On Asymmetric Business Cycle Effects on Convergence Rates: Some European Evidence*

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Abstract

In this paper, we provide empirical evidence for some European countries, over the period 1963-2000, on whether business cycle affects convergence process or catching-up. To do so, we first evaluate β-convergence. We find evidence in favour of this type of convergence for six countries (Spain, Portugal, Finland, Denmark, Sweden and Germany). Spain, Portugal and Finland are countries initially 'poor' with a growth rate larger than EU-15 average. On the contrary, Germany, Denmark and Sweden are countries initially 'rich' growing smaller than average. We observe that convergence rates in 'poor' countries has been larger during expansions than recessions while two of the 'rich' countries, Denmark and Sweden, experiment the opposite effect.

Keywords: stochastic convergence, cyclical convergence, Markov switching models

JEL classification: E32; O40; C22; C32

1 Introduction

For a long time economics considered cycles and trend growth separately. For example, the so-called multiplier/accelerator model could generate cyclical behaviour due to investment alternating between high and low levels leading to corresponding changes in aggregate demand and output, but could not also explain trend growth. The multiplier/accelerator model was developed as an extension of keynesian income-expenditure analysis where the disequilibrium between demand and supply on the goods market give rise to quantity adjustments, through investments in new capacity. Different extensions of this model included an exogenous growth trend but this trend had not effect on the duration or size of the cycle[1].

More recent growth or business cycle models have gotten rid of non-market clearing assumptions, yet without solving the difficulty of explaining the growth trend and its current relationship with the business cycle. This is the case of Solow's (1956) contribution and its extensions prior to the endogenous growth literature where no long-run trend would obtain in the absence of population growth or of exogenous technical progress. This is also true of business cycle models developed in a market-clearing context, either on the basis of unanticipated monetary shocks and informational rigidities or resulting from strong non-linearities in intertemporal preferences or arising from the combination between

[1] Goodwin(1967) was the first model of cyclical growth where the occurrence of economic fluctuations was modelled as a deterministic consequence of the growth process and more specifically of the variations in income distribution between wages and profits.

temporary productivity shocks and adjustment lags or inter-sectorial inertia as in the real business cycle literature by Kydland and Prescott (1982) and Long and Plosser (1983)[2].

Endogeneizing the growth process through the introduction of human capital investments, as in King and Rebelo (1986) or learning by doing as in Stadler (1990), removed these restrictive features. The main result is that suddenly increase in the quantity of money could stimulate a higher level of real economic activity in the short-run, then the same increase in money supply would be likely to result in more rapid learning by doing or in more intense Research & Development, and therefore in a burst of technological growth that would not otherwise have occurred. The main idea underlying Stadler (1990) can be summarized as follows: a positive productivity shock due to nominal contractual rigidities á la Fischer (1977) and Taylor (1980) or to informational rigidities á la Lucas (1972) should induce higher level of real economic activity in the short run. Real income will end up at a permanently higher level even after individual expectations have fully adjusted to the initial monetary shocks.

There is a large empirical literature establishing definitions of convergence and common trends. For example, Bernard and Durlauf (1995), *inter alia*, propose and test new definitions of convergence and common trends in GDP per

[2] See in Lucas (1972) a business cycle model developed in a market-clearing context on the basis of unanticipated monetary shocks and informational rigidities and in Benhabid and Day (1981) and Grandmont (1985) business cycle models resulting from strong nonlinearities in intertemporal preferences.

head for 15 OECD countries and reject convergence hypothesis but find substantial evidence for common trends. Carlino and Mills (1993) test catching-up effects observing whether GDP per head between two economies has a negative linear trend or not. In this case we could reject the hypothesis of convergence using a linear model when we have different velocities of convergence during our sample period. Under this result, we could talk of 'not gradual' convergence.

Besides the previous findings, there are several contributions which try to solve this problem. On the one hand, there are some papers allowing structural changes, such as Oxley and Greasly (1995) and Pallardó and Esteve (1999). On the other hand, we have some papers that consider variable parameters such as Hall et al. (1992) and Camarero et al. (1995).

In view of previous arguments and the scarcity of empirical studies on this topic, our goal in this paper is to extend the stochastic convergence methodology proposed by Carlino and Mills (1993) to observe how business cycle affects convergence process among European Union member countries. To provide an empirical framework for discussion we analysed the relation between trend and cycle in one direction: the effect that the cycle may have on the economy. As an example of this effect, a temporary boom caused by monetary expansion will also temporarily increase output research and aggregate amount of learning by doing in the economy. This, in turn, will put the economy on a higher trend path, with permanently higher output, research and development, and therefore growth rates under AK or Schumpeterian assumptions. The contribution of this study may be interesting for three reasons. First, EU countries have been involved in an economic integration process and they should have diminished economic discrepancies. In this case, we analyse real convergence between each European country and the 15 EU average. Second, the analysis of business cycle influence may be interesting as it helps to ascertain which countries have experienced a change in the trend growth according to the previous growth theories. If we observe a larger velocity of convergence in 'poor' countries than in 'rich' countries we would have real convergence inside EU. Third, we can observe which periods have been crucial in the convergence process.

For that purpose, we follow a procedure in three steps. First, we observe real convergence among 15 EU countries. Second, once we have obtained which countries show convergence, we analyse how business cycle affects their convergence process. Finally, we consider a non-linear model, the Markov Switching model (MS henceforth) proposed by Hamilton (1989) which is a useful modelling strategy to investigate the implications of business cycle on stochastic convergence. This latter methodology is also useful to derive similarities in business cycle among countries because the cycle is endogenously determined in the model.

Proceeding in this way, we obtain several interesting results. First, we find stochastic $\beta-$convergence for six European countries during the 1963-2000 period (Denmark, Finland, Germany, Portugal, Spain and Sweden) using semi-annual data GDP (PPP at 1995 prices) and population series extracted from the OECD database. The reference time series used to observe convergence is the EU-15 series which has been constructed by OECD using weighted averages of the individual countries with GDP-weights measured in units of PPP at 1995 prices. Three of those countries (Spain, Portugal and Finland) are initially 'poor' and with a growth rate larger than the EU average. In the other direction, Germany, Denmark and Sweden are initially 'rich' countries and with a smaller growth rate than EU-15 average. Second, we observe that countries with smaller than the average GDP per head have accelerated convergence during expansion periods while they remain constant in recession periods. In the 'rich' countries case the results are not identical. For Denmark and Sweden we find lower convergence during expansion periods than in recession periods. In the German case we do not find similar results.

The rest of the paper will be structured in the following way. Section 2 offers stochastic convergence definition and studies this type of convergence for EU-12 countries. Section 3 observes business cycle effects on stochastic convergence through a linear model. Section 4 applies Hamilton (1991) methodology to analyse business cycle effects on convergence. Finally, Section 5 concludes.

2 Preliminary analysis: real convergence between countries

In this section we introduce and apply a stochastic convergence definition proposed by Carlino and Mills (1993) for 15 EU countries[3].

We define d_{it} as the deviation of output in country i from output in another country or reference area,

$$d_{it} = y_{it} - y_t^* \tag{1}$$

where y_{it} is (logged) GDP per head in country i in period t and y_t^* is (logged) GDP per head in the reference area. We have stochastic convergence when d_{it} is a covariance stationary process, that is to say, $d_{it} \sim I(0)$. In other words, stochastic convergence exists when income per head differentials are transitory.

To make the basic point of the paper without introducing unnecessary complications, we modify the econometric model proposed by Carlino and Mills (1993). Following these authors we allow for persistence differences in output. This assumption implies two types of convergence: *absolute* or *conditional* convergence.

$$d_{it} = d_i^e + u_{it} \tag{2}$$

[3] There is no data available for Luxembourg during our sample period. So, we exclude it in our convergence analysis.

where d_i^e is income differential in equilibrium and u_{it} are income deviations from long-run equilibrium. The d_i^e term captures the possibility of convergence to different income levels in the long-run when countries have different structural parameters concerning preferences, technology, human capital level and population growth rate. if $d_i^e = 0$, we have *absolute* convergence , while we talk about *conditional* convergence in case $d_i^e \neq 0$.

The term u_{it} contains a linear trend and a stochastic process,

$$u_{it} = \varepsilon_{i0} + \beta_i t + \varepsilon_{it} \tag{3}$$

where ε_{i0} is the initial deviation from equilibrium and β_i is the 'convergence rate'. β-convergence exists in the following cases: (i) $\varepsilon_{i0} > 0, \beta_i < 0$. In this case we find an initially 'rich' country with a positive differential in income to the steady-state level; (ii) $\varepsilon_{i0} < 0, \beta_i > 0$. We have a 'poor' country with a negative differential to the steady-state level that it growths faster than the reference area. In the traditional cross-section tests an assumption of identical β coefficients it is imposed for all the countries. This approach also allows us different velocities of convergence among countries.

Substituting (3) into (2) we obtain:

$$d_{it} = \alpha_i + \beta_i t + \varepsilon_{it} \qquad \text{where} \qquad \alpha_i = d_i^e + \varepsilon_{i0} \tag{4}$$

To test whether convergence is guided by one of the previous situations we estimate equation (4). if $\varepsilon_{it} \sim I(0)$ we find stochastic convergence. We find

β-convergence (*catching-up)* in the following cases: (i) $\alpha_i > 0, \beta_i < 0$, (ii) $\alpha_i < 0, \beta_i > 0$. Finally, absolute convergence exists when $\alpha_i = \beta_i = 0$ and conditional convergence when $\alpha_i \neq 0, \beta_i = 0$.

A preliminary step in our analysis is to do an unit root test in the deviation of output in country i from output EU, d_{it} to observe what type of convergence exists. Figure 1 shows d_t variable in each of the fourteen countries in our sample. Our unit root tests could be sensitive to our elected test. We do four different unit root test in order to check that our results are robust. We use Augmented Dickey-Fuller (ADF) test, Kwiatkowski, Phillips, Schmidt, and Shin (1992), Elliott, Rothenberg, and Stock Point Optimal (1996) and Lobato y Robinson (1998). In appendix we offer our results for each EU country. We do not find evidence of stochastic convergence in four countries: France, Greece, Ireland and Netherland. Stochastic convergence exists in the rest of countries. Nevertheless, there are differences among them. We observe a *'catching-up'* effect or β-convergence for Spain, Portugal, Italy, Finland, Germany and Sweden and *conditional* convergence for Belgium, Italy and UK . We only find absolute convergence in Austria.

Table 1 reports results for convergence or 'catching-up' countries. As regards *conditional* convergence countries we observe several differences. In particular, Belgium has a larger than average steady-state level. In Italy and UK we find the opposite result, a steady-state level smaller than average. With regard to *'catching-up'* or β-convergence we find this type of convergence for six countries. So, Spain, Portugal and Finland are countries initially 'poor' with a growth rate larger than EU average ($\alpha_i < 0, \beta_i > 0$). Otherwise, Germany, Denmark and Sweden are countries initially 'rich' with a growth rate smaller than EU average ($\alpha_i > 0, \beta_i < 0$).

3 A linear model to analyse business cycle effects on convergence

The change in the relative income seems to be very different in expansions and recessions in the six countries where there are evidence of β-convergence. Table 2 decomposes total variation in relative income into variation in expansions and recessions. The expansion and the recessionary periods have been computed using the turning points reference chronologies series from the OECD.[4] The results shows that in all countries the behaviour of the relative income is extremely different depending on the business cycle phase. Major differences appears in "poor countries", for example, Spain has increased it relative income in 13,45 percentage points, but during recessions the relative income has diminished 2,15 percentage points. The difference is greater in Portugal and Finland where their relatives incomes have shown increases of 29,26% and 36,52% respectively in expansions while they have fallen 16,95 and 26,08 percentage points during recessions. For the rich countries also appears to be differences over the business cycle, although they are of lower size. For example, the convergence of

[4] see the following address: http://www.oecd.org/oecd/pages/home/displaygeneral/0,3380,EN-countrylist-509-15-no-no-287-509,00.html

Sweden to the EU has taken place due exclusively to the reccesionary periods where its relative income has fallen more than 15%, because in expansions it has decreased less than 2%. A formal test for the differences in the behaviour of the relative income between expansions and contractions could be computed using a test for equality of means, i.e to test if the changes in relative income in expansions is statistically equal to their mean in recessions. The results of this test are shown in table 3. As it could be seen, using the OECD definition of the cycle, there are significative differences for the change of the relative income in the initially "poor countries". For Spain, Portugal and Finland we reject the null hypothesis that the mean is equal in expansions and recessions at the 5% level. However, using this approach we obtain that the differences for the rich countries are not statistically different.

A first approximation to the impact of the business cycle in the convergence can be calculated using a binary variable to separate expansions and recessions. Thus, following the OECD turning points for the six countries analyzed above, we define the following dummy variable:

$$D_t = \begin{Bmatrix} 0 \text{ if the economy is in expansion at time t} \\ 1 \text{ if the economy is in recession at time t} \end{Bmatrix}$$

To measure the impact of recessions in the convergence rate we estimate the following equation

$$d_t = \alpha + \beta_1 t + \beta_2 t D_t + \eta_t \tag{5}$$

,so the convergence rate in expansions is given by β_1, while in recessions the convergence rate is equal to $\beta_1 + \beta_2$. Results are shown in table 4. For Spain, the convergence rate in expansions is twice than in recessions. In Finland, the convergence rate is positive in expansions whereas in recessions is not statistically different from zero. Denmark also shows a difference of 25% in its velocity of convergence over the business cycle. In the other three countries differences are smaller: 5% for Germany, 3% for Portugal and 6,5% for Sweden.

The definition of business cycle is a difficult and controversial task. In particular, the OECD definition is very critical since it only considers two posible states without posibility of intermediate situations. In addition, it is only disposable for a limited sample in some countries. In order to test for the robustness of our results we derive an alternative measure of the business cycle that does not impose a discrete choice for the business cycle phases. We compute a measure of the output gap for each country based on their GDPs.

There are several ways to measure business cycle depending on the used filter to extract the trend in the time series. In this paper we use the Hodrick-Prescott filter with a coefficient of 800 to get the cyclical component [5] and a cubic trend. The results applying both techniques are very similar[6]. Figure 2 shows HP filter and cubic trend results for six countries. We can observe similarities between both measures.

[5] We also apply HP filter with coefficients 400 or 600 obtaining similar results.

[6] The correlation coefficient between HP filter and cubic trend results is larger than 0.9 in countries with β-convergence.

In the previous section, we conclude that convergence process are not gradual but countries have deviations from its convergence path during long periods. This implies that shocks are very persistence and could produce an erroneous result in unit root tests depending on the used procedure. Figure 3 offers relative income and the convergence path or catching-up derived from the adjusted equation: $d_t = \alpha + \beta t + \varepsilon_t$. We observe how relative income deviates from convergence path in the six countries. To observe persistence deviations we could estimate correlations between series. Table 5 shows our results. We have a first-order autorregresive coefficient around 0.9 for all the countries. The largest coefficient is for the Spanish case (0.97).

There are multiple factor to explain deviations from convergence path. In this paper we focus on business cycle factor. Figure 4 shows relative income for each country with reference to EU-15 average and the output-gap measured through HP filter. We observe an important relation between both series. An initial exercise to quantify the business cycle effect on convergence process is to include the output gap variable as an additional regressor in the equation:

$$d_t = \alpha + \beta t + \varepsilon_t \tag{6}$$

First, we estimate the following equation:

$$d_t = \alpha + \beta t + \gamma ciclo + \eta_t \tag{7}$$

Coefficient γ offers us the importance of cycle in the convergence process. Table 6 shows us the main results. This variable is significant for six countries with stochastic convergence. The cycle variable captures differences between GDP and GDP trend (*output-gap*). The expected result is a growth above potential growth during expansion periods when γ is positive. When γ is negative we have the opposed result, economy is growing under the trend growth because it is in a recession phase.

The variable is positive and around one for countries with an initial low income and growth larger than the EU-15 average (Spain, Portugal and Finland). We observe an acceleration in convergence process during expansion phases while we have an stagnation during recession phases. $\widehat{\gamma}$ parameter is near from 1 in the three countries. This means that one extra point in long-run GDP growth implies a decrease in income differential by one point. Countries with an initial high income (Germany, Sweden and Denmark) results are not similar. Denmark and Sweden offer a positive $\widehat{\gamma}$ value and Germany a negative value. For Denmark and Sweden expansion periods have a negative effect in convergence process to EU-15 average while we have an acceleration during recession periods. In this case business cycle influence is contrary.

For the German economy we find a negative $\widehat{\gamma}$ coefficient. This result implies that cyclical fluctuations affects in the same way than in poor countries. Nevertheless, our findings show a low significance for the estimated coefficient for Germany and should be cautiously interpreted because there was structural changes in the time series as a consequence of German reunification.

4 A non-linear model to analyse business cycle effects on convergence

In this section we use a different econometric approach to analyse business cycle effects on convergence. We use an extension of the Hamilton (1991)'s Markov Switching methodology. that has had multiple advances from his original contribution[7].

The Hamilton model is useful in our context by three reasons. First, it allows to endogenously determine business cycle phases. This aspect supposes to avoid several critics about using HP filter or an alternative measure for the output gap. Second, it is easy to test whether convergence velocity for 'poor' countries has been larger during expansion than recession periods. The same result could be tested for 'rich countries in the opposite way. through this approach. Finally, we can observe how complementary business cycle is between countries. Next, we introduce the econometric model to estimate business cycle effects on convergence.

As is well-known, Hamilton's (1989) approach is based on the assumption that the actual state of the economy, i.e., recession (r) or expansion (e), is determined by an unobserved latent random variable with a Markovian structure. The version presented below is a meanshift one where the average growth rate of GDP(μ) is allowed to vary depending on whether the economy is in an expan-

[7] See Hamilton and Raj(2002)

sion, μ_e, or in a recession, μ_r. GDP growth is also assumed to be determined by an AR(p) process.

To test whether stochastic convergence has changed depending on the business cycle phase we jointly estimate the following two equations:

$$\begin{aligned} \Delta y_{it} &= \phi_{i1}\Delta y_{it-1} + ... + \phi_{ip}\Delta y_{it-p} + \mu_{ir}(1-\phi_{i1} - ... - \phi_{ip}) + \\ &\quad \Delta\mu_i(S_t - \phi_{i1}S_{t-1} - ... - \phi_{ip}S_{t-p}) + \eta_{it} \end{aligned} \tag{8}$$

$$d_{it} = \alpha(S_t) + \beta(S_t)t + \varepsilon_t \tag{9}$$

$$d_{it} = y_{it} - y_t^* \tag{10}$$

where Δy_{it} is the semi-annual GDP growth rate (seasonally adjusted) in country i, $\Delta\mu_i = \mu_{ie} - \mu_{ir}$, S_t is the state variable, η_{it} is distributed $N(0,1)$, d_{it} is the difference between (logged) GDP per head in country i and (logged) GDP per head EU-15, α and β measures the convergence process. We suppose this latter parameters depends on the business cycle phase.

The state variable in the model, S_t, is assumed to follow a discrete time Markov process which is characterized by the following transition probability matrix:

$$\begin{bmatrix} p_{rr} \, p_{er} \\ p_{re} \, p_{ee} \end{bmatrix} = \begin{bmatrix} p_{rr} & 1 - p_{ee} \\ 1 - p_{rr} & p_{ee} \end{bmatrix} \tag{11}$$

where:

$$p_{kj} = \Pr(S_t = j/S_{t-1} = k), \text{ with } \sum_{j=r}^{e} p_{kj} = 1 \text{ para todo i} \tag{12}$$

and p_{kj} is the probability of going from state k to state j (e.g. , p_{re} is the probability of going from a recession to an expansion, etc.). Finally, we assume that the transition probabilities are constant over time and are determined by the following logistic distribution functions:

$$p_{rr} = \Pr(S_t = r/S_{t-1} = r) = \frac{\exp(\theta_r)}{1 + \exp(\theta_r)} \tag{13}$$

$$p_{ee} = \Pr(S_t = e/S_{t-1} = e) = \frac{\exp(\theta_e)}{1 + \exp(\theta_e)} \tag{14}$$

where θ_r and θ_e are the parameters that determine the probabilities of being in a recession an in an expansion, respectively.

As Hamilton (1989) has shown, the previous assumptions allow us to obtain a sequence of joint conditional probabilities $\Pr(S_t = i, ..., S_{t-s} = j/\Phi_t)$, which are the probabilities that the GDP growth series is in state k or j (k,j=r,e) at times t,$t-1$, until $t-s$, respectively, conditional upon the information available at time t. By adding those joint probabilities we can obtain the so-called smoothed filter probabilities, namely, the probabilities of being in states r or e at time t, given the information available at time t:

$$\Pr(S_t = j/\Phi_t) = \sum_{k=r}^{e} ... \sum_{j=r}^{e} \Pr(S_t = i, ..., S_{t-s} = j/\Phi_t) \text{ k,j = e,r} \tag{15}$$

where Φ_t is a set of information in period t. The smoothed probabilities provide information about the regime in which the series is most likely to have been in time t at every point in sample. Therefore, they turn out to be a very useful tool for dating phase switches and could be employed in the estimated model in section 3.

Table 7 reports the results for the econometric model with $p = 2$ for the sample 1963:1 2000:1[8]. We begin with Spain where $\beta-$coefficient is clearly larger during expansion (0.00184) phases than during recessions (0.00075). The first regime corresponds to a low growth phase with a semi-annual growth rate of 1.00% (2.00% annually). This result implies that it is more appropriate to interpret that phase as one of mild growth rather than a proper recession. The second regime, in turn, corresponds more clearly to an expansion phase with an average semi-annual growth rate of 2.04%(4.08% annual). As regards the probabilities of remaining in each regime, they are estimated to be 0.70 for a mild-growth phase and 0.64 for an expansion. This probabilities implies

[8] Moreover, when extending the maximum lag length to $p_{max} = 4$, the BIC lag length criterion chooses p=1 for Finland and Sweden and p=2 for the rest of countries.

a mean duration of 3.33 semesters and 2.27 for mild-growth and expansion phases, respectively[9]. Figure 5 plots semi-annual growth rates and the smoothed filter probabilities of being in an expansion for the six countries. The largest probabilities correspond to second half of the 1970s and the first half of 1980s.

With regard to Finland, the first regime corresponds to a recession growth phase and the second regime to an expansion phase with an average semi-annual growth rate of -0.56%(-1.12% annually) and 1.80%(3.60% annually), respectively. The probabilities of remaining in each regime, they are estimated to be 0.65 for a recession phase and 0.82 for an expansion. This probabilities implies a mean duration of 2.86 semesters and 5.55 for mild-growth and expansion phases, respectively. $\beta-$coefficient is again larger during expansion (0.00135) phases than during recession (0.000209) periods.

As for Portugal, the results are fairly similar to the ones found for Finland. In fact, we have similar mean durations for recession and expansion phases (2.38 and 5.88 for recession and expansion phases, respectively). As in the cases of Finland and Spain we find a $\beta-$coefficient larger during expansion (0.00303) than during recession phases (0.00188).

As for Denmark and Sweden, the first regime again corresponds to a low growth phase with a semi-annual growth rates of 0.29% (0.60% annually) and 0.45% (0.90% annually). The second regimes show an average semi-annual growth rates of 1.80%(3.60% annually) and 1.30%(2.60% annually). As regards

[9] Mean duration in state k is defined as $1/(1\text{-}p_{kk})$, k=e,r.

the probabilities of remaining in each regime, they are estimated to be very similar 0.88 and 0.86 for a mild-growth phase and 0.88 (both) for an expansion, respectively. This probabilities implies similar mean durations. It becomes clear that the convergence effects are much larger in mild growth phases than expansions. We have $\beta-$coefficients of -0.0013 and -0.0072 for recession phases and -0.00012 and -0.0035 for expansion phases, respectively.

Lastly, the results for Germany are peculiar. We have the expected negative sign for the $\beta-$coefficient but we observe a larger value during expansion (-0.00134) than during recession (-0.00134) phases. With reference to regimes we have values of 0.51% (1.02% annually) and 1.51%(3.02% annually) for first and second regime semi-annual growth rates. The fact that we tend to find this result for the German case could be somewhat justified in terms of the re-unification effect on their cyclical behaviour.

It becomes clear that the convergence rates are much larger in expansion phases than recessions in 'poor' countries and the opposite result for 'rich' countries (except Germany). Indeed, the null hypothesis of symmetry ($\mathrm{H}_0 : \beta_e = \beta_r$) is clearly rejected with a p-values of 0.002 (Spain), 0.000 (Finland), 0.003 (Portugal), 0.000 (Denmark), 0.004 (Sweden) and 0.003 (Germany). Thus, the overall evidence is that the velocity of convergence varies conditioned on the business cycle state and depends on the initial position of the country (poor or rich respect to the EU-15 average).

5 Conclusions

In this paper we have examined whether business cycle affects convergence process or catching-up. In particular, we have centered on countries where we clearly find β-convergence evidence.

First, we test stochastic convergence for EU-15 countries using semi-annual data over the period 1963:1-2000:1 and only find evidence about that type of convergence for Spain, Finland, Portugal, Denmark, Sweden and Germany. Once we have tested stochastic convergence we proceed to analyse whether real convergence may depend on the phase/state of the business cycle that the economy is undergoing through a linear and a non-linear approach.

We find strong evidence that 'poor' countries (Spain, Portugal and Finland), whose initial relative income is low, show larger convergence rates during expansion periods than recession one. In 'rich' countries (Denmark and Sweden) we derive that convergence to EU-15 average exists but is smaller during in a state of expansion than recession. The German case is not a typical case because we have convergence to the EU-average but this convergence is similar to the poor countries (larger during expansion than recessions).

In sum, the overall evidence through two different approaches is that the velocity of convergence varies conditioned on the business cycle state and also depends on the initial position of the country ('poor' or 'rich') relative to the EU-15 average.

However, we think that further research could be done in this topic. In our approach we use a two step procedure choosing those countries where we find stochastic convergence. We could use an extension of the Markov-switching equilibrium-correction (MS-VECM) model introduced by Krolzig (1997) to test the main implications of this paper. Our main results will probably remains but we could probably find evidence about this type of asymmetric business cycle effect on convergence rate in another countries excluding at the beginning of our paper. Hence, the MS-VECM will allow us to contemplate the possibility of gradual convergence.

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Appendix: Unit root tests

In this appendix we offer results on four 'unit root' tests: Augmented Dickey-Fuller (ADF, 1979), Kwiatkowski, Phillips, Schmidt, and Shin (KPSS, 1992), Elliott, Rothenberg, and Stock Point Optimal (ERS, 1996) and Lobato-Robinson (LR, 1998). We specify the statistic, critical value and the final result. The null hypothesis varies depending on the test. So, in ADF and ERS the null hypothesis is the existence of a 'unit root', while in KPSS and LR is the stationarity in covariance.

SPAIN

Test	Statistic	Critical Value	Result
ADF	-2.47	-3.47	I(1)
KPSS	0.126	0.146	I(0)
ERS	16.15	5.68	I(0)
LR	-0.226	1.96	I(0)

AUSTRIA

Test	Statistic	Critical Value	Result
ADF	-3.71	-2.91	I(0)
KPSS	0.34	0.46	I(0)
ERS	20.9	3.04	I(0)
LR	0.001	1.96	I(0)

BELGIUM

Test	Statistic	Critical Value	Result
ADF	-3.95	-2.91	I(0)
KPSS	0.34	0.46	I(0)
ERS	21.7	3.04	I(0)
LR	-0.45	1.96	I(0)

GERMANY

Test	Statistic	Critical Value	Result
ADF	-1.64	-3.47	I(1)
KPSS	0.129	0.146	I(0)
ERS	15.61	5.68	I(0)
LR	-0.20	1.96	I(0)

DENMARK

Test	Statistic	Critical Value	Result
ADF	-3.45	-3.47	I(1)
KPSS	0.125	0.146	I(0)
ERS	11.33	5.68	I(0)
LR	-0.18	1.96	I(0)

FINLAND			
Test	Statistic	Critical Value	Result
ADF	-2.85	-3.47	I(1)
KPSS	0.145	0.146	I(0)
ERS	5.82	5.68	I(0)
LR	-0.48	1.96	I(0)

FRANCE			
Test	Statistic	Critical value	Result
ADF	-0.99	-2.90	I(1)
KPSS	0.473	0.463	I(1)
ERS	1.07	3.04	I(1)
LR	-0.26	1.96	I(0)

GREECE			
Test	Statistic	Critical Value	Result
ADF	-2.23	-2.91	I(1)
KPSS	0.537	0.463	I(1)
ERS	1.69	3.01	I(1)
LR	-0.24	1.96	I(0)

IRELAND

Test	Statistic	Critical Value	Result
ADF	1.78	-3.47	I(1)
KPSS	0.251	0.146	I(1)
ERS	1.84	5.68	I(1)
LR	-0.49	1.96	I(0)

ITALY

Test	Statistic	Critical value	Result
ADF	-2.75	-2.90	I(1)
KPSS	0.339	0.463	I(0)
ERS	21.98	3.04	I(0)
LR	-0.21	1.96	I(0)

THE NETHERLANDS

Test	Statistic	Critical value	Result
ADF	-1.33	-2.90	I(1)
KPSS	0.806	0.463	I(1)
ERS	2.32	3.04	I(1)
LR	-0.34	1.96	I(0)

PORTUGAL			
Test	Statistic	Critical value	Result
ADF	-3.61	-3.47	I(0)
KPSS	0.115	0.146	I(0)
ERS	11.58	5.68	I(0)
LR	-0.21	1.96	I(0)

SWEDEN			
Test	Statistic	Critical value	Result
ADF	-3.88	-3.48	I(0)
KPSS	0.072	0.146	I(0)
ERS	10.52	5.68	I(0)
LR	-0.30	1.96	I(0)

UK			
Test	Statistic	Critical Value	Result
ADF	-3.16	-2.90	I(0)
KPSS	0.229	0.463	I(0)
ERS	46.03	3.04	I(0)
LR	-0.48	1.96	I(0)

TABLE 1

Countries with stochastic convergence evidence

	$\widehat{\alpha}$	$\widehat{\beta}$	
Spain	-0.375 (-22.31)	0.00117 (4.02)	β-convergence
Austria	0.018 (1.63)		Absolute convergence
Belgium	0.049 (8.09)		Conditional convergence
Germany	0.250 (18.62)	-0.00238 (-6.37)	β-convergence
Denmark	0.205 (17.22)	-0.00143 (-5.99)	β-convergence
Finland	-0.111 (-6.78)	0.00150 (3.28)	β-convergence
Italy	-0.054 (-6.03)		Conditional convergence
Portugal	-0.752 (-22.89)	0.00519 (9.51)	β-convergence
Sweden	0.187 (22.70)	-0.00282 (-13.94)	β-convergence
UK	-0.081 (-7.70)		Conditional convergence

t-statistic between brackets

Standard errors are calculated through Newey-West method

TABLE 2

Changes in relative incomes over the business cycle

	Full sample	Expansions	Recessions	Sample period
Spain	13.45%	15.60%	-2.15%	1966-2000
Germany	-20.88%	-7.88%	-13.00%	1959-2000
Denmark	-1.37%	1.03%	-2.4%	1975-2000
Finland	13.44%	39.52%	-26.08%	1970-2000
Portugal	12.31%	29.26%	-16.95%	1973-1998
Sweden	-17.49%	-1.80%	-15.69%	1963-2000

Expansions and recessions have been computed using the turning points dated by the OECD.

TABLE 3

Test for equality of means between series

	Expansions	Recessions	F-statistic	Probability	Sample period
Spain	0.3999	-0.0740	4.7559	0.0325	1966-2000
Germany	-0.1751	-0.4489	0.4404	0.5090	1959-2000
Denmark	0.0381	-0.1001	0.1501	0.7001	1975-2000
Finland	1.0428	-1.1343	35.4237	0.0000	1970-2000
Portugal	0.8866	-0.9971	30.2831	0.0000	1973-1998
Sweden	-0.0429	-0.5060	2.1741	0.1448	1963-2000

This table presents the mean of the change in the relative income over the business cycle. Expansions and recessions have been computed using the turning points dated by the OECD.

CUADRO 4

Estimation of the equation $d_t = \alpha + \beta_1 t + \beta_2 t D_t + \eta_t$, where

$$D_t = \begin{Bmatrix} \text{0 if the economy is in expansion at time t} \\ \text{1 if the economy is in recession at time t} \end{Bmatrix}$$

	$\widehat{\alpha}$	$\widehat{\beta}_1$(expansions)	$\widehat{\beta}_1 + \widehat{\beta}_2$ (recessions)	R^2
Spain	−0.351 (−34.13)	0.000928 (4.51)	0.000457 (1.91)	0.28
Germany	0.195 (47.12)	−0.000301 (−2.70)	−0.000317 (−2.58)	0.96
Denmark	0.156 (10.86)	−0.000537 (−2.13)	−0.000675 (−2.49)	0.12
Finland	−0.053 (−2.91)	0.000776 (2.27)	−0.0000569 (0.14)	0.21
Portugal	−0.695 (−34.19)	0.004163 (11.05)	0.004045 (9.43)	0.72
Sweden	0.188 (27.76)	−0.002768 (−19.25)	−0.002948 (17.65)	0.85

t-statistic between brackets. Standard errors are calculated through Newey-West method. Expansions and recessions have been computed using the turning points dated by the OECD. To take into account the german reunification an additional dummy variable has been included to this country that take the value of zero before 1991 and value one otherwise. This dummy variable enter in the equation both additive and multiplicative.

TABLE 5

Income deviations persistence from convergence path

$$(d_t - \widehat{\alpha} - \widehat{\beta}t) = \widehat{\rho}(d_{t-1} - \widehat{\alpha} - \widehat{\beta}(t-1))$$

	$\widehat{\rho}$
Spain	0.971 (23.29)
Germany	0.917 (10.64)
Denmark	0.886 (19.55)
Finland	0.944 (25.18)
Portugal	0.911 (14.26)
Sweden	0.874 (17.99)

TABLE 6

Estimated equation: $d_t = \alpha + \beta t + \gamma ciclo + \eta_t$

	$\widehat{\alpha}$	$\widehat{\beta}$	$\widehat{\gamma}$	R^2
Spain	-0.375 (-26.94)	0.00121 (4.24)	1.017 (3.22)	0.57
Germany	0.250 (16.65)	-0.00238 (-6.15)	-0.452 (-1.57)	0.65
Denmark	0.205 (18.08)	-0.00142 (-6.90)	0.869 (4.62)	0.71
Finland	-0.114 (-10.64)	0.00159 (6.20)	1.139 (8.39)	0.68
Portugal	-0.752 (-25.52)	0.00519 (10.32)	1.108 (4.21)	0.89
Sweden	0.186 (22.11)	-0.00277 (-17.24)	0.819 (5.79)	0.91

t-statistic between brackets. Standard errors are calculated through Newey-West method. The variable *ciclo* has been computed using the Hodrick-Prescott filter.

TABLE 7

NON-LINEAR MODEL

$$\Delta y_{it} = \phi_{i1}\Delta y_{it-1} + ... + \phi_{ip}\Delta y_{it-p} + \mu_{ir}(1 - \phi_{i1} - ... - \phi_{ip}) + \Delta\mu_i(S_t - \phi_{i1}S_{t-1} - ... - \phi_{ip}S_{t-p}) + \eta_{it}$$

$$\& \ y_{it} - y_t^* = \alpha(S_t) + \beta(S_t)t + \varepsilon_t$$

	SP	GE	DEN	FIN	$PORT$	SW
μ_r	.44 (3.21)	.51 (2.92)	.29 (5.85)	−.56 (3.30)	−.81 (5.45)	.45 (1.99)
μ_e	1.70 (3.43)	1.51 (1.89)	1.58 (2.30)	1.80 (5.37)	2.12 (16.03)	1.30 (8.92)
ϕ_1	1.03 (34.20)	1.18 (37.00)	.45 (32.71)	.21 (27.56)	1.27 (34.71)	.32 (28.65)
ϕ_2	−.11 (12.28)	−.43 (6.74)	−.25 (3.53)	− −	−.74 (10.82)	− −
p_{rr}	.61 (5.32)	.82 (7.90)	.84 (8.50)	.65 (3.70)	.58 (3.00)	.86 (2.72)
p_{ee}	.66 (5.14)	.91 (5.28)	.88 (14.00)	.82 (6.39)	.83 (7.74)	.88 (2.69)
α	−.360 (23.95)	.239 (8.61)	.194 (3.05)	−.101 (1.67)	−.705 (2.17)	.167 (6.31)
β_r	.00021 (10.24)	−.00068 (10.91)	−.00127 (13.52)	.000209 (7.24)	.00188 (9.65)	−.0072 (1.71)
β_e	.00082 (10.27)	−.00134 (36.19)	−.00012 (13.14)	.00135 (2.84)	.00303 (7.24)	−.003549 (1.82)
σ	.0000092 (16.67)	.0000058 (10.91)	.000014 (4.09)	.0000056 (18.08)	.0000671 (1.93)	.000036 (9.26)
σ_c	.001 (51.76)	.00153 (36.19)	.00076 (8.25)	.0024 (23.81)	.0014 (4.11)	.00062 (11.40)
d_r	2.56	5.55	6.25	2.86	2.38	7.14
d_e	2.51	11.11	8.33	5.55	5.88	8.34
Log-lik	217.68	213.66	237.18	193.24	211.14	237.64

Figure 1
Differences in GDP per capita between each country and the EU-15

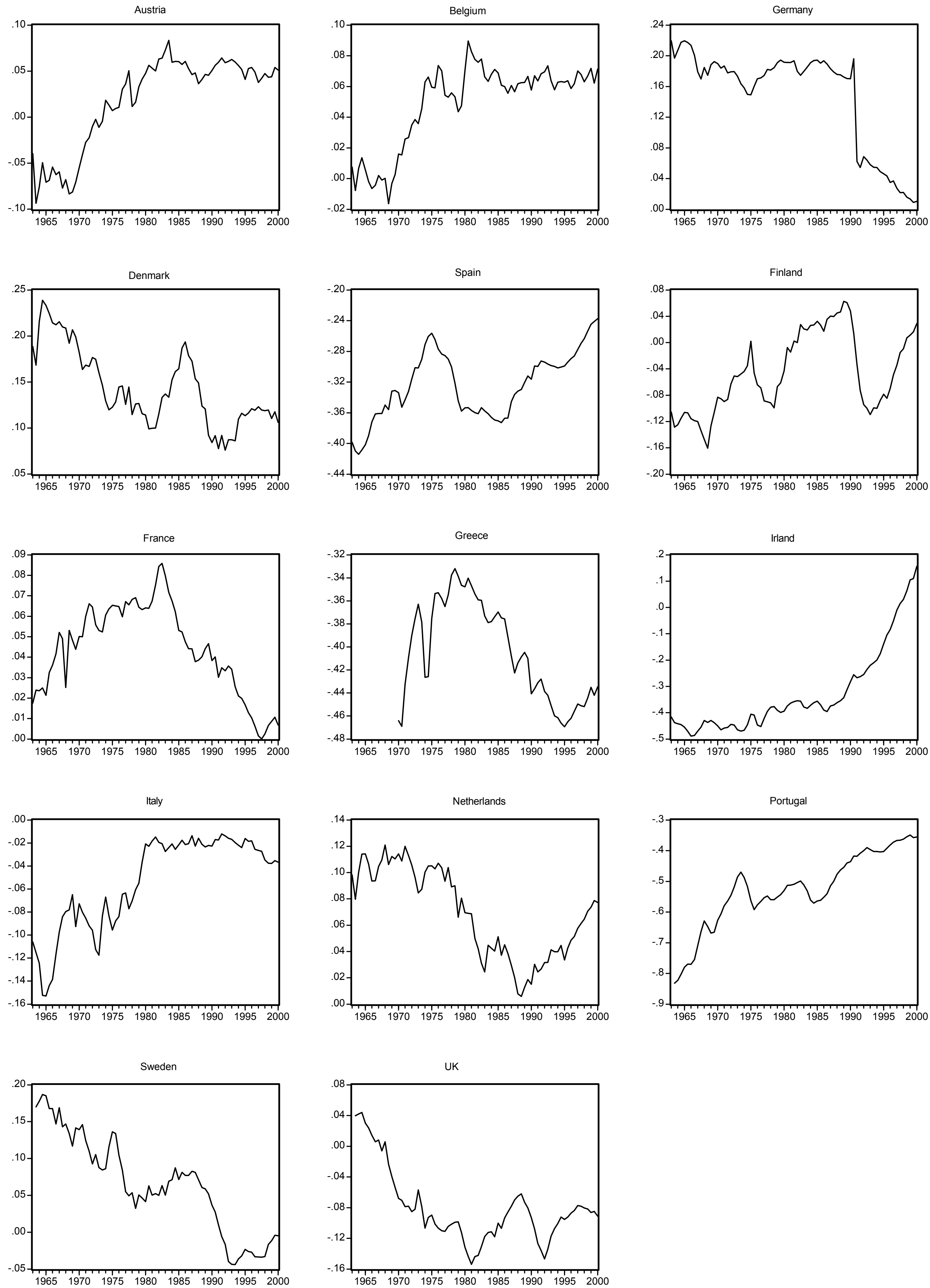


Figure 2
Output Gap computed using the Hodrick-Prescott filter (solid line)
and a cubic trend (dashed line)

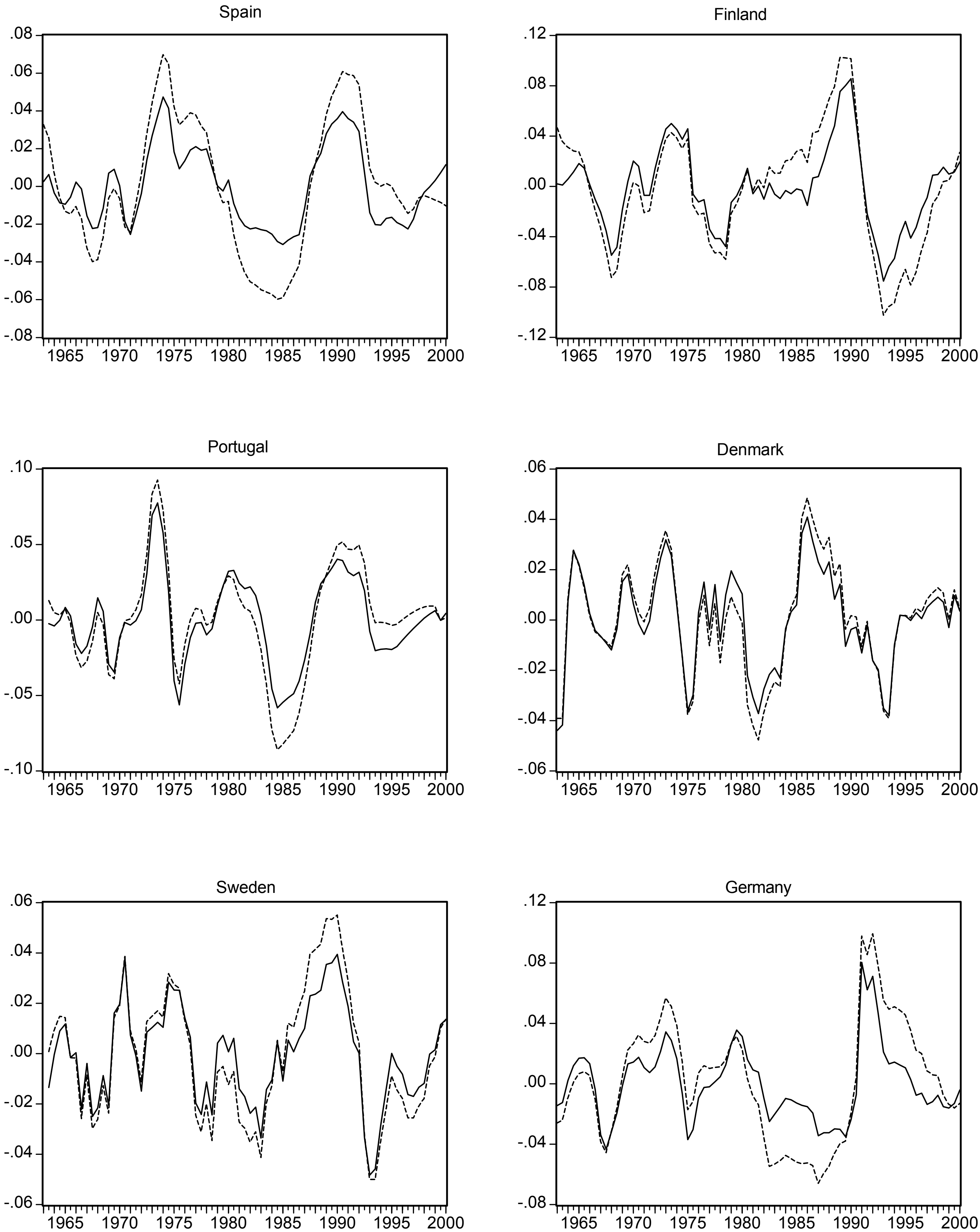
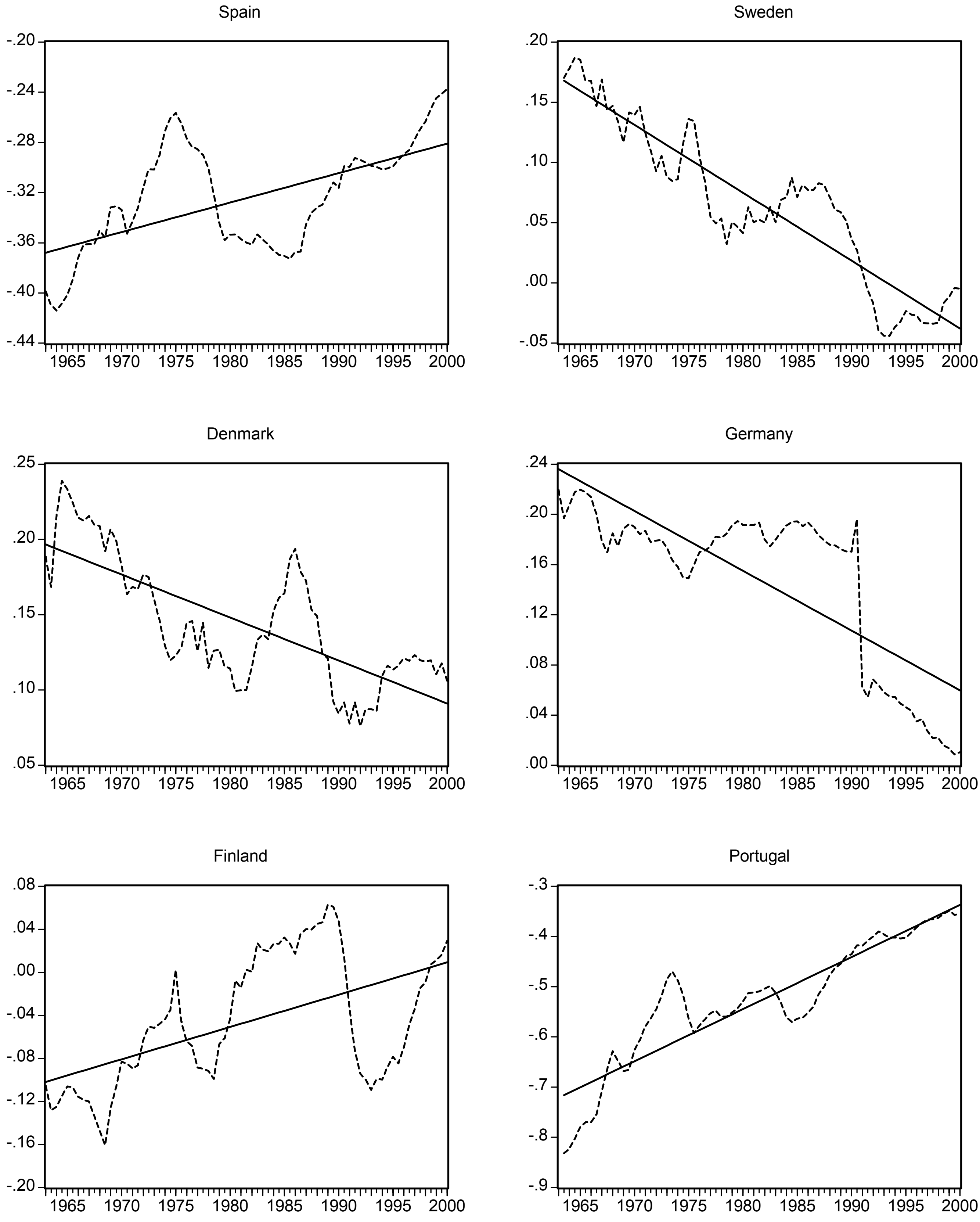
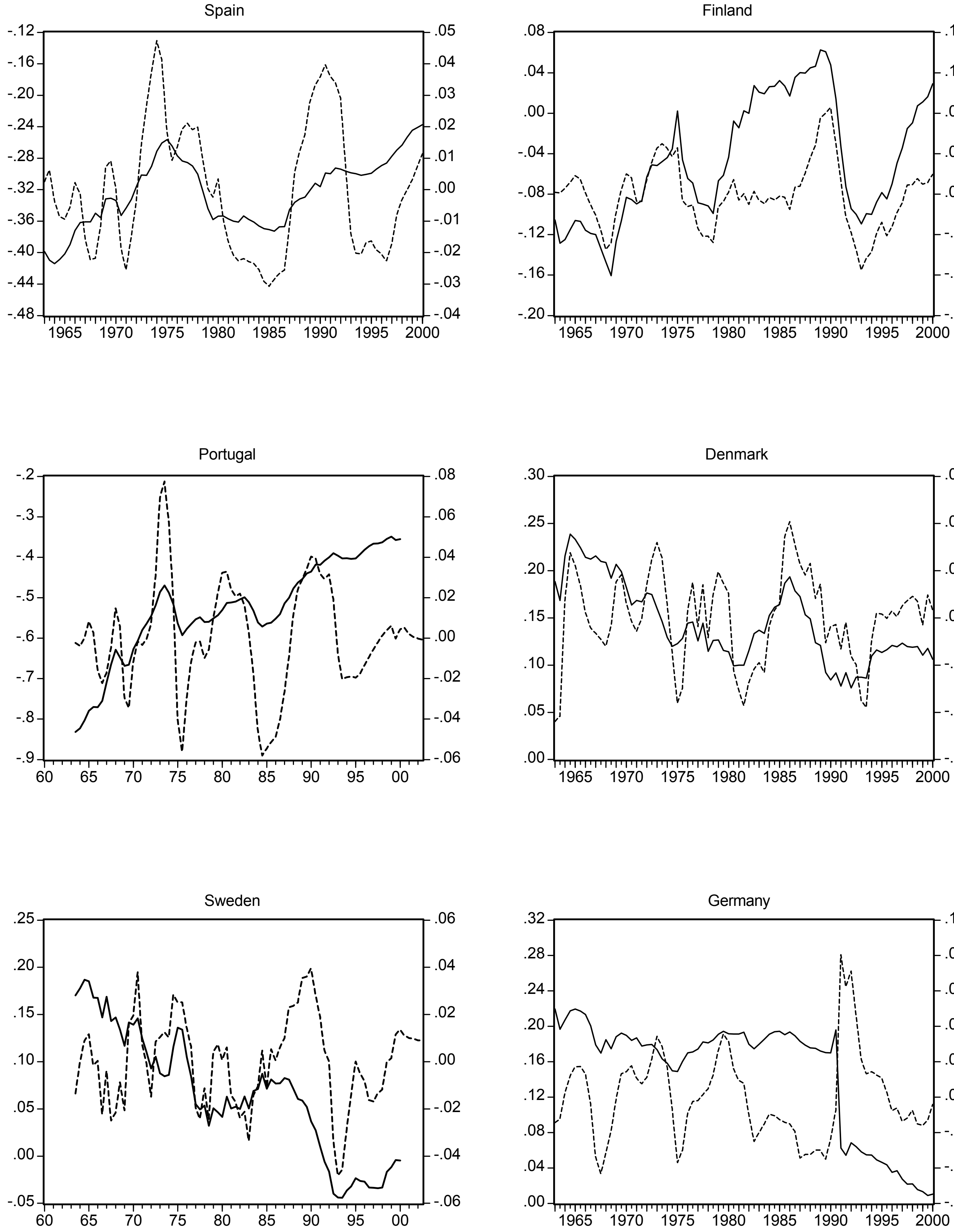


Figure 3
Relative income (dashed line) and convergence path (solid line)



Note: the convergence path is derived from the adjusted equation "relative income = a + bt"

Figure 4
Relative income (solid line, left scale) and output gap (dashed line, right scale)



Note: the output-gap has been computed using the Hodrick-Prescott filter with a smoothing parameter of 800 since we work with semi-annual data.