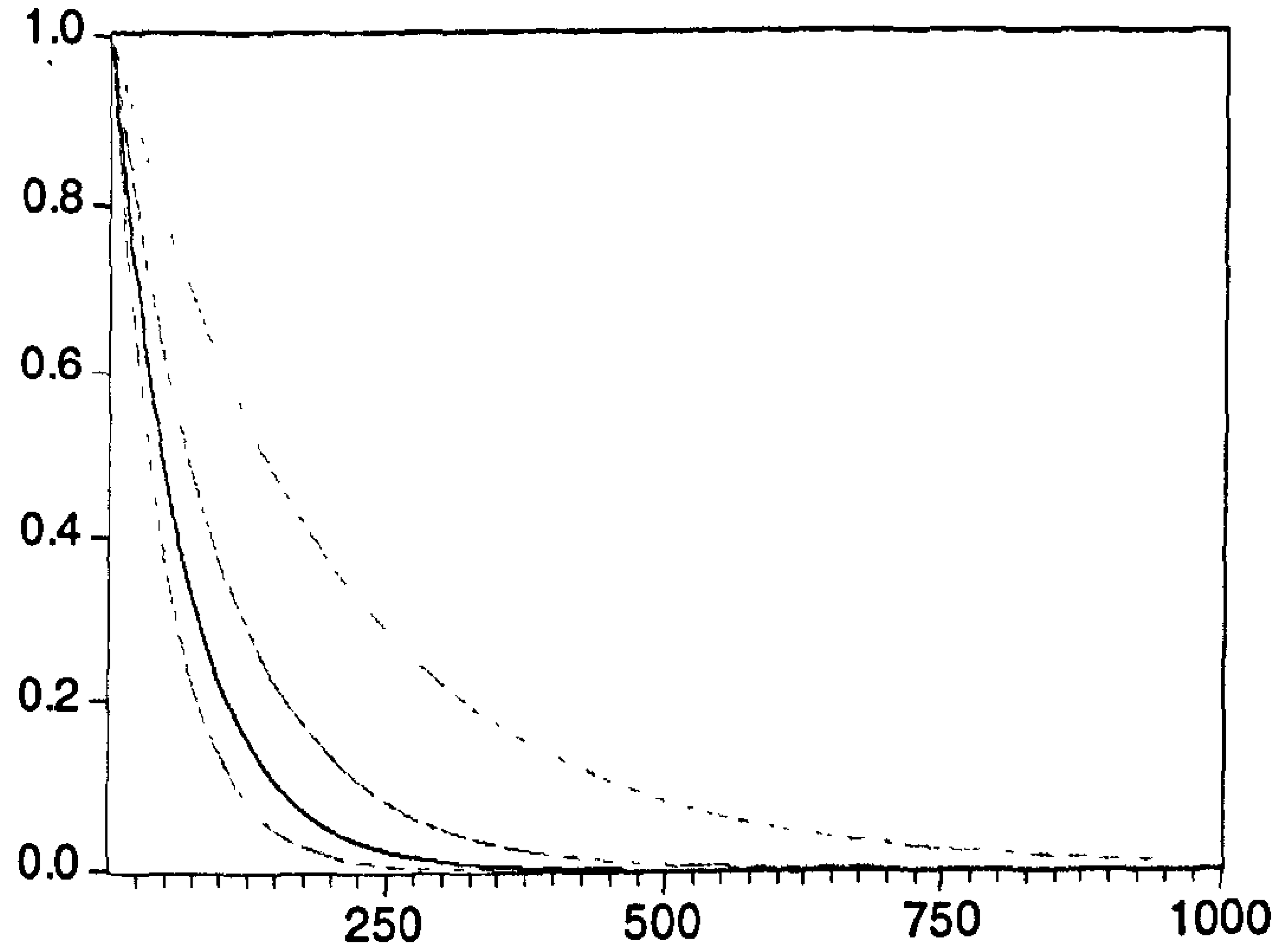
Secondly, it is interesting to notice how the size of ρ influences stationarity and how it regulates the convergence[17] dynamics:

- Disturbances are responsible for short run variations around the steady state.
- ρ is responsible for the "bounds of variation" around the steady state (i.e. a ρ close to 0 means an almost white noise process, a ρ close to

[16] i.e. temporary shocks to relative output - see above.

[17] note we are interested in its stochastic meaning - i.e. reversion to the steady state.

Figure 5.3: Speed of convergence



Note: $\rho = 1$ (parallel) and $\rho = 0.995, 0.99, 0.985, 0.98$.

1 almost a random walk) and observed behaviour may be indistinguishable from non-stationarity in finite samples.

Assuming no-disturbances, the following graph shows how fast the log difference in output goes to zero for ρ = 1, 0.995, 0.99, 0.985 and 0.98[18] - see figure (5.3). Note how this concept is the stochastic equivalent to the speed of convergence[19] introduced in chapter 2[20].

The process of convergence itself is "linearly" (ρ is constant) determined by ρ. Divergence is observed only for $\rho = 1$, convergence is faster as far as we reduce the values for ρ.

[18]The initial observation is set to 1 for convenience.

[19] ρ is a proxy for the speed of convergence of current to steady state output; the lower ρ the faster the reversion to the steady state

[20]Note that, at this stage, the dynamics followed by the economies under investigation are linear, and therefore describe the reversion to the steady state (i.e. catching-up to the same equilibrium) in a fashion similar to beta-convergence. Under this point of view however, we will see next that the strenght of this approach is its flexibility to be extended to the non-linear case.

In the FUR ρ is constant so, in terms of output differentials, we are assuming that, for convergence to occur, the distance from steady state will decrease always at the same rate. This in practice can be rather restrictive, instead it is common place to observe asymmetric adjustments (faster in one period slower in others) towards the (long run) steady state. Part of these asymmetries is certainly captured by the short run disturbances (ε_t), but in this respect the original *Carlino and Mills* (1993) model does allow limited long-run analysis.

Finally, the STUR better approximates the dynamics of the reversion to steady state following shocks to relative per-capita incomes, with advantages in, at least, two areas:

- Traditional fixed roots (FUR) notoriously under reject[21] the null hypothesis.
- The path towards convergence/divergence is driven by a linear process, which may be unrealistic in practice[22]. STUR can capture long-run asymmetric adjustments.

Note that under $w^2 = 0$ the distance from steady state does not change in time (so output diverges in time because of the short run random components), in all other periods the rate of adjustment towards the steady state dynamically changes. The higher the asymmetries in every period, the higher the convergence towards the long-run steady state.

[21]Note that altough unit root tests are generally portrayed as having low power there is some literature on unit root tests finding too much stationarity, typically in presence of structural breaks - see for example *Ventosa-Santaularia* (2009).

[22]Note that, in the terminology introduced in chapter 2, this is equivalent to assume that the speed of convergence (here the speed of mean reversion) is or is not constant.

5.1.2 Application

The procedure here is similar to *Yau and Hung* (2007) but applied to the 5th EU enlargement case[23]. When the null is rejected in favor of a stochastic unit root (STUR), the GDP per capita of the individual new member converges to the EU15 aggregate. The table below illustrates our results.

Table 5.1: Leybourne tests for a stochastic unit root

	LT	**LV**	**EE**	**CZ**
Z-stat	-0.021092	0.025811	0.224499*	0.011203
STUR?	no	no	yes	no
	SK	**PL**	**HU**	**SI**
Z-stat	0.113485	0.011203	0.25118*	0.287285*
STUR?	no	no	yes	yes

Note: Leybourne et al. (1996) 5% critical value: 0.215. *Source:* EUROSTAT (2007).

More generally, a log difference GDP per capita of two countries starting at different levels showing a STUR, is interpreted as a signal of convergence. Taking into account potential non-linear dynamics suggests positive evidence of convergence between EE, SL, HU and EU15. Moreover we are able to confirm beta convergence in the countries where we reject the null of a pure unit-root. For these, we can conclude, similarly to *Carlino and Mills* (1993), for stochastic convergence.

[23]For ease of comparison, we use the same Eurostat GDP per capita series as in chapter 4 (1995 - 2007).

5.2 Structural changes

Since *Perron* (1989) it is clear that performing a unit-root test in the presence of structural change can lead to non-rejection of the null when in fact it is not true[24]. This section explores a set of potential solutions to the problem given that it could potentially undermine our conclusions on stochastic convergence.

The existing literature on structural breaks offers a wide range of choices, among those we are looking for the possibility of allowing an unknown break date. The *Zivot and Andrews* (1992), *Perron* (1997) tests are often used under this circumstances or the iterative equivalent of *Chow* (1960) proposed by *Andrews* (1993) and *Andrews and Ploberger* (1994) and their extensions to the multi-break scenario (see *Bai and Perron* (1998) or *Bai and Perron* (2003) etc.). In the convergence literature, the *Lee and Strazicich* (2003) two-breaks LM test has been used by *Brüggemann and Trenkler* (2007) and *Cuñado and de Gracia* (2006) on a selected group of new member states.

Recently *Chrsitopoulos and Leon-Ledesma* (2009) applied the three steps test for a unit root in presence of multiple "smooth" unknown breaks proposed by *Becker et al.* (2006) to several output series and *Pascalau* (2008) applied a flexible LM variant of *Lee and Enders* (2006), to the *Nelson and Plosser* (1982) data set. This technique allows for breaks that are unknown in number, duration and form and as such it has some advantages to the alternatives listed above.

[24]i.e. unit root tests loose power if breaks are ignored.

Here we follow a variation on the *Chrsitopoulos and Leon-Ledesma* (2009) approach, which itself modifies the KPSS framework and models the breaks in the form of a non-linear Fourier expansion according to the model:

$$y_t = \delta_0 + \delta_1 \sin\left(\frac{2\pi kt}{T}\right) + \delta_2\left(\frac{2\pi kt}{T}\right) + \eta_t + \xi_t \tag{5.2}$$

$$\eta_t = \eta_{t-1} + u_t$$

where k is an estimated constant used to control the number of frequencies of the trigonometric function, $\xi_t \sim I(0)$ and u_t is independent and identically distributed with variance $\sigma_\eta^2 = 0$ under the null of stationarity[25].

In practice, we obtain the residuals from:

$$y_t = \delta_0 + \delta_1 \sin\left(\frac{2\pi kt}{T}\right) + \delta_2\left(\frac{2\pi kt}{T}\right) + v_t \tag{5.3}$$

Then we calculate a test statistic. *Becker et al.* (2006) calculate it as:

$$\tau = \frac{1}{T^2}\frac{\sum_{t=1}^{T}\hat{S}(k)^2}{\hat{\sigma}^2}$$

where $\hat{S}_t(k) = \sum_{j=1}^{t}\hat{v}_j$and $\hat{\sigma}^2$is a non parametric estimate of the true σ^2.

[25]Note also that it is also possible to test for trend stationarity augumenting the specification with a time trend - γt.

According to the authors there is a significant loss of power for high values of k and a mild size distorsion if δ_1, $\delta_2$or the sample size are small. The latter condition is quite restrictive in our case.

Chrsitopoulos and Leon-Ledesma (2009) on the other hand, perform a simple ADF based on the model:

$$\Delta \hat{v}_t = \alpha v_{t-1} + \sum_{j=1}^{p} \beta_j \Delta \hat{v}_{t-j} + u_t \tag{5.4}$$

setting the null hypothesis to $H_0 : \alpha = 0$ and simulating the limiting distribution of the test (labelled as FADF) with reference to the standard t-statistic $t_{ADF} = \frac{\hat{\alpha}}{s.e.(\hat{\alpha})}$.

Note that, even if this formulation allows a significant degree of flexibility[26], a generalised way of using a Fourier transform in a Dickey-Fuller setting would be:

$$y_t = \alpha(t) + \beta y_{t-1} + \gamma t + \varepsilon_t$$

$$\alpha(t) = \alpha_0 + \sum_{k=1}^{n} \alpha_k \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{n} \beta_k \cos\left(\frac{2\pi kt}{T}\right)$$

with $n \leq T/2$. This also means that our test is restricted to a single frequency with value given by k [27].

[26] *Pascalau* (2008) has a few examples

[27] *Becker et al.* (2006) suggest that a number of cumulative frequencies greater than two has the only effect of lowering the power of the test.

Table 5.2: Estimated k - SSRs

k \ Country	**cz**	**ee**	**hu**	**lt**	**lv**	**pl**	**sk**	**sl**
1	0.04*	0.93*	0.15*	0.65*	0.85*	0.18*	0.19*	0.12*
2	0.12	1.83	0.36	1.15	1.68	0.23	0.23	0.19
3	0.12	1.91	0.40	1.28	1.79	0.28	0.25	0.22
4	0.12	2.04	0.42	1.37	1.89	0.29	0.27	0.23
5	0.12	2.11	0.42	1.37	1.93	0.29	0.27	0.23

Note: * indicates minimum SSR.

Chrsitopoulos and Leon-Ledesma (2009) also suggest to model the residual (5.4) as a non-linear LTAR process and use the appropriate inf-t_{LTAR} statistic proposed by *Park and Shintani* (2005) to test for a unit-root. Although we see the opportunity of using a logistic transition function to measure the speed of mean reversion in relation to the current distance from steady state, we also acknowledge the contribution of *Choi and Moh* (2007).

In a comprehensive assessment of the power properties of 16 nonlinear tests for unit-roots – including *Park and Shintani* (2005) inf-t_{LTAR} – *Choi and Moh* (2007) conclude that in small samples ($T = 50$) the ADF test is comparable or outperforms all its competitors regardless of the true data generating process. We take this consideration as an indication not to expect significantly different conclusions on the existence of a unit-root, assuming a linear behaviour when the residuals are in fact non-linear.

If the disturbances are found to be stationary[28] *Chrsitopoulos and Leon-Ledesma* (2009) suggest to apply the F-statistic proposed by *Becker et al.* (2006) to test the presence of an unknown break. This conclusion is achieved imposing the trigonometric term in (5.2) equal to zero under

[28] If the opposite is true *Becker et al.* (2006) has low power and should be aviodeded.

Table 5.3: FADF tests

Country	k	FADF	p	Reject H_0?
ee	1	-1.08	3	no
lv	1	-1.38	4	no
lt	1	-0.23	6	no
hu	1	-1.23	4	no
pl	1	-0.37	4	no
sl	1	-0.92	0	no
cz	1	-1.73	0	no
sk	1	-0.39	4	no

Note: Leon-Ledesma et al. (2007) 5% critical value: -3.92. p: number of lags (SIC).

the null. The break is set to the alternative hypothesis i.e.:

$$H_0 : \delta_1 = \delta_2 = 0, \ H_1 : \delta_1 \neq 0 \cup \delta_2 \neq 0$$

The introduction of a trigonometric trend has the further advantage of correcting for potential cyclical components in the data. Since we are using higher frequencies in the time-series in comparison to beta-convergence, *Chrsitopoulos and Leon-Ledesma* (2009) is particularly appealing to us[29].

The frequency k is estimated in the range $k = 1, 2, ..., 5$ with reference to model (5.2) and the value returning the lower SSR is chosen: $k = \arg\min_{k \in [1,5]} (SSR_k)$ with $SSR_k = \sum_{i=2}^{T} (v^2)$. Not surprisingly the optimal frequency in the given set proved to be the unity (see Table 5.2).

The FADF statistic calculated on the residuals u_t for $k = 1$ and $y_t = g_t$ (the dependent variable is the difference of the log outputs) is reported in Table (5.3) whilst the Fourier series and the estimated disturbances are plotted in Figure (5.5).

[29] a periodic function should be able to capture residuals fluctuations - either cycles or seasonalities - in the series.

The clear result is that all the v_t series for every country under investigation are non-stationary and following *Choi and Moh* (2007) we extend this conclusion to the inf-t_{LTAR} test. This not entirely surprisingly giving the dynamics of the series plotted in Figure (4). We interpret the non-stationary residuals as evidence of no breaks in our series for the given sample and we note they tend to be stationary around a (negative) linear trend as far as $k \rightarrow 0$ and $k < 1$. In the impossibility of running a reliable F-test, we interpret this behaviour as an alternative to *Becker et al.* (2006).

Given the results from the first exercise, we also attempt a slight modification. This time we allow a different value for k in the sine and cosine (see eq. 5.3) allowing it to vary between 0 and 2 at steps of 0.1. Further we shift the period of investigation back to 1990 - 2004, in order to capture the early nineties break and leaving the post-enalrgement period outside the sample. For simplicity and ease of comparison we use annual Penn World Tables data. The results are reported in Figure (5.5) .

If we assume output declined in the eastern european economies during the period 1990 - 1995, we do not expect a break in the series representing the deviation from the group mean. However, this is not the case for some of the economies included in the picture, particularly some Baltic states (EE, LT). Visual inspection seems to suggest residuals may now be stationary in the majority of our cases[30] although we should not formally compare our results with FADF critical values to exclude the existence of a unit root in the output-differential series[31] since *Chrsitopoulos and*

[30]The only notable exception seems Hungary.
[31]i.e. testing for stochastic convergence.

Figure 5.4: Smooth breaks: $k = 1$

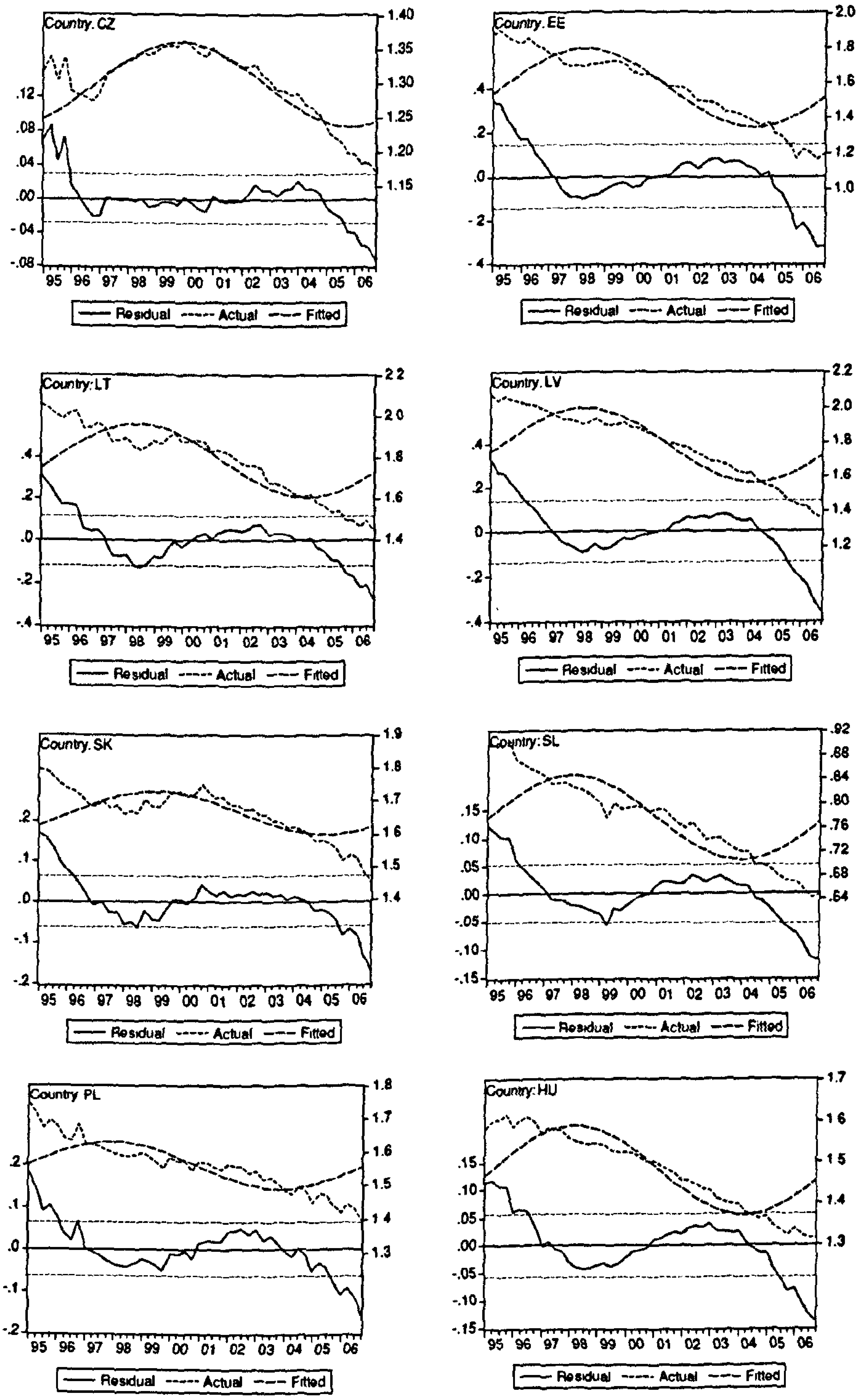
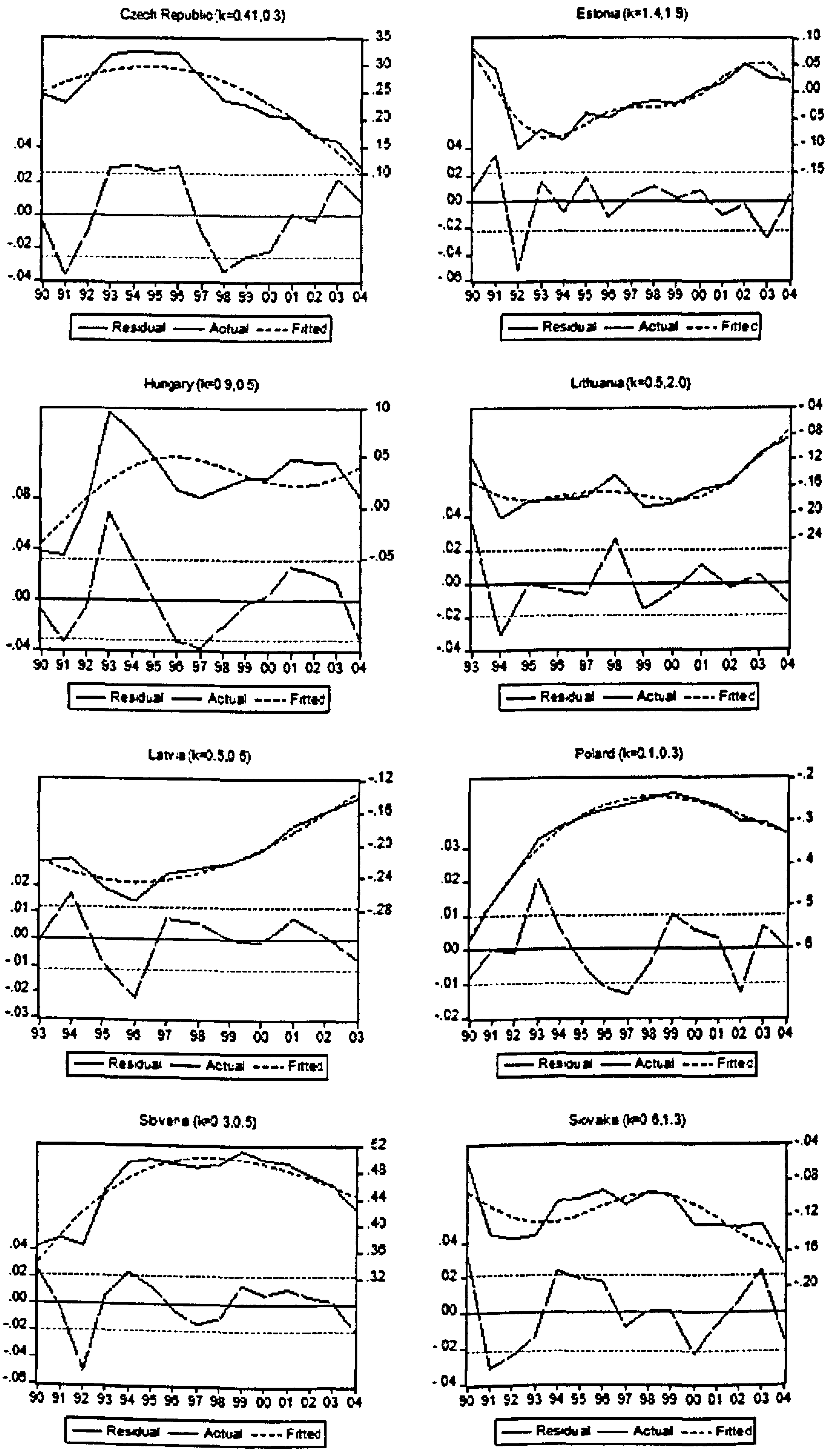


Figure 5.5: Smooth breaks $k_{1,2} \in (0, 2]$



Leon-Ledesma (2009) simulated the test only for integer values of k without controlling for separated values in the sinus and cosinus.

The lesson we learned from our results is that the *Chrsitopoulos and Leon-Ledesma* (2009) procedure has better performance in large samples with low frequency data potentially showing some cyclical behaviour, rather than small samples and/or higher frequencies where seasonalities are removed a priori. We also use this finding as evidence against the presence of cyclical components in our data. The analysis fails to identify significant breaks in the NMS10 output and in the time-span covered by our sample. At this stage, we take this as evidence against an "enlargement" effect[32] and in support of our empirical results in chapter 4 and the beginning of this chapter.

5.3 Panel data tests for convergence

The unit-root evidence we have collected gives a weaker sense of convergence between new and old EU members, if compared with beta regressions. We also know that structural breaks are not likely to compromise our results and stochastic unit-root slightly altered our list of converging economies. In these circumstances, it is challenging to draw a unique conclusion about convergence between the entire NSM8 group and the EU15s, that is not only a subjective judgement. As such, we need to introduce some more advanced statistics to progress in our empirical investigation. Panel data appear very convenient in this sense, so in the

[32] i.e. a sudden acceleration in output around the accession date - May 2004.

next sections we will try to extend the unit-roots and cointegration tests we used so far, to the longitudinal dimension. The econometric literature that deals with these issues is still relatively new, but has recived an enormous boost in the recent years. We will start looking at unit-roots and, in particular, we concentrate on second-generation tests since these were developed with the target of excluding potential cross-section correlations.

5.3.1 Panel unit-roots

Even within the group of second-generation tests for unit-roots in panel data many alternatives exist. Among those we choose *Pesaran* (2007), in particular for the good power he reports in small samples. A comprehensive review of the different approaches to unit roots in panels is available in *Hurlin and Mignon* (2007), *Gengenbach et al.* (2004) or *Giulietti et al.* (2006).

The model we use in our tests is an extension of the fixed unit-root tests we introduced in chapter 4 [33]. We present the statistical details and then we apply them to the EU enlargement. Given:

$$\Delta y_{i,t} = \alpha_i + \gamma_i t + \delta_i y_{i,t-1} + \beta_i \bar{y}_{t-1} + \sum_{j=0}^{p} \varphi_{i,j} \Delta \bar{y}_{t-j} + \sum_{j=1}^{p} \rho_{i,j} \Delta y_{i,t-j} + u_{i,t} \quad (5.5)$$

[33] Adding lags of the dependent variable to correct for potential correlation in the residuals result in insignificant coefficients in the AR(p) terms.

with, p number of lags, $i = 1, 2, ..., N$, $t = 1, 2, ..., T$, $\bar{y}_t = N^{-1}\sum_{j=1}^{N} y_{j,t}$ and $u_t \sim i.i.d(0, \sigma^2)$.

For every unit, the t-statistic is given by:

$$t_i(N,T) = \frac{\hat{\delta}_i}{s.\hat{e}._i(\hat{\delta}_i)}$$

Where $\hat{\delta}_i$ is an OLS estimate from equation (5.5). The $CADF_i$ limiting distribution is simulated by *Pesaran* (2007), who also shows that, for $T > 20$, the panel statistic is a cross-sectionally augumented IPS of the form:

$$CIPS(N,T) = N^{-1}\sum_{i=1}^{N} t_i(N,T)$$

At first, we test the null hypothesis of a unit root in a panel of ten accession countries ($N = 10$) and 48 observation ($T \sim 50$ - 1995.1 to 2006.4) with reference to the difference between their GDP per capita and the EU15 aggregate. This is equivalent to test the stochastic convergence hypothesis in a panel framework. Formally, if we cannot reject the null hypothesis:

$$H_0 : \delta_i = 0, \ \forall i \in 1, 2, ..., N$$

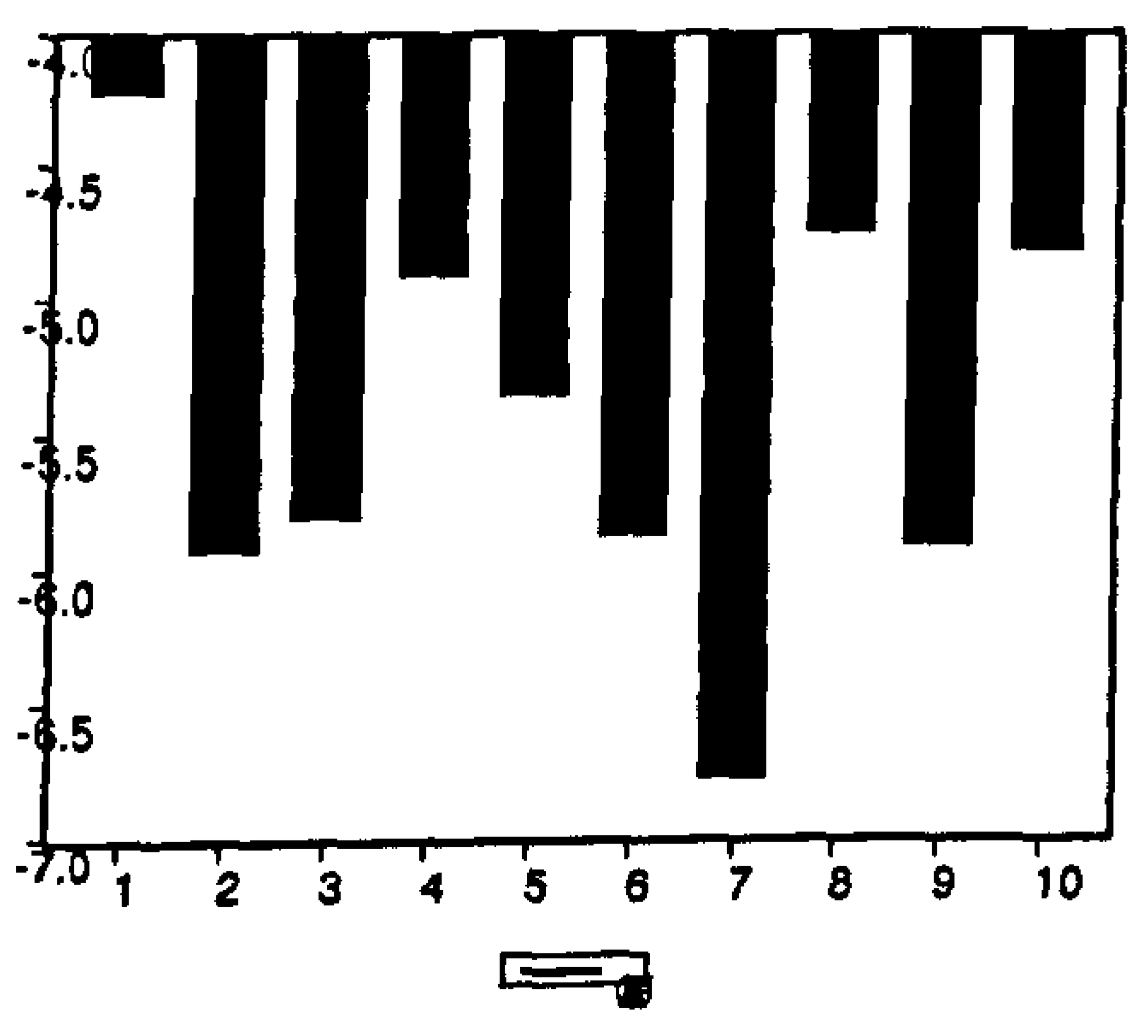
all series in the panel are $I(1)$, indicating non-convergence for all countries. Under the alternative hypothesis, at least one unit must be $I(0)$, hence some convergence in the panel.

Country	Code	$t_i(N,T)$
ee	1	-4.21785543932
lt	2	-5.92164681233
lv	3	-5.80220831226
cz	4	-4.91082425049
sk	5	-5.35089135117
cy	6	-5.86956929557
mt	7	-6.77656284582
pl	8	-4.75486737776
hu	9	-5.91901500589
si	10	-4.82640298288

Table 5.4: Pesaran (2003) t-statistics

Preliminary results are reported in table (5.6).

Figure 5.6: Pesaran (2003) panel unit-roots



Note: critical values -4.29 (1%), -3.70 (5%), -3.39 (10%).

With the country codes and individual $t_i(N,T)$ reported in table (5.4). Note how in principle the test is similar to pure unit-roots although, given the ad-hoc limiting distribution, we cannot draw intermediate[34] conclusion as in chapter 4.

Given the critical $CADF_i$ values reported in Table (5.4), the null of a unit

[34] i.e. on single countries

root is rejected at 1% for the majority of countries ($|t_i(N,T)| > |CADF_i|$)[35]. Note that these results, although usable for the aggregate statistic, are not a good indicator for convergence between individual countries and the old memners aggregate. However a similar result is obtained on aggregate using the panel $CIPS$ statistic:

$$CIPS = -5.43498436735$$

Having rejected the null of a unit root, we conclude for some convergence in GDP per capita, that is between at least one the NMS10 and the EU15 aggregate.

Therefore we repeat the exercise with a longer dataset ($T = 52$, 1995.1 - 2007.4), excluding Malta and Cyprus from the analysis, so it is easy to compare our results with cross-section evidence in previous sections. We also add one lag to our specification and we introduce the possibility of removing the time trend.

As shown in Table (5.5), this time we cannot reject the null hypothesis of a unit-root, therefore we conclude for no convergence in all countries. Note that $\bar{t}$ is the mean of of each unit individual ADF t-statistics as in Pesaran (2003), the $Z(\bar{t})$ is a standardised $\bar{t}$ which has a normal distribution and also allows for unbalanced panels as in Lewandowski (2006). Test decisions are based on a comparison with non-standard critical val-

[35]Being an avarage measure, the country rejecing more strongly the null of a unit-root, tend to push the entire group towards rejection. The same would be true for counties strongly not-rejecting but this is not the case in the particular example. Eventually, a weighted average can be used to tackle the problem.

Table 5.5: Peasran (2007) t-statistics (1995.1 - 2007.4)

Variable	g_t	g_t
Obs.	400	400
N	8	8
T	52	52
Lags	1	1
Deterministics	const	const+trend
Seas Adj.	yes	yes
C.V. 10%	-2.210	-2.720
C.V. 5%	-2.330	-2.830
C.V. 1%	-2.540	-3.040
$\bar{t}$	-1.961	-3.178
$Z(\bar{t})$	-0.557	-2.722
p-value	0.289	0.003*

* denotes rejection of the null hypothesis.

ues[36] for $\bar{t}$ and calculation of p-values for $Z(\bar{t})$. The test equation was augumented in order to deal with autocorrelation.

These results are not totally surprising, given the evidence we collected at the national level and are what we expect with a longer dataset improved specification and excluding MT and CY[37]

For the sake of comparison, we also attempt another widely used panel unit-root test: *Hadri* (2000). Here, all the eight series in the panel are stationary processes under the null hypothesis. Further, the LM test is performed assuming: homo/heteroskedastic disturbances accross units and controlling for serial dependence in errors.

Results are summarised in table (5.6). This time we reject the null quite strongly so, once again, there is no evidence in favour of overall con-

[36]See Pesaran (2003).

[37]These are small countries and we feel their per capita series may not correctly reflect the behaviour of other NMS8 countries.

Table 5.6: Hadri (2000) panel unit-root

Variable	g_t	g_t	g_t	g_t
Seas Adj.	no	no	yes	yes
Test stat	Z_μ	Z_τ	Z_μ	Z_τ
Homo	87.78*	18.07*	88.34*	61.74*
	(0.000)	(0.000)	(0.000)	(0.000)
Hetero	86.06*	20.9*	83.68*	51.45*
	(0.000)	(0.000)	(0.000)	(0.000)
SerDep	30.81*	15.1*	29.89*	21.75*
	(0.000)	(0.000)	(0.000)	(0.000)

* denotes rejection of H_0.

vergence, since at least one of the log differences in the panel is non-stationary.

5.3.2 Panel cointegration

Our preliminary tests suggest a scarce support to convergence on individual-country basis. Probably, we should read this result as a sign that the aggregate NMS8 output relative to EU15 has no tendency to absorb shocks. However, since in chapter 4 we used cointegration tests to double check our unit-roots results[38], we feel that a similar exercise would be useful even when using panel data. In section 4.3 we discussed how cointegration can be tested either using the Engle-Granger or the Johansen approach. The second however, has the advantage of dealing better with multiple co-integrating relations and therefore can be easily used in a multy-country setting. On the other hand, unit-roots tests on output differences can also be used to deal with multiple countries in a panel framework. Further, this is probably a better choice if the interest is absolute

[38]and this way we introduced some increased evidence in favor of convergence

convergence.

Given these considerations, the question becomes whatever is needed to consider panel cointegration tests to deal with output convergence in multiple countries.

Instead of searching for $N - 1$ cointegrating relations in N countries, the strategy would be to construct two panel series[39] and look for a single co-integrating relation between the two.

By its very nature, this exercise seems a bit suspicious: whilst it is possible to construct a panel series of a convenient group of countries, a benchmark series would not be equally easy, as it would consist mainly of the same data in the time dimension replicated in all units of the panel. Adding more than two series would not be feasible either, since in a panel structure these are expected to be new variables rather then new countries, which are now relegated into the longitudinal dimension. The main advantage of the Johansen approach (dealing with multiple cointegrating relations) seems unusable in a panel context.

In practice, these considerations make *Maddala and Wu* (1999) less interesting than, for example, *Pedroni* (1999) or panel unit roots tests for the pourposes of this chapter[40]. Further, it might make sense to consider carefully the issue of cross-country correlation and adopt second generation tests.

[39]i.e one for per capita GDP of new EU members and the other with a benchmark GDP per capita.

[40]However, the test will still be usefull in chapter 6, for testing cointegration between two different variables relevant to the same set of new EU members. Hence the formalisation of Pedroni (1999) in the next paragraphs.

Finally, *Pedroni* (1999)'s paper is interesting in the sense that he distinguishes between homogeneity and heterogeneity in the way he writes the alternative hypothesis on the unit roots of the estimated residuals. Whilst the null is fixed to no-cointegration, the alternative varies between no unit roots in all (homogeneous convergence across all countries) or in some (heterogeneous convergence in some countries) members of the panel.

Given these considerations, we formalise *Pedroni* (1999) in this chapter, but we apply a variant of its test that is introduced later in this section. In short, *Pedroni* (1999) extends the *Engle and Granger* (1987) cointegration test to panel data. For example given the following panel regression (with N units):

$$y_t = \alpha_n + \delta_t + \sum_{k=1}^{M} x_{k,n,t}\beta_k + \varepsilon_{i,t}$$

for $t = 1, 2, ..., T$, $n = 1, 2, ..., N$ and $m = 1, 2, ..., M$. With a single explanatory variable, no constant or trend simply:

$$y_t = \beta x_{n,t} + \varepsilon_{n,t} \tag{5.6}$$

The null hypothesis of no cointegration, i.e.

$$H_0 : \hat{\varepsilon}_{n,t} \backsim I(1)$$

is tested with reference to the auxiliary regression:

$$\hat{\varepsilon}_{n,t} = \rho_i \hat{\varepsilon}_{n,t-1} + u_{n,t} \tag{5.7}$$

looking for a unit-root, so that:

$$H_0 : \rho_n = 1$$

i.e. non-stationary residuals in equation (5.6).

In a panel setting it is easy to the alternative hypothesis can be formulated either as

$$H_1 : \rho_n = \rho < 1$$

i.e. an homogeneous root lower than one (the within-dimension), or more generically as:

$$H_1 : \rho_n < 1, \ \forall i$$

i.e. an heterogeneous root lower than one (different in every unit, the between-dimension).

To calculate the test statistic however, Pedroni looks also at the difference regression:

$$\Delta y_{n,t} = b \Delta x_{n,t} + \eta_{i,t}$$

and calculates the long-run variance of $\hat{\eta}_{n,t}$ (called $\hat{L}^2_{11,n}$) using kernel estimation.

We can now apply the same rationale to output series and use cointegration to test convergence. Formally, we can extend equation (4.12) to a panel of $n = 1, 2..., N$ countries, where i and j should denote the chosen and benchmark outputs:

$$\log y^i_{n,t} = \beta_n \log y^j_{n,t} + \varepsilon_{n,t}$$

the estimated residuals are tested for stationarity using the usual DF/ADF specification:

$$\hat{\varepsilon}_{n,t} = \log y^i_{n,t} - \hat{\beta}_n \log y^j_{n,t}$$

$$\hat{\varepsilon}_{n,t} = \rho_n \hat{\varepsilon}_{n,t-1} + \mu_{n,t}$$

The null hypothesis is set to no cointegration (non-stationary residuals in all units). Under the alternative, the unit root is less than one and the same in all u nits under homogeneous cointegration (within-dimension / panel statistics):

$$H_0 : \rho_n = 1, \forall n \ , \ H_1 : \rho_n = \rho < 1$$

Or less than one but different across units (heterogeneous cointegration/ between-dimension / group statistic):

$$H_0 : \rho_n = 1, \forall n \quad , \quad H_1 : \rho_n < 1$$

Clearly, the major difficulty is to choose the benchmark output series. As we know, this can be done assuming $\log y^i_{n,t}$ is e.g. the log per capita output in the different members of the panel and $\log y^j_{n,t}$ is a log per capita benchmark output which, intuitively would have the same values across all units. Note that having a different benchmark for every country can be an excessive generalisation. In fact, rejecting non-cointegration, panel members would all share a long-run relation with their benchmark. Differently, the benchmark should be unique for every country in order to infer the idea of some common convergence within the area.

As anticipated, we now propose an application to NMS8 convergence based on an alternative to the panel cointegration tests mentioned so far, proposed by *Nyblom and Harvey* (2000)[41]. In the specific case, the null hypothesis is set to no common trends among the members of the panel. Under the alternative, the units of the panel should have at least a common trend but potentially more. One again the test may be not very informative for a large number of units[42]. However, in much of our

[41]Note this is a test of the rank of the covariance matrix of the disturbances driving a multivariate random walk, and strictly speaking is not a panel-data test. However, the methodology here, is very close to the original Bernard & Duralf contribution (differently from the pairwise tests in chapter 4), except it does not use the Johansen's framework. Further, another advantage of this test is it does not require any models to be estimated, even if serial correlation is present.

[42]i.e. in this situation a panel version of Johansen would be more appropriate.

application we are essentially comparing a given series (output in new members) with a benchmark series (output in the old members) so the test is probably good enough[43] for this case. Table (5.7) describe the results of the test.

Note that, in the table, t_1 assumes *iid* random-walk errors, t_2 a non-parametric adjustment for the long-run variance, g_t is a series describing the deviation of NMS8 output from the EU15 aggregate, and y_t per capita output. Seasonalities are irrelevant.

In all cases we reject the null hypothesis, so there is at least one common trend among the eight series in the panel. This means the series share a long run trend - i.e. they converge in the *Bernard and Durlauf* (1995) sense. This is not surprising, when we look at the deviation from the same trend (EU15), but the conclusion holds for per-capita output series too. The difficulty, however, is counting the number of common trends under the alternative[44]. As such, we take this conclusion only as a mild evidence of convergence to a common trend, confirming more or less what we knew from the unit-root analysis: it is likely that some new members converge to the output levels of the new members, but it is also very likely that the mechanism involves only a subset of the NMS8 group[45].

[43]i.e. the number of units is small.

[44]Although the limiting distribution should be re-simulated, in principle the test allows to specify the rank of the covariance matrix of the disturbances driving the multivariate random walk under the null. In the particular case, this is set to zero or no common trends. A rank greater than zero leave us uncertain between zero (no cointegration) and an undefined number of common trends under the alternative.

[45]i.e. a smaller "club" of converging economies

Table 5.7: Nyblom-Harvey tests

Deterministics	const	const+trend	const	const+trend	const	const	const+trend	const	const+trend
Variable	$log(g_t)$	$log(g_t)$	y_t	y_t	$log(y_t)$	y_t	y_t	$log(y_t)$	$log(y_t)$
Seas. Adj.	no	no	no	no	no	yes	yes	yes	yes
C.V.s ($N=8$)									
10%	1.8710	0.6897	1.8710	0.6897	1.8710	1.8710	0.6897	1.8710	0.6897
5%	2.0687	0.7442	2.0687	0.7442	2.0687	2.0687	0.7442	2.0687	0.7442
1%	2.5208	0.8686	2.5208	0.8686	2.5208	2.5208	0.8686	2.5208	0.8686
Test stats									
t_1**:**	7.0681	2.0214	7.0516	2.0850	7.1025	7.2742	2.2417	7.2613	2.2437
t_2**:**	2.6627	0.9054	2.6667	0.9115	2.6695	2.7183	0.9754	2.7087	0.9743
Reject H_0?	yes	yes	yes	yes	yes	yes	yes	yes	yes

5.4 Conclusions

Across this chapter we have tried to improve our understanding of the state of convergence between new and old members of the European Union. A better specification of the transition dynamics, tested using stochastic unit roots models, allowed us to add a few countries to the list of converging new members. We also noted that, during the last decade, no significant breaks altered the behavior of output series or invalidate our early results. The biggest challenge proved to a find a single conclusion about the state of stochastic convergence between the NMS8 and EU15 block. Panel unit-roots and multivariate cointegration tests were used to test this possibility and in general gave a negative answer. However, the conclusion that some new members were individually converging remains and, whether statistics suggest that this should be safe enough to conclude for aggregate convergence of the eastern block, it is probably more sensible to think in terms of smaller groups of converging economies.

Chapter 6

The role of international trade

GIVEN the evidence in support of short-run beta-convergence in previous chapters, and the partial support in favor of stochastic convergence, we now try to assess whether this process may have been significantly facilitated by international trade. This is a possibility not accounted for in the standard neoclassical model, nor deeply investigated in the enlargement literature, but one which can potentially explain the differences we observe across countries. We begin with some background discussion to clarify various theoretical and empirical issues.

6.1 Background

A natural question in the mind of the researcher measuring the degree of output convergence associated with the fifth EU enlargement, is whether this is a consequence of the integration process. The answer is not obvious, especially if thought of in terms of neoclassical (Solow-Swan) or endogenous (Arrow-Romer) growth theories only. In this chapter, we focus on a process of integration characterized by a substantial degree of trade liberalization as has been the case for the 5th EU enalrgement.

There has been some theoretical endorsement of the importance of international trade in output convergence and economic integration - e.g *Rivera-Batiz and Romer* (1991), *Ben-David and Loewy* (2003), but scarce support from the empirical literature. Whether or not the theoretical argument is strong, empirical confirmation has been difficult to obtain. The hypothesis has been tested under a variety of different points of view and methodologies: lately *Dollar* (1992), *Sachs and Warner* (1995), *Edwards* (1992) focused both on the research of an optimal indicator of trade openness and on its relation with economic growth, whilst *Ben-David* (1993) tests convergence pre and post liberalization. In general, these authors suggest that trade can stimulate growth. On the other hand, there is also a significant branch of the literature dedicated to prove the opposite. All of the four last-mentioned papers were strongly challenged by *Rodriguez and Rodrik* (1999) on the main consideration that "measures of trade barriers are often correlated with other growth-inhibiting factors" and “trade policy indicators that have been used in the empirical literature are not particularly good”[1] . In a more recent paper, *Rodriguez* (2007) also responds to comments[2] on his original 1999 critique and the contributions of *Wacziarg and Welch* (2003) , *Warner* (2003) and *Dollar*

[1]See *Dollar and Kraay* (2004).
[2]See for example *Jones* (2001).

and Kraay (2004). He maintains the view that the new evidence still does "not alter the conclusion that standard measures of trade policies are basically uncorrelated with growth".

Among all these options, we will concentrate on the *Ben-David* (1993) approach, and the *Rodriguez and Rodrik* (1999) and *Rodriguez* (2006) critiques. In particular, the first author uses as theoretical background the factor prices equalization theorem (FPE) by *Samuelson* (1964) and *Helpman and Krugman* (1985). He also refers to the neoclassical growth theory as a source of explanation for convergence, when trade has no impact on reducing income disparities among countries. In a later paper, *Ben-David and Loewy* (2003) augment the Solow approach to take into account the impact of international trade developing, de facto, an endogenous growth alternative[3]. We believe the second attempt has greater relevance in our particular context. The *Ben-David* (1993) approach, however, is mainly empirical. It focuses on measuring the state of convergence in two post-liberalization and pre-liberalization sub-periods with reference to EU countries after the second World War, between 1950 and 1985. In contrast to the experience of the founding countries, the process of trade liberalization followed by the new members of the EU in the last 10 years has been relatively smooth with no clear break date. Moreover, country-specific accession agreements, were negotiated on individual bases[4]. In this context it is obviously challenging to identify a

[3]Trade becomes technology-enriching, so that the latter is not exogenous to the model anymore.

[4]Note this consideration does not exclude the possibility that intra-group trade may have increased during the period under investigation. See e.g. *Spies and Marques* (2009).

unique divide between liberalization and non-liberalization making this part of Ben-David's methodology difficult to replicate[5].

6.2 Trade and convergence

Since part of the existing research confirms some degree of convergence between old and new members[6], the considerations above suggest the fifth round of EU enlargement offers an opportunity to test the impact of trade on output. Investigating the role of trade can also give some indications of whether the process of integration between the old EU members and the new eastern European economies, stimulated convergence between these groups of countries.

Similarly to Figure III in *Ben-David and Loewy* (2003), we start observing the impact of integration on trade by inspecting the share of imports from inside EU and the rest of the world over GDP - see Figure (6.1).

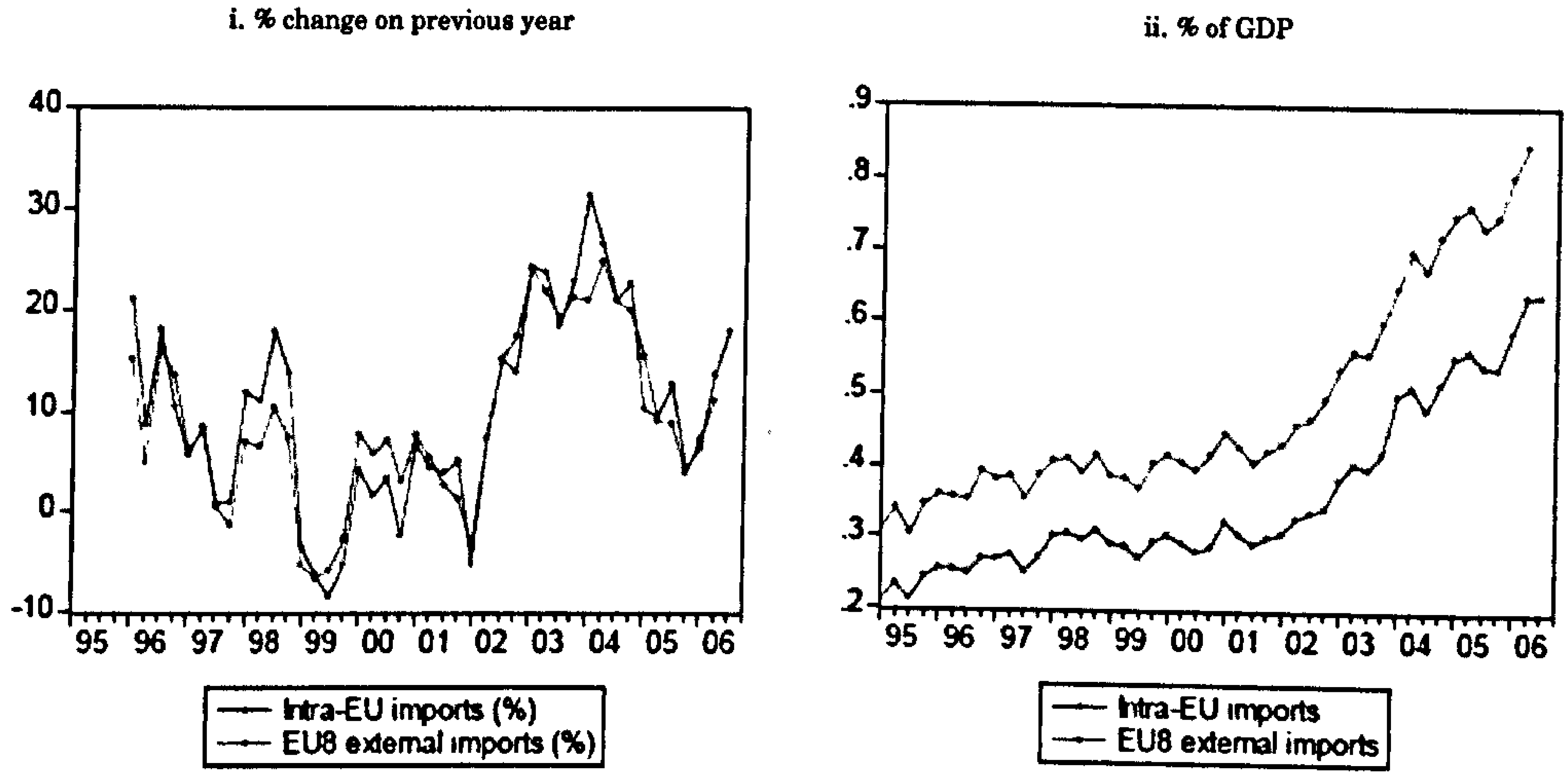
The dynamics of the two series appear to be similar, possibly sharing a common trend, albeit different in levels, with a constant difference between the volumes of imports from the two regions[7]. A break in trend is identifiable around 2002. Considering that the full EU membership of these economies started in May 2004, the acceleration of imports anticipates the political integration. This behavior does not appear entirely

[5] We will see later that, in these circumstances, it is more convenient to focus on trade volumes. Much of Ben-David contribution, however, is still useful to our research, as detailed in next sections.

[6] See chapter 3, or our own conclusions in chapters 4 and 5.

[7] The old EU members in the case of intra-eu imports and rest of the world for external imports.

Figure 6.1: Ratio of NSM8 imports to GDP



surprising, given that trade in the majority of sectors was already liberalized at that date for all NMS8. We note this preliminary evidence as a sign that integration has produced a beneficial effect on trade and we move one step forward looking at its influence on output in the area.

6.2.1 A closer look at Ben-David (1993)

The choice of *Ben-David* (1993) was to use the sigma-convergence[8] concept to measure income dispersion during the initial pre and post trade liberalization periods of the EU6[9]. However, as we know from chapter 4, the time-series literature has developed an alternative formulation of convergence introduced by *Bernard and Durlauf* (1995). The aim of this section is to link the two perspectives, adding additional elements to *Rodriguez and Rodrik* (1999). The original *Ben-David* (1993) argument can be re-interpreted as following:

[8]i.e. the decline in time of the variability of output accross a set of countries is seen as convergence. For its relation with beta-convergence see e.g. *Young et al.* (2007).
[9]Belgium, France, Italy, Luxembourg, the Netherlands, and Germany.

Firstly, the central argument of Ben-David is that, following TFP arguments in *Balassa* (1964) and *Samuelson* (1964), when the degree of trade liberalization increases then convergence should occur. Following this logic, when convergence is confirmed among a set of liberalizing countries, if we can exclude other factors, then its determinant should be free trade. Starting from the assumption that a set of countries liberalised at a set point in time, the only thing that is left is measuring convergence. However, if this assumption of simultaneous trade liberalisation is difficult to substantiate simply by looking at historical policy changes, it is still possible to measure the degree of effective trade expansion[10]. This is not what Ben-David was doing in his original paper but, given the higher heterogeneity in the timing of their trade agreements with the old EU members, it seems the better option for the NMS8. This way we can also introduce time-series techniques and test the direction of the causal relation between GDP per capita and trade openness.

Secondly, *Ben-David* (1993) uses the dispersion of relative income as a measure for convergence (sigma-convergence). The link between relative incomes can be explored more generally in terms of its long-run dynamics using the concepts of stationarity and cointegration.

Finally if, as already mentioned, the process of liberalization is diffused in time[11], it can be sufficient to observe that the degree of trade liberalization and the output are moving in the same direction (i.e. sharing a long-run / cointegrating relation) and that the direction of causality be-

[10]measured using the conventional indicator of openness given by total trade over output as in *Frankel and Romer* (1999).

[11]i.e. making it difficult to clearly identify a pre- and post-liberalization stage

tween the two variables goes from the first to the second.

We refer to the last concept as "smooth" trade liberalization. In the next sections we try to apply this approach to the EU enlargement.

6.2.2 Relevance to the EU enlargement

We know that some research on the state of convergence in the new member states during the last decade already exists[12]. Also, if this period is seen as subdivided into pre- and post-liberalization episodes, then the results of these studies can be interpreted in the *Ben-David* (1993) view as positive or negative evidence of the impact of trade on convergence. An example is *Ingianni and Zdarek* (2009). The authors apply sigma and time-series based tests of convergence to eight EU economies in the period 1995-2006. They further subdivided the sample in two parts 1995-2002 and 2002-2006 and find positive evidence of sigma-convergence, which could be potentially explained by increasing trade volumes between EU15 and NMS8.

Another important assumption of *Ben-David* (1993) is the idea that the only driving factor of convergence is trade liberalisation and "all its other determinants can be excluded". This last consideration is very dependent on the specific framework he was referring to and it may be difficult to generalise. However, using the concept of causality as detailed in section (6.3.1) allows a more generic formulation which also captures the effects of other factors potentially involved in the determination of convergence.

[12]See Chapters 3 to 5.

Clearly some considerations cannot be applied to our particular case. The *Ben-David* (1993) context differs from the enlargement context in the consideration of at least a few points. At the time he considers:

1. Convergence in the EU was a new trend emerging after the liberalization.
2. Countries not joining the free-trade agreement did not experience the same levels of convergence with the EU liberalising countries.
3. Other not-integrated economies around the world did not experience the same levels of convergence among themselves in the same period of time.
4. The contribution of other factors to EU convergence was not as relevant as trade liberalization.

The first three were explicitly criticized by *Rodriguez and Rodrik* (1999); we are going to analyse their relevance for the EU enlargement.

The general consideration is that, since it is difficult to identify a pre- and post- liberalization period in the last decade for the new members, it is also difficult to test condition (1) exactly in the same way as *Ben-David* (1993). An alternative could be expanding the period of time under investigation (e.g. pre 90s) although empirically it represents a big challenge[13]. The Rodriguez critique focusses on the identification of a long run trend in convergence in the pre liberalization era. It is argued that

[13]For example under the perspective of data availability, reliability and disaggregation for accession countries.

the choice of countries in the original empirical exercise biases its final results. Clearly, the context is very specific and it is likely that the critique does not apply in other situations. We note that, in the light of existing literature on convergence, it also makes sense to try a different approach to the identification of the trend. An often used alternative, which we are going to use in the next sections, is cointegration. This choice however carries the modified definition of output convergence introduced in chapter 4.

Regarding point (2) *Rodriguez and Rodrik* (1999) argue that the state of convergence is measured in *Ben-David* (1993) using the group of non-liberalizing instead of the liberalizing countries as a benchmark. Following a stricly "neoclassical" perspective discriminating between the two may be conceptually difficult if we assume multiple steady states are associated with one choice. Emipirically however, it would be possible to follow Rodriguez suggestions using different methodolgies, although we feel time-series techniques - i.e. *Bernard and Durlauf* (1995), can be more flexible in accomodating multiple steady states. An alternative solution proposed by *Rodriguez and Rodrik* (1999) was a simple correction of the sigma statistic. For the EU enlargement case, comparing with other countries would probably mean relying on Eastern economies which did not benefit from free trade agreements in the period 1995 - 2006. Because of the peculiar mechanism of accession, this group excludes economies at different stages of negotiation which can have already lowered tariffs in specific sectors , making the empirical exercise quite challenging.

Point (3) is criticised by Rodriguez on empirical grounds, mainly on the consideration that there is "asymmetry in [the] selection of diverging and converging areas". Convergence and divergence is seen as a function of geographical distance and the original conclusion is reversed when looking at East Asian and Latin American countries. As usual, we note that convergence can be measured using a different methodology. Moreover, trying to prove (3) in our context would mean extending the Ben-David analysis to period 1995 2006 with potential empirical difficulties.

Point (4) is one of the strongest assumptions of Ben-David and must be considered carefully. In particular, in the case of the EU enlargement there might be other factors which were not fully relevant for the old members of EU (FDI, migration, labour mobility, reallocation of production units, etc... - see for example *Ghatak et al.* (2009).

6.3 Empirical Analysis

This section aims to address some of the issues discussed above by introducing an alternative empirical methodology. This is applied to the fifth EU enlargement, with results reported in section (6.3.2).

6.3.1 Methodology

An interesting exercise, which is not explicitly considered in the literature cited above, consists of testing the relation between trade and output using causality tests. This is a commonly applied methodology in empirical work based on time-series data - see e.g. *Liu* (2009), and we believe it can help the debate[14].

As in the case of regressions-based exercises, the choice of a meaningful indicator for trade openness is an important, preliminary issue. Among the existing alternatives mentioned in section (6.1), we note that the case of NSM8 countries offers little choice. *Dollar* (1992) real exchange rates distortion and variability indexes should be avoided because the heterogeneous transition towards fixed exchange rates (ERMII) of the countries under investigation. The *Sachs and Warner* (1995) or modified *Wacziarg and Welch* (2003) dummy can be calculated only assuming a reliable measure of all its components[15] is readily available for all new member states. Similar difficulties arise for all the nine openness indicators surveyed by *Edwards* (1998). The most convenient choice appeared to be using an indicator similar to *Frankel and Romer* (1999) and relate per capita income with trade share (to EU) in the eight new members. Note that this paper has been criticized by Rodriguez based on considerations similar to what we reported in section 6.2.2 point (3). However, the methodology we are using is quite different and unaffected by geographical components[16], so we calculate the degree of openness as the ratio of import and exports over GDP for every country.

[14]See also *Zaman* (2008).

[15]Average tariff rates, non tariff barriers as % of imports, socialist economic system, state monopoly of exports, black market premium during the 70s and 80s.

[16]An alternative way of extending the analysis considering the role of distance as long as the geo- graphical diversication of intra/extra regional trade, would be using some indicators of revealed trade preferences / relative geographic diversication and correcting for bilateral trade differences as recently proposed by *Iapadre and Tironi* (2009).

In particular, we propose a three-steps testing procedure.

Firstly (**Step 1 or S1**), we test for cointegration[17] between openness and per-capita GDP. For individual countries, a single relation between these two variables implies they share a long-run relation (a stochastic trend).

Secondly (**Step 2 or S2**), we test for causality[18] between openness and per-capita GDP. This allows us to understand whether the long run relation identified in step 1 is driven by the first or the second variable[19]. This way we can determine whether, in each of the new EU members, current values of their per capita GDP are determined by past levels of intra-EU openness or vice-versa.

Finally (**Step 3 or S3**), we test for cointegration between new EU members' individual per-capita GDP and the EU15 average GDP. If also this last condition is satisfied, new members are stochastically converging[20] to old members (S3) and convergence is caused by trade openness (S1 + S2).

We repeat these three steps for all eight new members and we also look at aggregated results using panel-data cointegration and causality tests. Results will be discussed in section (6.3.2). Before progressing however, it is important to discuss formally the way we use the concept of causality[21].

[17]We follow *Johansen* (1991)'s definition, defined formally in chapter 4.

[18]We will use *Granger* (1969) as detailed below. Note that in this context it may also be relevant to consider the *Mosconi and Giannini* (1992) or *Yamamoto and Kurozumi* (2006) tests for non-causality. See also *Granger* (2001).

[19]Note that it is also consequence of the Engle-Granger representation theorem that, if cointegration exists, there must be causality between the two variables.

[20]See chapter 4.

[21]The concept of cointegration, including cross-section and panel tests, is discussed in chapters 4 and 5.

Our reference framework is *Granger* (1969). Using the same notation of chapter 4, consider the unrestricted VAR(p):

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + ... + A_{p-1} y_{t-(p-1)} + A_p y_{t-p} + Bx_t + \varepsilon_t \tag{6.1}$$

with $\underset{(1,k)}{y} = [y_1, y_2, ..., y_k]$ a vector of dependent variables[22], $\underset{(1,d)}{x} = [x_{1,}, x_2, ..., x_d]$ a vector of deterministic components[23], A_j the coefficient for the lagged y_{t-j} and ε_t a random innovations vector.

In differences - i.e. a DVAR(p):

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + Bx_t + \varepsilon_t \tag{6.2}$$

where we define $\Pi = \sum_{i=1}^{p} A_i - I$, $\Gamma_i = -\sum_{j=i+1}^{p} A_j$.

If the dependedent variables are stationary, i.e. $\underset{(1,k)}{y} \sim I(0)$, *Granger* (1969) suggests to use an F-test, with reference to the null hypothesis that the l^{th} variable (y_l) does not cause the m^{th} variable (y_m) in the $\underset{(1,k)}{y}$ vector, with $l = 1, ..., k$ and $m = 1, ..., k \neq l$. Formally:

$$\begin{cases} \Gamma_{i,lm} = 0, \forall i = 1, 2, ..., k-1 \\ \Pi_{lm} = 0 \end{cases}$$

Note also that since we assume the rank of Π is greater than zero ($r(\Pi) = \tau > 0$), by definition we can rewrite:

[22]For example, openness and GDP for one of the eight new EU members.
[23]Stationary for simplicity

$$\Pi = \alpha\beta'$$

where both α and β are $kx\tau$ parameter matrices.

If the dependent variables are non-stationary - i.e $\underset{(1,k)}{y} \sim I(1)$, the test can proceed only if these are cointegrated[24]. This condition is ensured by imposing the appropriate restriction to the matrix $\Pi = \alpha\beta'$, and transforming the unrestricted DVAR (6.2) into the following VECM[25]:

$$\Delta y_t = \alpha\beta' y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + Bx_t + \varepsilon_t$$

where $1 < r(\alpha\beta') < k$ to ensure cointegration[26]. Note that β is a matrix such as its columns are now the coefficients of stationary combinations of the series in $\underset{(1,k)}{y}$ (i.e. cointegrating vectors), formally $\beta' \underset{(1,k)}{y} \sim I(0)$. Stating the null of non-causality is only a matter of taking into account the restriction on the Π matrix:

$$\begin{cases} \Gamma_{i,lm} = 0, \ , \forall i = 1, 2, ..., k-1 \\ \Pi_{lm} = \sum_s \alpha_{ls}\beta_{sm} = 0 \end{cases} \tag{6.3}$$

Since the VECM is a system of equations with (non-linear) cross-equation restrictions on their coefficients, the major issue is the estimation of β_{sm}.

[24]this is important to rule out spurious regressions

[25]de facto a restirced DVAR itself

[26]Note that this idea is the basis of the Johansen's test presented in chapter 4. A test on the rank of an estimated Π matrix, allows to capture signs of cointegration among the variables in $\underset{(1,k)}{y}$. Differently here, cointegration is imposed restiricting the rank of Π to avoid spurious regressions.

This is needed for testing the null (6.3) using F-tests and to calculate their asymptotic distribution, that, now, would be non-standard.

Alternatively, it is sometime possible to run a non-causality test based on the unrestricted VAR(p) after testing for cointegration between the variables of the $\underset{(1,k)}{y}$ vector.

For example, *Sims et al.* (1990) show that in trivariate systems the Wald F-test for causality is asymptotically chi-squared if cointegration is present and involves the variable that is excluded under the non-causality null.

More generally, *Toda and Phillips* (1993) show that, causality-testing asymptotics are chi-squared when the sub-matrices of α and β that are "relevant under the null"[27] have full rank.

Finally and most importantly, as *Konya* (2004) notes, this is assured in the bivariate cointegrated case[28] and Wald tests in a levels VAR are therefore asymptotically chi-squared.

Our three steps procedure, only needs testing for causality in a bivariate system[29], so we can afford to use the VAR(p) in (6.1), once we rule out non-cointegration. Therefore we can reformulate our test as following.

Abandoning the matrix notation for simplicity and with reference to two generic non-stationary but cointegrated variables x and y[30], we start

[27] See (6.3).

[28] This the context of causality that is required, for example, in Table (6.4).

[29] We either test for causality between openness and gdp country by country or between one country GDP and the EU15 average.

[30] These will be substituted with GDP and openness, later on in our application.

estimating the following simple[31] models (with no deterministic components):

$$y_t = \alpha_0 + \sum_{i=1}^{L} \alpha_i y_{t-i} + \sum_{i=1}^{L} \beta_i x_{t-i} + \varepsilon_t \tag{6.4}$$

$$x_t = \gamma_0 + \sum_{i=1}^{L} \gamma_i x_{t-i} + \sum_{i=1}^{L} \delta_i y_{t-i} + \mu_t \tag{6.5}$$

with L: maximum number of lags (e.g. AIC or SIC).

The null hypotheses are set to:

$$H_0 : \beta_1 = \beta_2 = ... = \beta_L = 0$$

in (6.4) for y not caused by x, and:

$$H_0 : \delta_1 = \delta_2 = ... = \delta_L = 0$$

in (6.5) for x not caused by y. In both cases the *Granger* (1969) procedure involves estimating the residuals $\hat{e}_t$ and $\hat{u}_t$ of the restricted models:

$$y_t = \alpha_0 + \sum_{i=1}^{L} \alpha_i y_{t-i} + e_t$$

[31]These are presented here for ease of comparison with the panel equivalent discussed at the end of this section

$$x_t = \gamma_0 + \sum_{i=1}^{L} \gamma_i x_{t-i} + u_t$$

and finally deriving the Wald F-statistics :

$$S_1 = \frac{(\sum_{t=1}^{T} \hat{e}_t - \sum_{t=1}^{T} \hat{\varepsilon}_t)(T - 2L - 1)}{L(\sum_{t=1}^{T} \hat{\varepsilon}_t)} \sim F_{L,T-2L-1}$$

$$S_2 = \frac{(\sum_{t=1}^{T} \hat{u}_t - \sum_{t=1}^{T} \hat{\mu}_t)(T - 2L - 1)}{L(\sum_{t=1}^{T} \hat{\mu}_t)} \sim F_{L,T-2L-1}$$

Alternative methods for testing causality include, simple AR systems, instantaneous systems and linear feedback as in *Geweke* (1982). The latter allows the decomposition of the linear dependence between x and y into three forms of linear feedback: from x to y, from y to x, and "instantaneously" between x and y. The advantage is not only the ability of identifying a causal relation between the two variables but also the degree of feedback (strength of relation) between them. A detailed survey based on this approach is available in *Granger* (2001). Further investigation in this sense would certainly be beneficial to explore the magnitude of causality and we note it as a potential area for future research.

So far our test allows only to look into individual countries[32], whilst it may also be interesting to explore the NMS8 group as a whole. It is possible to maintain the reference to a bivariate system by using panel-data techniques.

[32]e.g. we can afford to test causality between openness and per capita GDP as required by S2, one country at the time.

Recently *Hurlin* (2008) proposed a test for Granger non-causality in heterogeneous panels which should serve our purpose. The models presented above are modified as follows. For example, extend (6.4) to a group of countries $n = 1, 2...., N$ at time $t = 1, 2, ..., T$:

$$y_{n,t} = \alpha_{n,0} + \sum_{i=1}^{L} \alpha_n^{(i)} y_{n,t-i} + \sum_{i=1}^{L} \beta_n^{(i)} x_{n,t-i} + \varepsilon_{n,t}$$

where $\beta_n = [\beta_n^{(1)}, ..., \beta_n^{(L)}]'$ and suppose the individual effects $\alpha_{n,0}$ are fixed for simplicity. The author tests the null hypothesis of homogeneous non-causality (HNC) against the alternative of causality still allowing for potential non-causality for some (not all) units. Formally:

$$H_0: \ \beta_i = 0\,, \forall i = 1, 2, ..., N$$
$$H_1: \ \begin{cases} \beta_i = 0 & \forall i = 1, 2, ..., N_1 \\ \beta_i \neq 0 & \forall i = N_1 + 1, N_2 + 2, ..., N \end{cases}$$

where N_1 unknown but $0 < \frac{N_1}{N} < 1$. Note that when $N_1 = N$, H_1 is in fact H_0 and there is no-causality for all the members of the panel (HNC). If $N_1 = 0$ there is causality for all members of the panel (HC). The test statistic is calculated averaging the individual Wald statistics for every country:

$$S_{N,T}^{Hnc} = \frac{1}{N} \sum_{n=1}^{N} S_{1,n}$$

following a similar methodology used in panel unit-roots tests by e.g. *Im et al.* (2003) or *Pesaran* (2007) . Critical values (5%) are either stochastically simulated from 50.000 replications or approximated from a standardized $\widetilde{Z}_N^{Hnc}$ statistic[33]. Monte-carlo simulations are available in the paper and show the test has good power in finite samples ($T = 10, 25, 50$).

6.3.2 Results

Having introduced our three steps procedure, we present the results of an application to the eight countries involved in the first step of the fifth European enlargement based on datasets from the IMF Directions of Trade Statistics and Eurostat New Chronons and UN Population Division. Key series are pictured in Figure (6.5) and Figure (6.6). Before progressing, in Figure (6.2) we provide an impression of a similar exercise using simple regressions in the context of beta/sigma-convergence. The outcome is easy to read, with the first two pictures showing clear signs of catching-up[34] and a scatter diagram unable to capture any correlation between trade openness in the area. We will see how, testing for stochastic convergence, leads to a different evidence.

Our cointegration results for **Step 1 (S1)** are reported in Table 6.1 for single countries. In Table 6.2, we repeat the exercise for the aggregated NSM8 group using panel data[35]. In the last case. it is interesting to note that the *Pedroni* (1999)[36] tests show how the unit-root in the residuals is

[33]See *Hurlin* (2008) for further details.
[34]A negative coefficient for β and dispersion of GDP per capita diminishing in time.
[35]i.e. we create a 52x8 panel, where new members make the longitudinal dimension.
[36]For a formal introduction see chapter 5.

Figure 6.2: Trade Openness and Catching-up

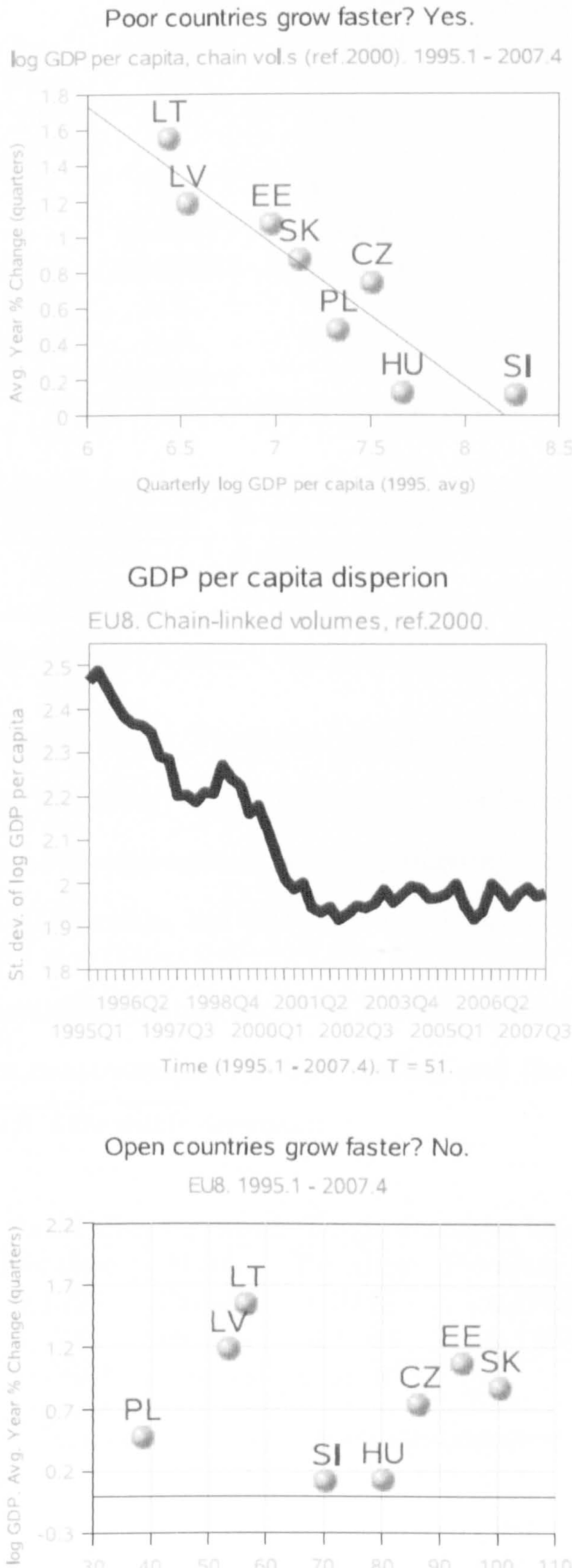


Table 6.1: [S1] Long-run dynamics: multicountry OPN, GDP.

	LT°	LV°	EE°	CZ°
None	23.17722	23.87522	13.48084	18.08383
At most 1	0.002391	0.681248	0.155566	0.107913
Reject: H0 None	1%	1%	5%	1%
Reject: H0 AT1	N.R.	N.R.	N.R.	N.R.
Coint. Rels.	1	1	1	1
	SK	**PL°**	**SI**	**HU**
None	10.81877	14.30869	12.76467	7.328329
At most 1	0.020087	0.720219	4.223345	2.930365
Reject: H0 None	N.R.	5%	5%	N.R.
Reject: H0 AT1	N.R.	N.R.	5%	N.R.
Coint. Rels.	unknown	1	>1	unknown

Note: N.R. not rejected. 1% critical values: 16.31 (none), 6.51 (AT1).

Table 6.2: [S1] Panel cointegration tests (Johansen based): OPN, GDP

H_0	Fisher/Trace	P-value	Fisher/max-eigen	P-value
None	43.13	0.0003*	39.14	0.0010*
At most 1	18.54	0.2935	18.54	0.2935
Coint. Rels.	1		1	

(*) Rejection at 5%. Critical values: Maddala and Wu (1999), combining Fisher (1932) and Johansen (1991, 2001)

rejected only between units. Therefore, we can assume the roots are below unity but not the same[37] in all countries. This behaviour is reflected in the results of the disaggregated exercise, showing how the relation between OPN and GDP exists, but it is not very strong accross the NSM8s.

Disaggregated causality results for **Step 2 (S2)** are summarised in Table 6.4. Series were deseasonalised before testing and the test is run only

[37]We reject the null in the within-dimension.

Table 6.3: [S1] Panel Cointegration (Engle-Granger based): OPN, GDP

Stat.	P-value	Stat.	P-value	P-value (**)	Notes
Panel PP	0.1327	*Panel* ν	0.3228	0.2833	Hom. coint.
Panel ADF	0.1535	*Panel* ρ	0.1763	0.1303	
Group PP	0.0056*	*Group* ν	0.0159*		Het. coint.
Group ADF	0.0049*				

(*) Rejection at 5% (**) From weighted stat. Critical values: Pedroni (1999).

Table 6.4: [S2] Granger causality (Trade openness and GDP)

	CZ°	**EE**	**HU°**	**PL°**
GDPK⇏OPN	0.27746	0.62524	-	0.18068
OPN⇏GDPK	0.01023*	0.84716	-	0.00343*
	LV°	**LT°°**	**SK°**	**SI°**
GDPK⇏OPN	0.35768	0.00188*	-	0.69810
OPN⇏GDPK	0.02306*	0.59577	-	0.00233*

GDP chain-linked vol.s (2000), per capita, seasonally adj. (°) OPN to GDP. (°°) GDP to OPN. (*) Rejection at 5%. T=51. P-values in table.

between variables that are cointegrated according to **S1**[38].

For CZ, PL, LV, SI we reject the null of openness not causing GDP per capita. In all these countries, Table 6.4 shows trade is contributing to growth and not the opposite. In order to capture the full picture, it can be convenient to work[39] with panel data and calculate the Hurlin average $S_{N,T}^{Hnc}$ statistic. Results are provided at the end of this chapter in Table (6.11) and show that within the NSM8 group there is no overall or individual causality from GDP to EXP or IMP. However there is some causality (potentially paired with some non-causality in individual countries) from IMP and possibly EXP to GDP. Decreasing the number of lags on the other hand, reduces the support to the export/import -led growth hypothesis and allows some causality in both directions (rejection of the H_0 in all cases). The relation between OPN and GDP is even more difficult to interpret. Whilst it seems quite clear that a causal relation between OPN and GDP exists in some countries, it is not easy to exclude the possibility that it also operates in the opposite direction (GDP to OPN). Table (6.5) illustrates for individual countries.

[38] i.e. we exclude Hungary and Slovakia.

[39] instead of a more subjective approach - i.e. counting the number of countries that show a direct causal relation between GDP and OPN, etc...

Table 6.5: [S2] Imports-led growth.

	CZ°	EE°°	HU	LT
GDP⇏IMP	0.40850	0.01491*	0.03178*	0.05136
IMP⇏GDP	0.00811*	0.93046	0.05815	0.00807
Lags (L):	1	1	1	5
	LV°	**PL**	**SK°**	**SI°°**
GDP⇏IMP	0.77825	0.02071*	0.20299	0.00168*
IMP⇏GDP	0.01942*	0.02695*	0.02491*	0.71306
Lags (L):	1	1	1	1

Notes: GDP at market prices, seasonal adjusted. (*) Indicates rejection at 5%. (°) IMP to GDP (°°) GDP to IMP. T = 51.

The case of "inverse" causality (e.g. OPN⇏GDP but GDP⇒OPN) could be seen as an indication of a small contribution of trade to growth. If openness does not cause growth but the opposite is tested true, we can imagine the stimulus is generated mainly by other beneficial consequences of the integration process (FDI, migrations, spillovers, etc...) and then transmitted to trade (e.g. raising import volumes: GDP⇒IMP)[40]. This seems to be true for Lithuania in the case of openness and Estonia, Slovenia if strictly focusing on imports.

Simultaneous causality between components of trade (IMP or EXP) and output is also observed with interest in the literature. For example *Weber* (2007) underlines how a bivariate cointegration between GDP and imports can be theoretically seen as dependent on price inelasticity in the import function and stationarity in real exchange rates under PPP. This is the case of Poland, as evidenced by Table (6.5).

Another approach often used in the literature is trying to isolate the contribution of exports to growth (export-led growth: ELG). A survey of the

[40]In this context, it might also be interesting to do a panel VAR with output per capita, trade, FDI and human capital, as it would be of interest for policy makers to know what factors are relatively more important in driving convergence towards the EU average. Note however, this exercise might be hard to carry out due to data problems.

Table 6.6: [S2] Export-led growth

	CZ°	EE°°	HU°	LT°°
GDP⇏EXP	0.43591	0.00898*	0.21206	0.03260*
EXP⇏GDP	0.04654*	0.24812	0.01070*	0.17315
Lags (L):	1	1	1	1
	LV°°	**PL°**	**SK°**	**SI**
GDP⇏EXP	1.0E-06*	0.67098	0.42147	0.35212
EXP⇏GDP	0.31546	0.00271*	0.02847*	0.31590
Lags (L):	1	1	1	1

GDP at market prices, seasonally adjusted. (°) EXP to GDP. (°°) GDP to EXP. (*) Rejection at 5%. T=51.

literature, with specific reference to causality, is available in *Giles and Williams* (2000).

Individual country contributions can be disaggregated easily from Table (6.6), however it is difficult to identify a unique direction of causality for all eight economies.

Finally, with reference to **Step 3 (S3)**, tests for stochastic convergence[41] between individual new EU members and the EU15 average are shown in Table (6.7) and output gaps are pictured in Figure (6.3). Figure (6.4) shows the quarterly growth rate around the EU15 aggregate and the variation in output differentials between 1995 and 2007.

Summarising, the empirical evidence presented so far does not give the firm conclusion that trade volumes contributed to convergence between new and old EU members.

[41]Note this is discussed at lenght in chapters 4 and 5. Here we propose an equivalent application based on the IMF dataset.

Table 6.7: [S3] Stochastic convergence: output differentials with EU15.

	LT	LV°	EE°	CZ°
None	36.30821	27.71801	36.32323	16.47171
At most 1	5.588638	3.825346	3.803221	0.750101
Reject: H0 None	1%	1%	1%	1%
Reject: H0 AT1	5.00%	N.R.	N.R.	N.R.
Coint. Rels.	>1	1	1	1
	SK°	**PL**	**SI**	**HU**
None	23.83750	7.134780	20.45711	7.949469
At most 1	0.109044	0.081142	4.217939	1.107816
Reject: H0 None	1%	N.R.	1%	N.R.
Reject: H0 AT1	N.R.	N.R.	5%	N.R.
Coint. Rels.	1	unknown	>1	unknown

Note: N.R. not rejected. *1% critical values: 16.31 (none), 6.51 (AT1).*

Figure 6.3: [S3] Stochastic convergence: output gaps

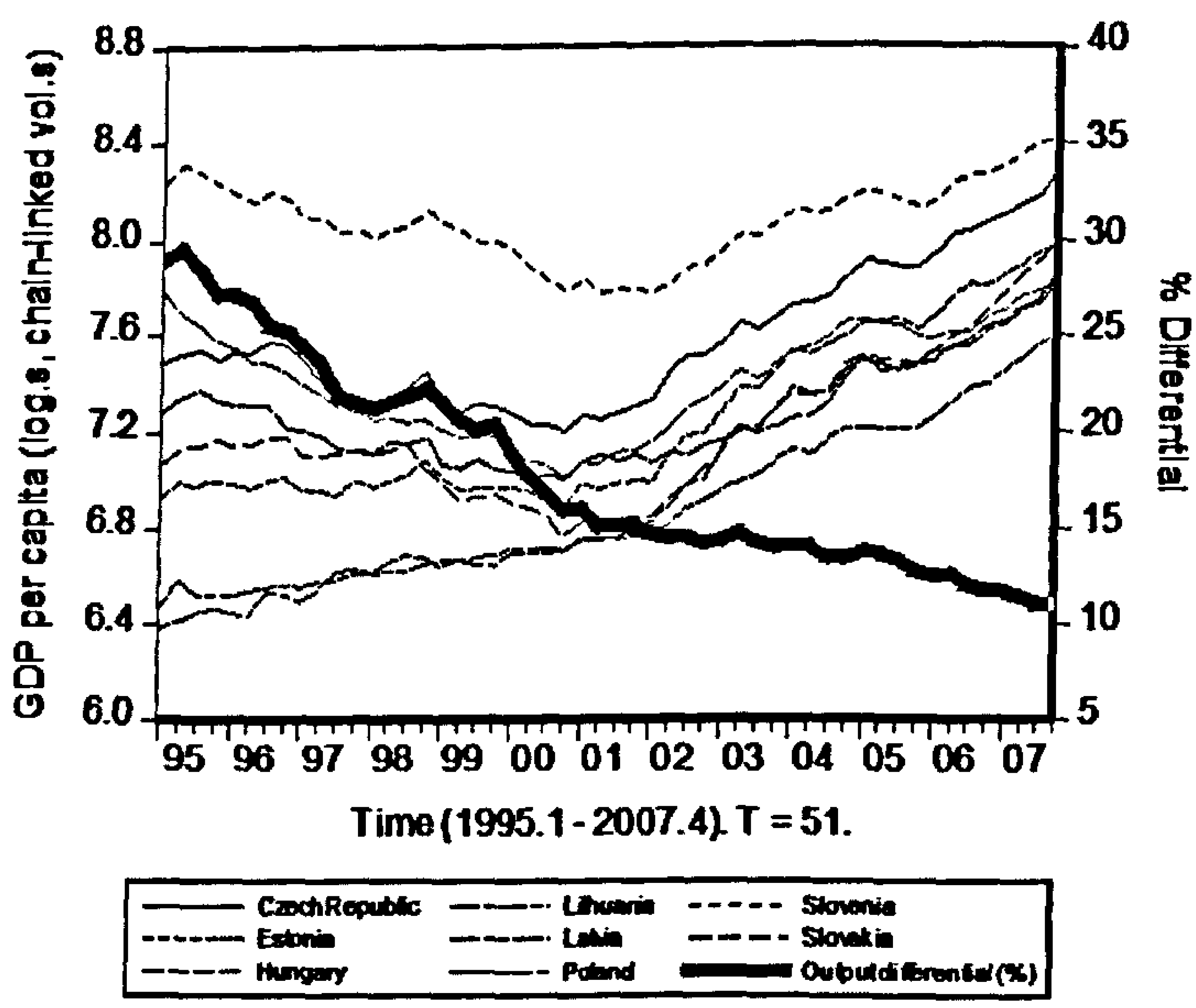
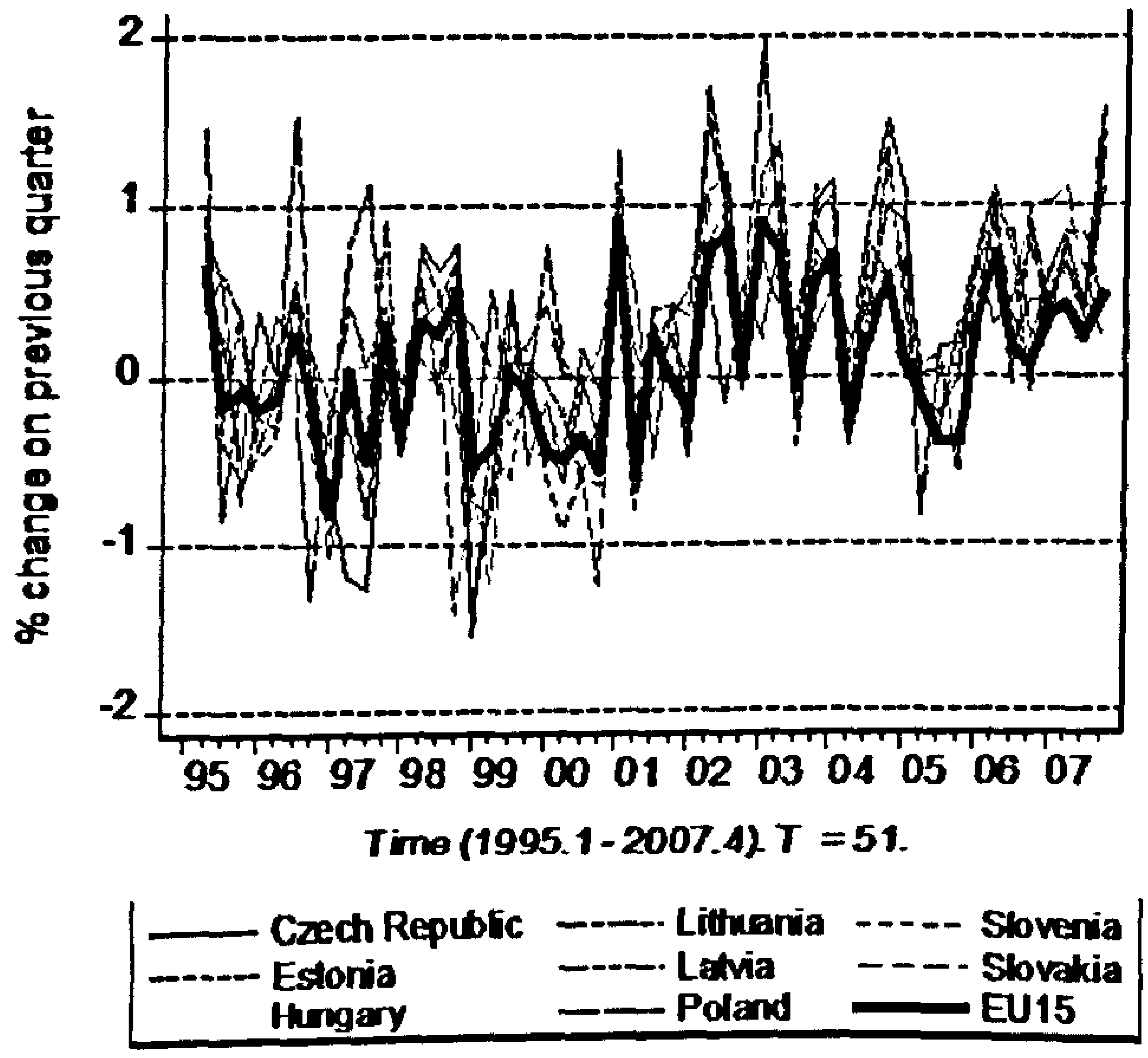


Figure 6.4: [S3] Stochastic convergence: log GDP p.c. growth rates



An additional test[42]

Given the weak evidence in favour of convergence in Step 3 (S3) and in Chapters 4 and 5, the claim[43] that openness does not contribute to output convergence[44] may appear suspicious to the reader, unless we can convince him that there is also convergence between the residuals of the long-run relation estimated in Step 1 (S1) and the average GDP per capita of old EU members.

In the test that follows, we are going to estimate the residuals ($\varepsilon_{i,t}$) of the long-run relation[45] that is behind the co-integration test in Step 1 (S1),

[42] I am in debt to Dr. Hong Li for her substantial contribution to this section.
[43] see previous section
[44] between old and new EU members.
[45] e.g. for the linear combination $\alpha_1 OPN_{i,t}+\alpha_2 GDP_{i,t} = \varepsilon_{i,t}$, $OPN_{i,t} = -\frac{\alpha_2}{\alpha_1}GDP_{i,t}+\varepsilon_{i,t}$ then $\varepsilon_{i,t} = OPN_{i,t} - \beta GDP_{i,t}$ with $\beta = -\frac{\alpha_2}{\alpha_1}$.

Table 6.8: Co-integration: Step 1 residuals ($\varepsilon_{i,t}$) with $GDP_{eu15,t}$.

i	**cz**	**ee**	**hu**	**lt**	
None (p-value)	0.0113	0.0016	0.0019	0.0048	Trace
At most 1 (p-value)	0.2557	0.5738	0.4834	0.0244	Trace
None (p-value)	0.0126	0.0010	0.0013	0.0266	Max. Eig.
At most 1 (p-value)	0.2557	0.5738	0.4834	0.0244	Max. Eig.
Coint. rel's.	1,1	1,1	1,1	2,2*	
i	**lv**	**pl**	**sk**	**si**	
None (p-value)	0.0539	0.0257	0.0073	0.0002	Trace
At most 1 (p-value)	0.9097	0.1142	0.7129	0.0549	Trace
None (p-value)	0.0349	0.0492	0.0045	0.0006	Max. Eig.
At most 1 (p-value)	0.9097	0.1142	0.7129	0.0549	Max. Eig.
Coint. rel's.	1,1	1,1	1,1	1,1	

Notes: Johansen Max. Eig. and Trace tests. Two lags (*) No convergence

Table 6.9: Panel Coint: Unrestricted Cointegration Rank Test

No. of CE(s)	Trace Stat.*	Max Eig Stat.*	Prob.
None	85.07	81.34	0.0000
At most 1	23.73	23.73	0.0955

Notes: N=8, T=52, Obs. = 416, Two lags. (*) uses asymptotic χ^2 distrib.

and then use cointegration[46] to test stochastic convergence between residuals $\varepsilon_{i,t}$ and the average GDP per capita of old EU members ($GDP_{eu15,t}$).

Empirical results of pairwise cross-section *Johansen* (1991) cointegration tests for all eight[47] new members are reported in Table (6.8).

In order to capture the aggregate picture, a panel Johansen-Fisher cointegration test is attempted and results are shown in Table (6.9) and (6.10). Note the trace and maximum eigenvalue statistics are equivalent to Table (6.8) but, this time, we also report p-values used to compute the Fisher statistic. Results of the two approaches are not dissimilar[48] and show desired evidence of stochastic convergence. Since it is found that there

[46]for a discussion see chapter 4

[47]note $i = 1, 2, ..., 8$.

[48]all series share a single cointegrating relation except Lithuania

Table 6.10: Panel Coint: Individual cross-section results

Cross Section	Trace Test	Prob.**	Max-Eign Test	Prob.**
None				
cz	16.0628	0.0113	14.5456	0.0126
ee	20.7509	0.0016	20.3176	0.0010
hu	20.3377	0.0019	19.6955	0.0013
lt	18.1321	0.0048	12.7640	0.0266
lv	12.1258	0.0539	12.1065	0.0349
pl	14.0237	0.0257	11.2635	0.0492
si	25.3396	0.0002	21.3684	0.0006
sk	17.1342	0.0073	16.9377	0.0045
At most 1				
cz	1.5173	0.2557	1.5173	0.2557
ee	0.4333	0.5738	0.4333	0.5738
hu	0.6422	0.4834	0.6422	0.4834
lt	5.3680	0.0244	5.3680	0.0244
lv	0.0193	0.9097	0.0193	0.9097
pl	2.7602	0.1142	2.7602	0.1142
si	3.9712	0.0549	3.9712	0.0549
sk	0.1965	0.7129	0.1965	0.7129

Notes: (**) MacKinnon-Haug-Michelis (1999) p-values

is stochastic convergence between the long-run residuals of the long-run relation from S1 and the average per-capita GDP of old EU members, the claim that openness does not contribute to output convergence[49] seems acceptable. The overall picture is discussed in greater detail in the next - concluding - chapter and it is better understood from the panel exercises presented above in this and previous sections.

6.4 Conclusions

We started from the consideration that there is not much consensus on the relation between trade, growth and convergence. We took elements

[49] see earlier empirical findings in this section.

from the major contributions in the field and we proposed an empirical methodology that mixes ideas from the existing literature - mainly Ben-David (1993), and time series-techniques so we could use the same approach to convergence we introduced in chapter 4. We noted that NMS8 suffered from a degree of heterogeneity in their trade policy (and in their path towards trade liberalization) that is higher than in other studies where countries were chosen ad-hoc. This heterogeneity is reflected in our results and motivated us to move to panel data to assess formally the impact of effective trade on convergence in the eastern block of the European Union. Differently from some of our reference literature, we find that it is only in a limited number of cases[50] that would it be safe to conclude that increased trade volumes accelerated growth in the set of countries that started at lower levels of GDP per capita. This conclusion is not totally surprising and may have motivated the Rodriguez critiques we mentioned in this chapter. Further, even if only marginally, it is also clear from our results that a higher degree of openness has been beneficial[51] to some economies and generally does not hinder growth in poor countries[52] either. In these particular circumstances, policies targeting trade volumes do not appear particularly effective in the long-run but protectionism is not endorsed.

[50]and certainly not for the full set of NMS8 we investigated using *Pedroni* (1999) and *Hurlin* (2008) tests.

[51]i.e. our results do not endorse protectionist policies.

[52]The only instance of divergence being Slovenia.

Figure 6.5: Trade Openness and GDP

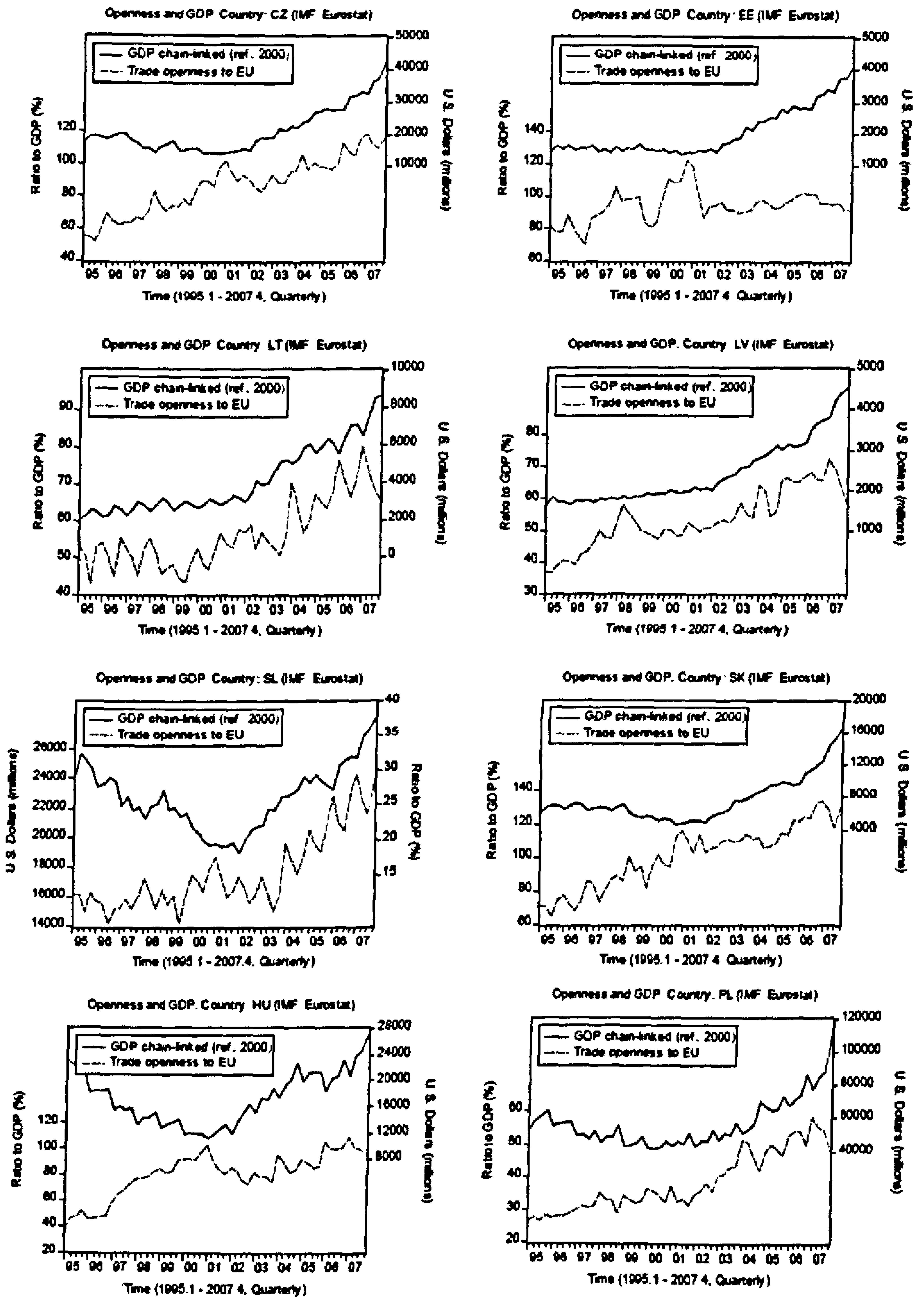


Figure 6.6: Intra-EU Exports and Imports value

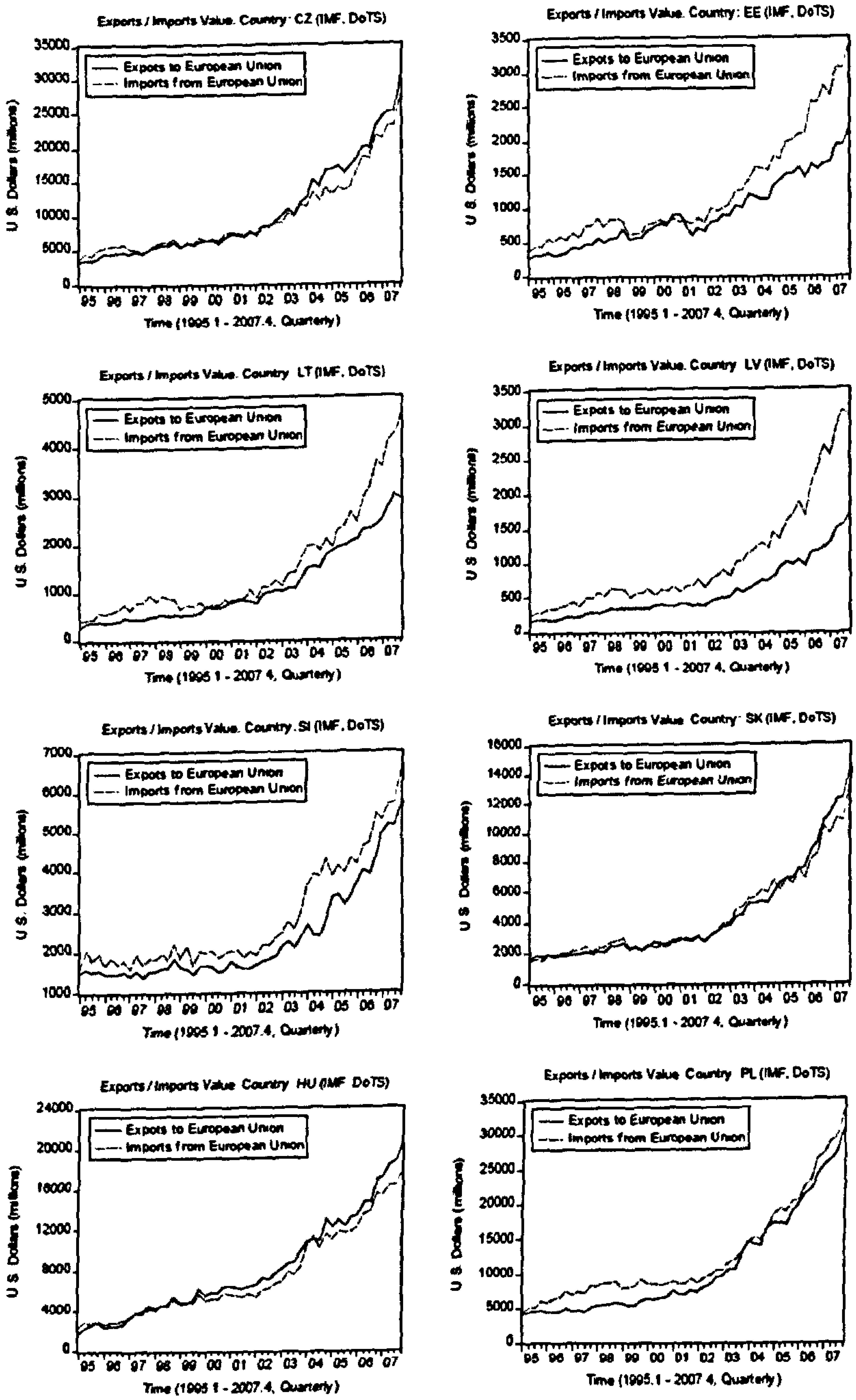


Table 6.11: Hulrin (2008) Panel Non-Causality

H_0	L	S_n CZ	EE	HU	LT	LV	PL	SK	SI	$S_{8;43}^{Hnc}$	$c_{8,43}$	$\tilde{c}_{8,43}$	Judg.	
GDP⇏OPN	3	1.6773	2.1415	1.1356	1.7704	1.4315	3.1672	1.6051	3.1376	2.00827	R	NR	R	*
OPN⇏GDP		1.9781	3.3291	0.7957	0.8306	0.4909	2.8892	5.8008	3.9085	2.50287	R	R	R	***
GDP⇏IMP	3	1.2709	4.2226	1.1704	1.1611	1.1946	0.7062	0.6247	1.6548	1.50066	NR	NR	NR	***
IMP⇏GDP		1.2179	1.5720	1.7213	0.2146	2.1129	2.0869	5.7632	2.9137	2.20032	R	R	R	**
GDP⇏EXP	3	1.8385	2.0402	0.9669	0.5145	0.0624	1.3054	0.3538	2.1896	1.15891	NR	NR	NR	***
EXP⇏GDP		1.2685	3.1373	0.9220	1.0354	1.3037	1.5707	4.2596	2.3884	1.98568	NR	NR	NR	*
GDP⇏OPN	4	1.3594	2.7051	1.3287	2.5010	0.5248	2.0306	3.4729	4.6345	2.31962	R	R	R	***
OPN⇏GDP		3.0879	1.4133	1.3551	1.4624	1.2126	4.0719	3.6684	2.2843	2.31949	R	R	R	***
GDP⇏OPN	1	4.4209	5.5953	4.6129	4.5800	6.3552	1.1914	2.4194	3.7101	4.11065	R	R	R	***
OPN⇏GDP		6.4976	4.7352	2.8512	1.9466	1.1987	3.0358	12.3385	0.9363	4.19251	R	R	R	***
GDP⇏IMP	1	3.4418	6.0207	5.8345	2.1434	7.0037	0.8722	0.8602	3.0329	3.65120	R	R	R	***
IMP⇏GDP		3.6431	3.0068	0.0818	0.7324	5.3289	2.5055	11.6559	1.9992	3.61918	R	R	R	***
GDP⇏EXP	1	13.7452	3.3837	4.3790	4.2664	4.5703	0.0752	2.4929	3.1311	4.50548	R	R	R	***
EXP⇏GDP		2.1702	2.3402	0.1673	0.0051	2.9330	2.0805	6.9271	0.6108	2.15427	R	R	R	***

Notes. The approximated and simulated critical values for $N = 8$ and $T = 43$ are interpolated from Table 4 in Haurlin (2008): $c_{8,43}(0.05) = 2.1350$ and $\tilde{c}_{8,43}(0.05) = 1.9958$. R indicates rejection of the null hypothesis (homogeneous non-causality), NR inability to dismissH_0. A subjective judgment is provided based on interpolated and non-interpolated c.v's (*** very significant). L is the number of lags. S_n and $S_{8,43}^{Hnc}$ are respectively the country and average Wald statistics.

Chapter 7

Conclusions

Two major conclusions flow from this research. Firstly, in the last ten years there has been far less convergence between old and new members than was initially believed. Secondly, international trade has had a limited role in this process and may have followed from the faster growth in poor countries, rather than leading to it.

With reference to the first conclusion, in Table (7.1) we present a summary of our cross-sectional tests for convergence. When looking at stochastic convergence, we started from the consideration that using standard ADF tests[1] is equivalent to assuming linearisation around the steady state, which results in a constant speed of mean reversion. However, we noted it is a consequence of *Barro and Sala-i Martin* (1992) that the speed of convergence depends on the distance from steady state and it is not necessarily fixed in time. We then considered an asymmetric speed of

[1] used e.g. by *Carlino and Mills* (1993)

adjustment and we argued how the technique proposed by *Chrsitopoulos and Leon-Ledesma* (2009) is not statistically superior to linear autoregressive models. Differently, we imposed a stochastic variant of the linear unit root tests (the STUR), which gave some alterations on our initial results.

Table 7.1: Time-series convergence?

	HU	SI	EE	LT	LV	SK	PL	CZ
Fixed Root	Y***	N	N	N	N	N	Y***	N
Stochastic Root	Y	Y	Y	N	N	N	N	N
Cointegration	Y	Y	Y	Y	Y	Y	Y	Y
Overall	Y	Y-	Y-	N	N	N	Y	N

Notes: Y (yes) positive evidence of convergence) N (no) no evidence of converegnce.

Where aggregated beta-regression analysis predicts very strong absolute convergence [2], we could see some degree of heterogeneity among the NSM8 countries that can be explained by the theoretical implications[3] of the new time-series methodology. Beta convergence limits the investigation to the transition towards a common steady state; stochastic convergence captures a long run behaviour[4] including any potential short-run deviation from it. In the neoclassical framework, if such stationary fluctuations are observed, there is concrete evidence that a common steady state[5] has been already reached within the period under investigation. We could not get a strong support for this hypothesis at the country-level in LT, LV, SK, CZ. Similarly, panel unit-roots and cointegration tests generally gave signals of non-convergence at the aggregated

[2]See chapter 4.

[3]i.e. removing the assumption of a fixed speed of convergence to the steady state. This choice also makes the model closer to its original neoclassical formulation.

[4]stationarity around a zero/positive mean

[5]with temporarily deviations from it

Table 7.2: Empirical summary: single countries

		EE	LT	LV	CZ	SK	HU	PL	SI	NMS8
Cointegration,	*i. Openness*	Y	Y	Y	Y	?	-	Y	-	Y
NMS GDP with:	*ii. EU15 GDP***	-	Y	Y	Y	Y	-	-	-	NA
Causality,	*i. Openness*	-	-	Y	Y	Y	?	Y	?	-
to NMS	*ii. Imports*	-	-	Y	Y	Y	-	-	-	NA
GDP from:	*iii. Export*	-	-	-	Y	Y	-	Y	-	NA
Trade promotes	*convergence?*			Y	Y	Y?	-	-	-	-

Notes: Y: yes. -: no, NA: not available (*) Panel tests (**) Y indicates a long run relation between EU15 and individual GDP per capita.

level. This observed behaviour makes convergence in the neoclassical sense an on-going process and a likely condition for the future that has not been already satisifed in the enlarged Europe.

With reference to our second major conclusion, the empirical evidence on trade is summarized in Table 7.2.

Cointegration has been used for establishing a long run relation between individual-counties GDP per capita and their openness to trade and for testing stochastic convergence to the old members' aggregated GDP. Finally, to make sure output was stimulated by trade and not vice-versa, we tested for *Granger* (1969) causality. Overall, the only countries for which we could confirm co-existence of all three desired relations were the ex Czechoslovakia (although statistically weak for SK) and Latvia. In Estonia, trade and growth seem related and growth promotes trade (inverse causality). The latter however does not contribute to convergence. In Lithuania trade and convergence appear related but again convergence promotes trade. In Hungary trade does not promote convergence. Finally in Poland and Slovenia trade promotes national growth but not convergence to EU15. Trade may contribute to divergence in Slovenia. At the aggregated level, the *Hurlin* (2008) panel non-causality test gives support for some import or export lead growth, only when an appropriate specification had been chosen. The relationship between openness and growth however, still proved rather weak.

We also discussed how the empirical *Ben-David* (1993) approach does not hold perfectly as found by *Rodriguez and Rodrik* (1999) and the impact of trade over output convergence may not be so substantial, especially in the last decade as noted by *Rodriguez* (2006). We could see the necessity of maintaining alive a debate which has accompanied economic research since its beginning, although for its own nature it seems unlikely to have a strong relevance for EU convergence. Further, we showed the limits of strictly endorsing the positive role of trade for growth but without the intention of advocating the merits of opposite protectionist strategies (i.e imports substitution).

The empirical result that trade volumes are not a major determinant for convergence in the enlarged EU brings an advantage: it makes it relatively safe to look at our results in the light of the two mainstream contributions to economic growth we discussed in chapter 2. Potentially, this exercise could give us some theoretical insight on the relationship between European integration[6] and output convergence. The two conditions, to be useful in the context of the enlargement debate, must hold contemporaneously. If any positive contribution of integration exists, is this able to push growth more strongly in countries with lower initial values of per capita output? In other words, was the convergence between

[6]Note that our empirical evidence suggests we should probably exclude trade from the list and focus on the supply side. This seems also the route followed by the literature (see chapter 6) and makes the use of the neoclassical or endogenous growth models less problematic. In this sense, we focus on economic integration but not trade integration.

current and new member states of the European Union favored by its recent enlargement?

The answer varies according to the theoretical model and the benefits it associates with integration. Further, the second variable is partially controllable by policymakers[7] meaning they may have some tools to sustain the convergence process if needed. The exogenous growth model is weaker in dealing explicitly with the potential benefits of an enlargement[8]. On the other hand, through the assumption of diminishing returns, it is well suited to deal with faster-growing, low-income economies. Within the endogenous, Arrow-Romer, growth literature the two variables relevant to growth are population growth (n) and savings (s) [9]. Population is a critical variable and subject to migration effects[10], savings are closely linked to investments in equilibrium so that higher capital inflows can play a major role. The more likely consequence of integration however, is higher spillovers and more effective learning-by-doing. This condition, being asymmetrically beneficial for less developed countries, has the potential of pushing convergence. In this context, a convenient option is mixing production functions of the two models as in *Jones and Manuelli* (1990). This strategy allows controlling catching-up in an endogenous growth framework and we suggest the need to make reference to this and similar pieces of research for the interpretation of empirical results in the area of the EU enlargement.

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[7]In the context of nominal convergence, see the ECB convergence criteria.
[8]Note however the mentioned relation between FDI and growth rates.
[9]See Chapter 2.
[10]We saw how almost all eastern economies have declining total populations.

As a final note, this research is intentionally[11] limited to trade in its ambition to explain convergence between Eastern and Western Europe. It is possible that factors like financial integration, large capital inflows and a reduction of balance-of-payments constraints have driven observed dynamics of per-capita output. Existing literature shows favourable external financing conditions may contribute to rapid catching-up, giving rise to financially-driven convergence. Additional work may be needed to evaluate financing conditions in Eastern Europe and establish whether similar conclusions should be dismissed in the light of the weak evidence of convergence we collected with reference to the new members of the European Union. In case of a negative answer, it may be intersting to establish whether openness itself is the by-product of financially-driven convergence, domestic policies[12] on attracting foreign capital inflows conditional on the level of human capital and the role of multinationals in technology transfer.

In conclusion, we showed how the apparently easy exercise of measuring the success[13] of the European Union eastern enlargement, is in fact very sensitive to the methodology used. It can attract the empirical researcher with the prospect of an easy proof of concepts well established in the standard growth theory, but at a closer look it reveals a large heterogeneity in the behaviour of the new members economies. This last consideration does not exclude convergence per-se, but it certainly urges a continuing research in the coming years.

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[11]Note this is a common choice in the literature - see e.g. *Ben-David and Kimhi* (2004) for an application to openness and convergence.
[12]Fiscal, monetary and financial sector.
[13]in terms of economic convergence

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