WIIW Working Papers

No. 14

June 2000

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Potential Switchovers in Comparative Advantage: Patterns of Industrial Convergence

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Vienna, July 5, 2000

Abstract

Although there exists a vast literature on convergence and divergence of income levels across countries or regions at the aggregate level, there is only little work on convergence and/or divergence processes of productivity and wage levels at the more disaggregated industrial level. These are especially important in the context of international trade as these determine the dynamics of comparative advantages and the resulting trade structures between developing and developed countries. In the first theoretical part, we discuss some theoretical aspects of uneven sectoral productivity and wage catching-up processes and their links to dynamic comparative advantages and trade structures. In the second part we present an econometric study of catching-up of wages, productivity, and labour unit costs. The analysis is conducted at the industrial level (ISIC 3-digit) over the period 1965-1995 for a set of catching-up economies compared to more advanced countries.

JEL-Classification: F14, L6, O10, O14, O30, O41

Keywords: catching-up, comparative advantages, unit labour costs, convergence patterns, industrial development

Contents

List of Figures

List of Tables

POTENTIAL SWITCHOVERS IN COMPARATIVE ADVANTAGE: PATTERNS OF INDUSTRIAL CONVERGENCE

Michael A. Landesmann and Robert Stehrer [1]

1 Introduction

There is some evidence that catching-up countries (like Japan, NIC's) are doing quite well especially in technically more sophisticated branches (like electronics, ...) and are becoming rapidly net exporters in these branches. This aspect of the development process is neither captured in traditional trade theory (with its emphasis on static (or long term) equilibrium structures nor in growth theory analysing mainly aggregate phenomena). But in the course of development there often occurs (rapid) structural change and uneven technological progress across sectors which is not captured by these theories and the applied empirical analysis in this field. In this paper we shall apply the notion of the 'advantage of backwardness' by Gerschenkron (1952) at the industrial level and analyse convergence of labour productivity levels for different types of industries. For the international trade dimension we also examine the dynamics of sectoral wages which together with productivity increases determines the pattern of comparative advantages. In a Ricardian model these two components determine the comparative cost advantages of two countries which, in the context of catching-up, can be characterised as the leader and the follower countries. In this paper we shall thus examine the evolution of (labour) productivity and wage levels at the industrial level and hence the development of relative labour unit costs. The basic trade theoretical framework is the Ricardian model of comparative advantages and the basic implicit learning process examined is the Gerschenkron hypothesis.

The main hypothesis of this paper is that countries are catching-up relatively faster in the higher-tech than in the lower-tech sectors in productivity levels whereas wages are growing at more similar rates across sectors (i.e. there is a wage drift). If this pattern is empirically relevant, the competitive pressure for the more advanced countries will be felt from two types of catching-up economies: First the lagging economies which maintain the traditional pattern of comparative advantages (type A) and another type of catching-up economies which are gaining comparative advantages in the higher-tech sectors (type B). The impact of the first group of economies on the (labour market) performance of the more advanced economies was widely discussed in the literature. But there is not much literature on the second type of catching-up countries (see, however, Landesmann and Stehrer, 2000).

To demonstrate that there can in fact be a switchover in the structure of comparative advantages, Figure 1.1 shows the evolution of unit labour costs for two types of industries (low tech and medium to high-tech) of an average of catching-up countries versus the leader country US. As can be seen clearly, there occured a switchover in the comparative advantage structure at the beginning of the 1980's.[2]

In this paper we emphasize the technology side (productivity catching-up) of this phenomenon. On the other hand, changing factor endowments could also have an impact on the structure of comparative advantages: if there is a switchover in the relative factor endowments

[1] We acknowledge support from the *Jubiläumsfonds* of the Austrian National Bank in the context of the project 'Economic Integration, Catching-Up, and Labour Markets'.

[2] For details see Section 3.

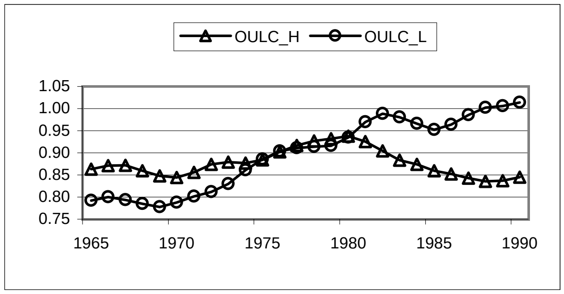


Figure 1.1: Comparative advantage switchover

across countries a comparative advantage switchover is also expected from the traditional Heck-sher Ohlin approach. But this seems to be an empirically less relevant explanation for changes in comparative advantage structures. It could, however, add additional support for the first type of dynamics. More importantly, a changing endowment structure can also change the 'learning capability' or 'absorption capacity' of a country and thus lead to changing patterns of catching-up in sectoral productivity levels and to changes in comparative advantages.[3] Thus an accumulation of human capital (or skills) could have impacts via 'technological learning' and be in this sense the reason for catching-up.

We have to emphasize, first, that we analyse only changes in labour productivity and not in total factor productivity (TFP) and, second, that the paper only refers to convergence in productivity *levels* and wage rates at the industrial level. This means that we do not discuss convergence in industrial *structures*.

The paper is mainly divided into two parts. The first part deals with theoretical issues of possible catching-up paths which can (given the dynamic behaviour of wages) lead to changing patterns of comparative advantages. Here we discuss some patterns of catching-up which are already referred to in growth and trade theoretical models. The second part then presents results of empirical and econometric research on the dynamics of productivity and wages, which shows that in fact one can observe changing patterns of comparative advantages over time between catching-up and leader countries.

2 Patterns of industrial convergence - a classification

In this section we try to classify possible patterns of convergence and divergence. Some of the trajectories mentioned here, will be used in the interpretation of empirical data in section 3. Although we shall not give an exhaustive typology of possible patterns, we show that there can be a surprising variety of such patterns even with very simple formulations of convergence processes.

To make the description in this section as simple as possible we take only two sectors into account. Furthermore, these two sectors are assumed to start off with the same productivity level in the leader country (normalized to 100) and are growing with the same, exogenous, and constant rate of growth g_i^L. (In this sense we do not distinguish at this stage between high- and low-tech sectors, which could be defined either by having relatively high *levels* of productivity or

[3]For a dynamic multi-sectoral trade model which discusses these impacts of uneven technological progress, distribution of Schumpeterian rents, and changing factor requirements, see Landesmann and Stehrer (2000).

having relatively high *growth rates* of productivity.) These assumptions are only made in order to simplify the discussion of sectoral convergence paths. Formally, these assumptions can be stated as differential equations of the type

$$\dot{k}_i^L(t) = g_i^L k_i^L(t) \qquad i = 1, 2$$

where $k_i^L(t)$ refers to the productivity level of the leader country L in sector i at time t. g_i^L is the growth rate of productivity. Solving this simple differential equation yields the general solution

$$k_i^L(t) = k_i^L(\tau) \exp^{g_i^L(t-\tau)}$$

2.1 Disaggregating neoclassical convergence processes

A first useful application is the simple extension of the neoclassical convergence analysis (for an overview, see especially Barro and Sala-i-Martin, 1995) to the industrial level. In the leader-follower model of Barro and Sala-i-Martin (1997) the growth rate of output per employee depends on the gap to the leader country. In the following we assume that the growth rate of productivity in a sector i of a follower country c, denoted by g_i^c depends on the gap of this particular industry i to the productivity level in the leader country in this particular industry i and the exogenous rate of growth g_i^c.

$$k_i^c(t) = k_i^c(\tau) \exp^{[g_i^c + \gamma_i^c(\tau)](t-\tau)} \tag{2.1}$$

where

$$\gamma_i^c(\tau) = \frac{\left(1 - \exp^{-\beta_i^c(t-\tau)}\right)}{(t-\tau)} G_i^c(\tau) \equiv \tilde{\beta}_i^c G_i^c(\tau)$$

is the rate of growth due to convergence (taken from Barro and Sala-i-Martin, 1995) and

$$G_i^c(\tau) = \ln \frac{k_i^L(\tau)}{k_i^c(\tau)}$$

is the gap. This formulation averages over the time span $(t - \tau)$ and can thus be used as discrete approximation to the continuous system in simulation studies or in empirical analysis.[4] Taking logarithms of equation (2.1) and first differentiating with respect to time t gives

$$\dot{k}_i^c(t) = [g_i^c + \gamma_i^c(\tau)] k_i^c(t)$$

In the subsequent sections we present some patterns of convergence for two sectors between a leader and a follower country. Although these patterns can be interpreted for a number of variables (e.g. wages, productivity, quality levels) we shall for the moment interpret the variable as productivity levels. Comparative advantages at this stage refer only to the evolution of relative productivity movements across sectors. The implication of additional wage movements will be discussed below. For the moment, this restriction can also be interpreted as the assumption that wage rates are constant or that wage rates are growing at the same rate in both sectors. As pointed out above, the following analysis assumes that productivity is growing in the leading

[4]This formulation of $\tilde{\beta}_i^c$ guarantees that it approaches 0 as $\tau \to \infty$ and tends to β_i^c as $\tau \to t$. This can be shown by application of L'Hôpital's rule.

country at the same exogenous and constant rate in both sectors: $g_1^L = g_2^L = 0.025$. This is also the exogenous growth rate in both sectors of the follower country ($g_1^L = g_2^L = 0.025$). The figures presented are approximations of the continuous equations above by setting $\tau = t - 1$. The starting values are $k_i^L = 100$, $i = 1, 2$ for the leader country and $k_1^c = 50$ and $k_2^c = 25$ for the follower country (hence, industry 2 is the industry with the larger initial gap). The figures show the trajectories of the following variables:

A: the logarithmic productivity levels: $\ln k_i^L(t)$ and $\ln k_i^c(t)$

B: the difference of the growth rates of the levels: $\frac{\dot{k}_2^c}{k_2^c}(t) - \frac{\dot{k}_1^c}{k_1^c}(t)$

C: the evolution of the gaps $G_i^c(t)$

D: the difference of the gaps $G_2^c(t) - G_1^c(t)$

E: the changes of the gaps $\dot{G}_i^c(t)$

F: the difference of the changes in the gaps $\dot{G}_2^c - \dot{G}_1^c$

This last variable is determined by differentiation of the gap with respect to time and inserting the growth rate. This gives

$$\dot{G}_i^c(t) = g_i^L - (g_i^c + \gamma_i^c) = (g_i^L - g_i^c) - \tilde{\beta}_i^c G_i^c(t) \qquad (2.2)$$

Note that the growth rate of the gap $\frac{\dot{G}_i^c(t)}{G_i^c(t)} = \frac{1}{G_i^c(t)}(g_i^L - g_i^c) - \tilde{\beta}_i^c$ is constant in the case where $(g_i^L - g_i^c) = 0$. Further this expression gives

$$\dot{G}_2^c(t) - \dot{G}_1^c(t) = (g_2^L - g_1^L) - (g_2^c - g_1^c) - [\tilde{\beta}_2^c G_2^c(t) - \tilde{\beta}_1^c G_1^c(t)] \qquad (2.3)$$

For equal exogenous rates this gives the result

$$\dot{G}_2^c(t) - \dot{G}_1^c(t) > 0 \qquad \Longleftrightarrow \qquad \frac{\tilde{\beta}_1^c}{\tilde{\beta}_2^c} > \frac{G_2^c(t)}{G_1^c(t)}$$

In this case the gap is closed faster in the second industry, the industry with the larger initial gap. This is equivalent to the statement that the growth rate of the productivity level of the second industry $\frac{\dot{k}_2^c}{k_2^c}$ is higher than in the first industry. Further, equation (2.2) says that for different exogenous growth rates and if $g_i^L > g_i^c$:

$$\dot{G}_i^c = 0 \qquad \Longleftrightarrow \qquad \frac{g_i^L - g_i^c}{\tilde{\beta}_i^c} = G_i^c$$

Thus sector i is falling behind if it is too close to the technology frontier and cannot catch-up fully with the leader. This means that one 'stable gap' exists towards which catching-up countries will move without ever fully catching-up.

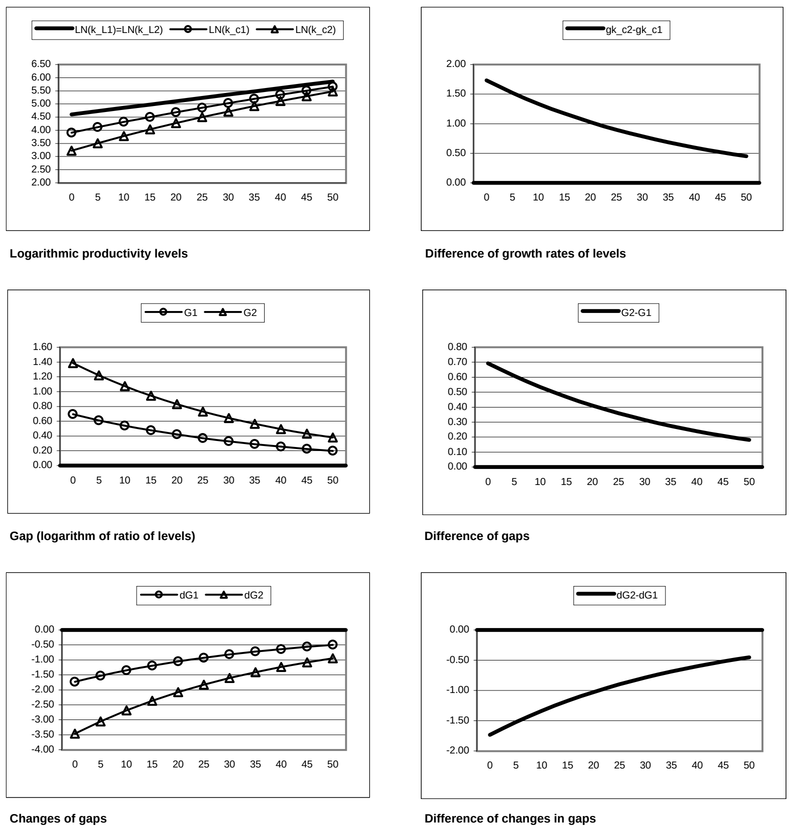


Figure 2.1: Equal convergence parameters

2.1.1 Same coefficient of convergence

The simplest case is when all industries in the follower country have the same coefficient of convergence $\beta_i^c = 0.025$ for $i = 1, 2$. Figure 2.1 presents the time paths of the variables mentioned above. Both industries are converging to the level of the advanced country (see Panel A). But the speed of convergence is faster in the second industry than in the first one, as this industry has higher gaps over this period (see Panel C and D). This also implies higher rates of growth in levels in the second industry (Panel B). Panels E and F shows that the changes in gaps (i.e. reductions in the gaps) are higher in the second industry. In this case differences of the growth rates of the industries in the follower country are only due to differences in the initial gap (i.e. the 'advantage of backwardness' in one industry relative to the other).

2.1.2 Distinct coefficients of convergence

A slightly more complicated pattern emerges if one assumes different coefficients of convergence. These different coefficients of convergence can result from specific industry characteristics such as inflow of FDI, sectoral learning curves, etc.

Figure 2.2 presents the case where the coefficient of convergence is higher in industry 1 than in industry 2, $\beta_1^c = 0.075 > \beta_2^c = 0.025$. In this case the growth rate of the productivity levels

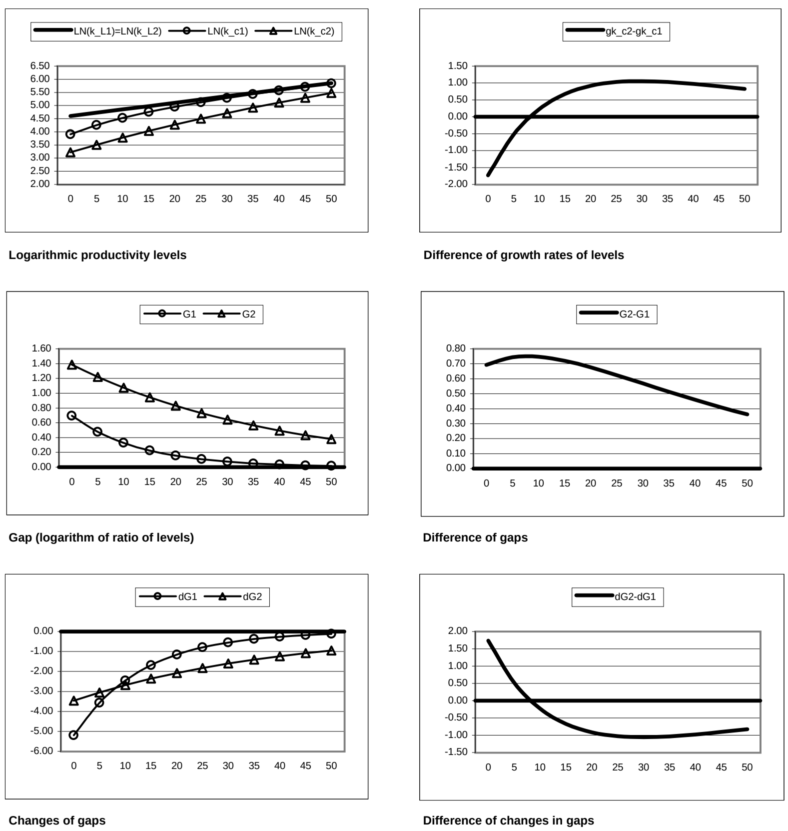


Figure 2.2: Patterns of convergence with $\beta_1^c > \beta_2^c$

is higher in the first period in industry 1 because of the higher coefficient of convergence β_1^c

and despite the smaller gap in this period. But, because of this fast convergence, the growth component of convergence gets smaller and becomes less important which results in lowering the difference of the growth rates between sectors 2 and 1 (Panel B). In this phase also the difference of the levels and the gap widens (Panel D). From the sitchover point ($t = 8$) on the productivity level of sector 2 grows faster than in industry 1. Sector 1 has lost its 'advantage of backwardness', but sector 2 converges relatively fast despite the low coefficient of convergence because of the higher gap. The change (reduction) of the gap has become bigger in industry 2 than in industry 1 (Panel E) in the second period; or the difference in the growth rates of the gaps (Panel F) has become negative. As one can also see in Panel B, the difference of the growth rates between the two sectors over the period $t = 0 - 8$ was negative and is becoming smaller, then switches to a positive level (higher growth rate in sector 2) where the difference is first widening but starts getting smaller (from $t = 30$) because sector 2 - as mentioned above - looses the 'advantage of backwardness' (i.e. has exploted the potential from closing the technology gap) due the catching-up process.

Another pattern occurs if the coefficient of convergence is higher in the second industry ($\beta_2^c = 0.075 > \beta_1^c = 0.025$). The trajectories are presented in Figure 2.3. Sector 2 is catching-up

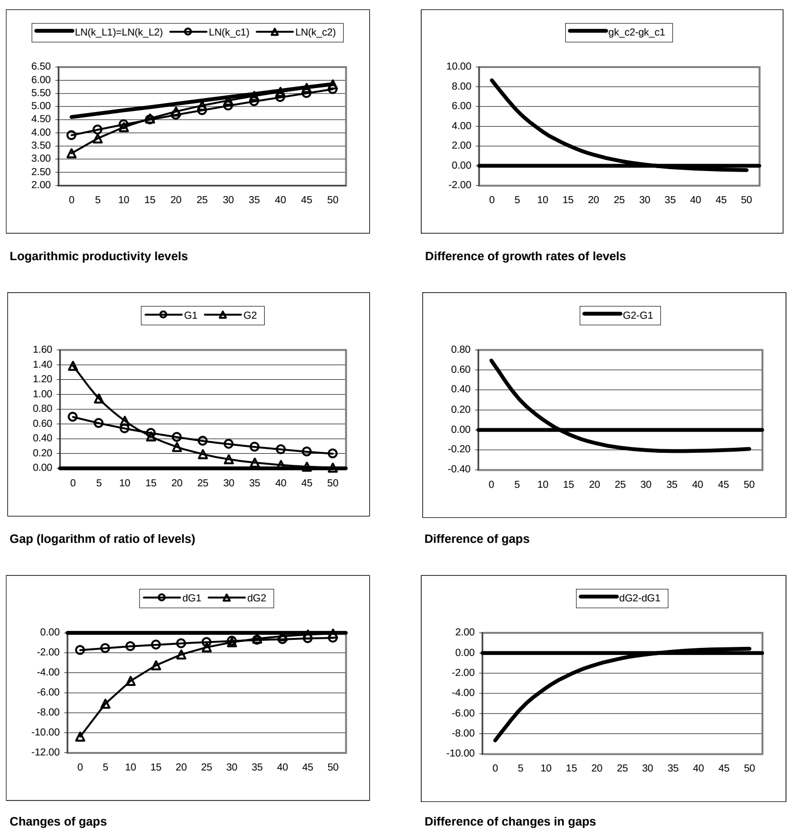


Figure 2.3: Patterns of convergence with $\beta_1^c < \beta_2^c$

rapidly because of the higher parameter β_2^c and the larger gap in the initial phase. Due to this rapid convergence it looses the relative 'advantage of backwardness' at about $t = 13$ when the gaps are equal (see Panel C). But the growth rate of the productivity level remains higher in the second sector as the parameter of convergence is relativly higher in this sector. But as this sector is loosing more and more of the 'advantage of backwardness' the growth rate falls relatively faster than in sector 1. Indeed at about $t = 32$ the pattern of relative convergence switches, as - due to the relatively higher gap - sector 1 is now growing relatively faster (Panel B) or - stated alternatively - the changes in the gap become higher in sector 1 than in sector 2.

2.2 Catching-up and falling behind

It turns out that the catching-up processes described above can be seen as a special case of a model introduced by Verspagen (1992) who proposes a formulation where a country can also fall behind, dependent on the size of the gap and on the 'learning capability'. This behaviour can be introduced by a specific knowledge spill-over term in equation (2.2) above (see Verspagen, 1992) which is specified as[5]

$$\dot{G}_i^c(t) = (g_i^L - g_i^c) - \tilde{\beta}_i^c G_i^c(t) \exp^{-\frac{1}{\delta_i^c} G_i^c(t)}$$

For $\delta_i^c \to \infty$ the last term goes to 1 and becomes the necolassical model introduced above. The general formulation of the model allows for a bifurcation in the dynamics of the technology gap. If $(g_i^L - g_i^c) > 0$ then there can be either convergence if the 'learning capability' is high for a certain size of the gap (or, vice versa, given the 'learning capability' if the gap is not too large) or divergence in situations with a relatively low 'learning capability' and a high initial gap.[6] Thus this formulation allows to model a bifurcation of the catch-up process in a country where one sector is catching-up while the other is falling behind. (Of course, the model also tracks situations where either both sectors are catching-up or both are falling behind.) This pattern is shown in Figure 2.4. Here the two sectors in the catching-up economy have the same exogenous growth rates in the two sectors $g_i^c = 0.0125$ and have also the same convergence parameter $\tilde{\beta}_i^c = 0.025$. They differ only in the learning parameter. Sector 1 has a very low learning capability, $\delta_1^c = 1$, whereas this learning capability is much higher in sector 2 with $\delta_2^c = 25$. Although the initial gap is smaller in sector 1, this sector is falling behind (Panel C). Sector 2 is catching-up and overtaking the first sector in the long run. The difference of the growth rates between sectors 1 and 2 is shrinking, as the 'advantage of backwardness' is lost over time. In the long run sector 1 will grow with the own exogenous rate g_1^c whereas sector 2 will grow with the rate of growth of the advanced country (partly due to spillovers and partly due to the own exogenous rate).

Additionally one can exploit the non-linearity of this model to show interesting comparisons of catching-up processes within one country. Figure 2.5 shows a catching-up pattern where we used the same parameters as before (Figure 2.4) but set $\beta_1^c = 0.100$. This means that in this sector a relatively large gap has a high and positive impact on the growth rate ('backwardness effect') on the one hand, but also low learning capacity. Thus the time trajectory depends on the relative strength of these two factors. As can be seen in Panels E and F the change of the gap G_1^c is relatively high in the initial period ($t = 0 - 20$) because of high spillovers.[7] But then the dynamics slows down as the advantage of backwardness gets smaller and the learning capacity

[5] The original formulation in Verspagen (1992) is slightly different, although the implications are the same.

[6] Different exogenous rates of growth between a follower and a leader country implies in this model that the follower country can never catch-up fully with the leader country and can even fall behind if it is very close to the leader. For details see Verspagen (1992).

[7] In this model the spillovers reach a maximum where $G_i^c = \delta_i^c$.

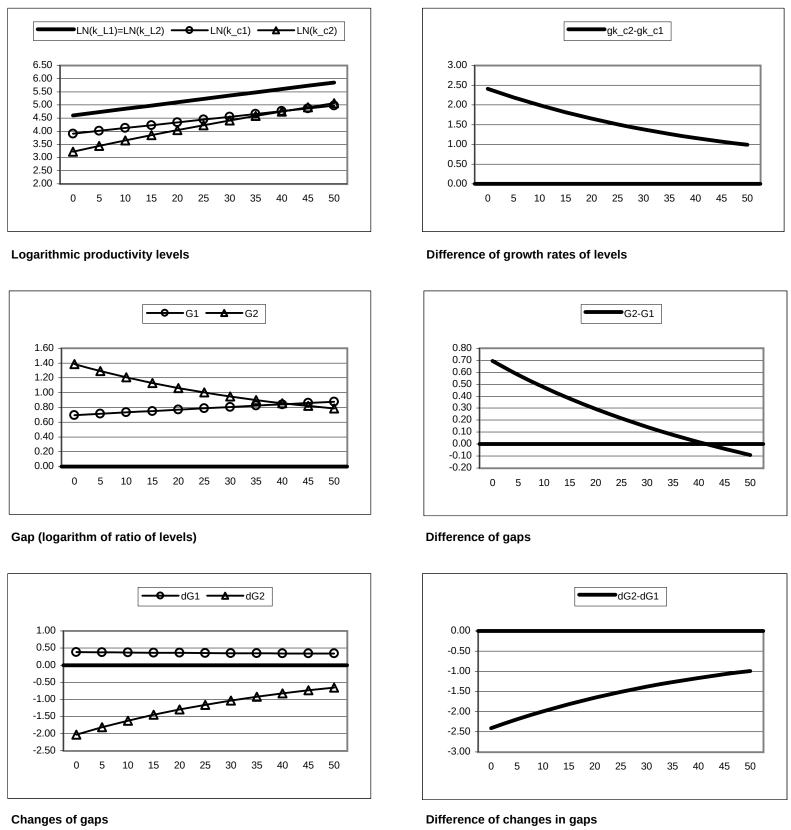


Figure 2.4: Catching-up and falling behind I

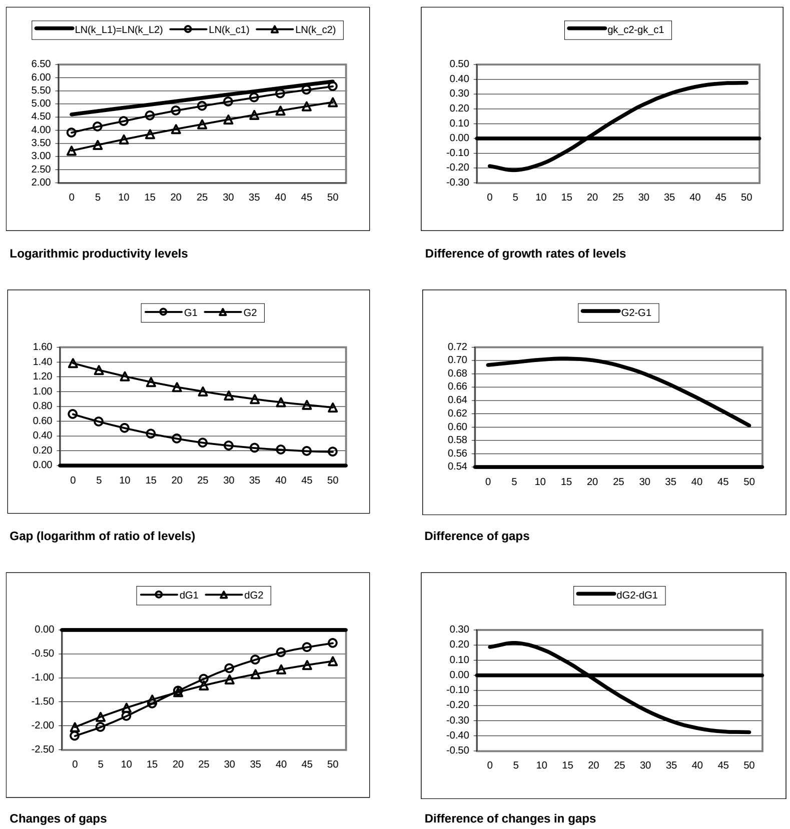


Figure 2.5: Catching-up and falling behind II

is low. This slowing down of the process is less important for the second sector. In sector 2 the catching-upadvantage of backwardness is lower $\beta_1^c > \beta_2^c$ but the catching-up is less constrained by the higher initial gap. At time $t = 20$ when the gaps are equal, the dynamics of this sector become higher than in sector 1. As the gap is closed rapidly in the first phase, the 'constraint' from the low learning capacity in this sector shows up more strongly which reduces the overall growth rate.

2.3 Further discussion

In this section we shall present shortly other formulations of patterns of catching-up which are discussed in some strands of the literature on technology and trade.

2.3.1 Krugman's ladder

The patterns presented above can be confronted with another type of formulation of industrial convergence processes formalized, for example, by Krugman (1986) but already discussed in the seminal paper by Dornbusch et al. (1977). Here we state the model in a slightly different way to allow comparisons with the discussion above. In this model there is only one factor of production (labour) and the industries are ranked by the growth rates of the (labour) productivity levels, g_i, which are also interpreted as the industries' technology intensities. The (labour) productivity level of the advanced country (the technology frontier) is rising with a constant rate

$$k_i^L(t) = k_i^L(\tau)\exp^{g_i(t-\tau)}$$

A catching-up country lags λ^c years behind the frontier. This lag λ^c is assumed to be equal for all industries. Thus the unit labour requirement in this country is

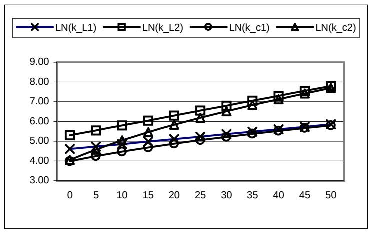
$$k_i^c(t) = k_i^L(\tau)\exp^{g_i(t-\tau-\lambda^c)} = k_i^L(\tau-\lambda^c)\exp^{g_i(t-\tau)}$$

Catching-up is then modeled as reducing the time lag λ^c. By assumption, this time lag is equal across sectors and is also reduced equally across sectors. This means that the follower country adopts the best practice technologies with the same time lag across all industries. But since the productivity growth rates across industries are different there will always be a hierarchy of productivity gaps between the leader and the follower country. This is modeled in Krugman (1986) as a one time shift. For further discussion we replace this assumption with a continuous formulation

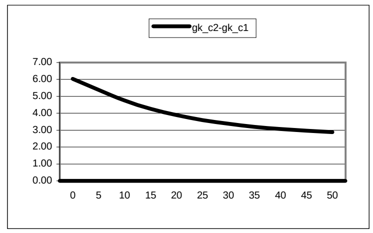
$$\dot{\lambda}^c(t) = \beta^c\lambda^c(t)$$

which implies that the time lag is reduced at a constant rate. Assuming that $g_1^L = g_1^c = 0.025$ and $g_2^L = g_2^c = 0.050$, thus assuming that sector 2 is the high-technology sector, and $\beta^c = 0.05$ we get the time trajectories which are presented in Figure 2.6. First one can see that the greatest productivity gains take place in sector 2, the high-technology sector. But the differences in the catching-up process diminish over time. In the long run (with complete catching-up) the difference of the growth rates of the productivity levels is equal to the difference of the exogenous growth rates $g_2^L - g_1^L$. But one can also see that the hierarchy of the industries between the follower and the leader country remains the same.

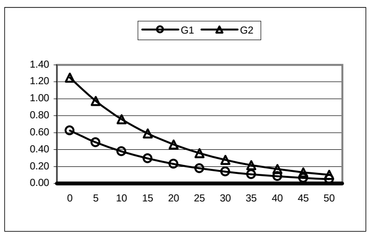
Further interesting patterns of sectoral catching-up can arise if one assumes that $\beta_1^c = 0.25 > \beta_2^c = 0.05$, which means that reducing the time lag is far easier in industry 1 (the low tech



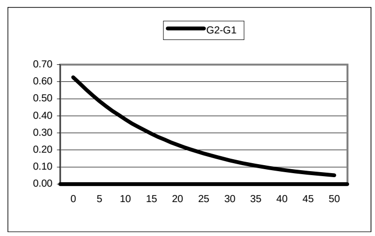
Logarithmic productivity levels



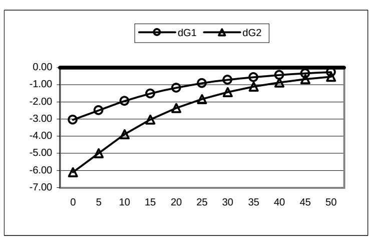
Difference of growth rates of levels



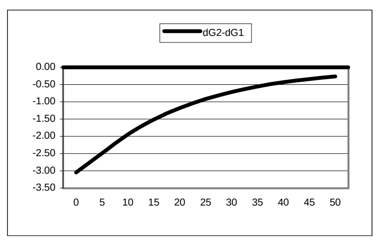
Gap (logarithm of ratio of levels)



Difference of gaps

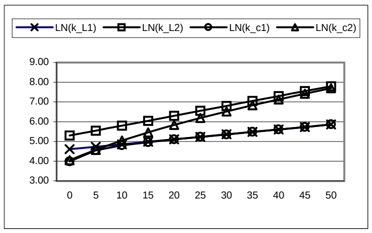


Changes of gaps

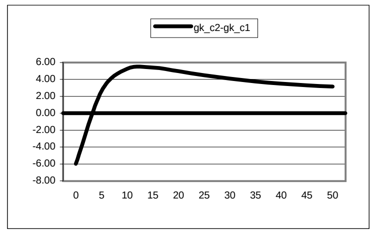


Difference of changes in gaps

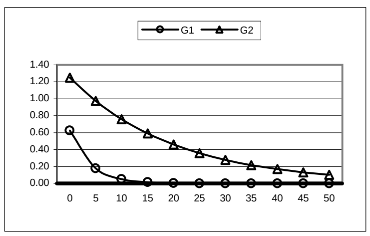
Figure 2.6: Time trajectories in the Krugman model I



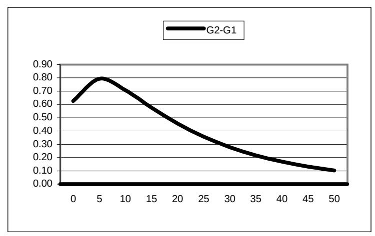
Logarithmic productivity levels



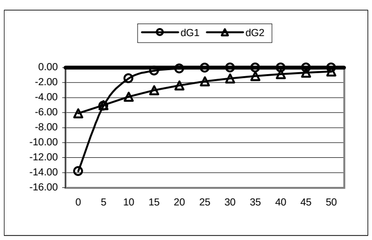
Difference of growth rates of levels



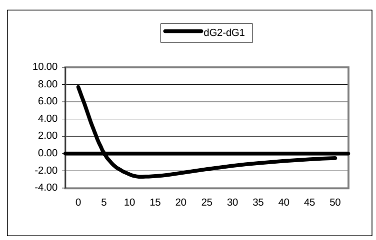
Gap (logarithm of ratio of levels)



Difference of gaps



Changes of gaps



Difference of changes in gaps

Figure 2.7: Time trajectories in the Krugman model II

industry) than in industry 2. In this case the evolution of the productivity levels, gaps and relative rates of change show the pattern reproduced in Figure 2.7. There will be rapid catching-up in the low tech sector in the initial phase. This leads to a higher productivity growth rate in sector 1 (see Panel B) and a widening of the gap across sectors (Panel D). But in the second phase sector 2 shows the higher growth rates partly due to the higher exogenous growth rate, but also because of the higher rate of catching-up as can be seen in Panel F.

Further one could also change the initial time lag of the industries, $\lambda_1^c \neq \lambda_2^c$ or reverse the relative size of the parameters β_i^c. In this case there could also arise a switchover in the hierarchy of the gaps and/or a switchover in the relative dynamics of the gaps.

2.3.2 Sigmoid shaped patterns

In the literature on technology diffusion and adoption of new technologies, sigmoid shaped patterns are very prominent; for an overview on these topics, see e.g. Sarkar (1998) and Karshenas and Stoneman (1995). This pattern is formalised by assuming that the technological trajectories follow the path:

$$\frac{\dot{k}_i^c}{k_i^c}(t) = \beta_i^c \left(1 - \frac{k_i^c(t)}{k_i^L(t)}\right) + g_i^c$$

where the growth rate depends on the gap (here defined as $\frac{k_i^c(t)}{k_i^L(t)}$) and an exogenous rate of growth. This formulation implies that the growth rate of the productivity level in the follower country is low if either the gap is very high or the country (sector) is very close to the leader. The implications are very similar to the trajectories traced by the Verspagen (1992) model and the modified (i.e. with unequal reductions in the time lag) model by Krugman (1986) and needs not be discussed here. In this formulation there can also occur a falling behind in the case that

$$\frac{\dot{k}_i^c}{k_i^c}(t) < g_i^L$$

2.3.3 Inter-industry dependences and further aspects

There are some other factors which in this paper are only mentioned but not further discussed. First there is the possibility that there are inter-industry dependences, in the sense that there are dynamic complementarities in the learning processes. Such spillovers of technological advances may occur unevenly across sectors. As discussed above there can be treshold levels in an industry which determine whether there occurs catching-up or falling behind. In an interdependent system this can have complicated implications: For example, if one industry does not manage to catch-up, this can have a negative effect on other industries.

A second aspect is that there can be learning-by-doing effects at the industrial level or cumulative growth effects in a Kaldorian manner (the Kaldor-Verdoorn mechanism). This would mean that the rate of growth of productivity is endogenously determined as a function of output level or output growth. For a recent discussion on these topics and empirical comparative studies see e.g. Targetti and Foti (1997).

2.4 Productivity, wages and unit labour costs

In the context of international trade, the evolution of (relative) productivity levels is not the only variable which shapes the patterns of competitiveness. One also needs to discuss the evolution of the wage rates at the industrial level. Both the evolution of productivity and wages determine unit labour costs and thus comparative advantages in the long run. Unit labour costs c_i^c are defined as:

$$c_i^c = \frac{1}{k_i^c} w_i^c = a_i^c w_i^c$$

where a_i^c is the labour input per unit of output and w_i^c is the wage rate. The evolution of the unit labour costs is then given by

$$\frac{\dot{c}_i^c}{c_i^c} = \frac{\dot{a}_i^c}{a_i^c} + \frac{\dot{w}_i^c}{w_i^c}$$

For the evolution of the patterns of comparative advantage one has to examine the growth rates of wages and productivity in the leading and the follower country. The evolution of the unit labour costs relative to the leading country $\frac{c_i^c}{c_i^L}$ can be derived by differentiating this expression with respect to time. This gives

$$\frac{(\dot{c_i^c/c_i^L})}{(c_i^c/c_i^L)} = \left(\frac{\dot{a}_i^c}{a_i^c} + \frac{\dot{w}_i^c}{w_i^c}\right) - \left(\frac{\dot{a}_i^L}{a_i^L} + \frac{\dot{w}_i^L}{w_i^L}\right) = \left(\frac{\dot{a}_i^c}{a_i^c} - \frac{\dot{a}_i^L}{a_i^L}\right) + \left(\frac{\dot{w}_i^c}{w_i^c} - \frac{\dot{w}_i^L}{w_i^L}\right) \qquad (2.4)$$

As a starting point let us look at a situation at which wages are growing exactly with the same growth rates as productivity in both countries and industries, thus $\left(\frac{\dot{a}_i^c}{a_i^c} + \frac{\dot{w}_i^c}{w_i^c}\right) = \left(\frac{\dot{a}_i^L}{a_i^L} + \frac{\dot{w}_i^L}{w_i^L}\right) = 0$. This means that wage rates are growing in line with industry level productivity and workers are fully compensated for increases in productivity. In this case, nothing would change in the comparative advantage situation of two (or more) countries as relative unit labour costs would remain constant. Thus if wages reflect fully relative productivity movements across sectors the patterns of comparative advantage will not change.

The other extreme is to assume that wages are equalised across sectors in an economy (which is an assumption going back to Ricardo). Then the expression above becomes

$$\frac{(\dot{c_i^c/c_i^L})}{(c_i^c/c_i^L)} = \left(\frac{\dot{a}_i^c}{a_i^c} + \frac{\dot{w}^c}{w^c}\right) - \left(\frac{\dot{a}_i^L}{a_i^L} + \frac{\dot{w}^L}{w^L}\right) = \left(\frac{\dot{a}_i^c}{a_i^c} - \frac{\dot{a}_i^L}{a_i^L}\right) + \left(\frac{\dot{w}^c}{w^c} - \frac{\dot{w}^L}{w^L}\right)$$

Generally, the textbook Ricardian model with any number of goods and a uniform wage rate has the only equilibrium solution with $p_i^c = c_i^c = a_i^c w^c$ and comparative advantages would be determined only by relative productivity movements. In a dynamic context with sectorally uneven progress in productivity as is implied by the convergence patterns discussed in section 2 the assumption of identical wage rates across sectors has the implication that workers in the sector with relatively higher productivity increases are not fully compensated for these productivity increases. The productivity gains are spread over the whole economy through general wage rate increases (and/or general price level declines) and changes in relative prices. This case[8] is used in the model by Krugman (1986) discussed above. In fact, in the Ricardian model with a continuum of goods (see Dornbusch et al., 1977; Krugman, 1986), the result of

[8]In the special case that $\left(\frac{\dot{w}^c}{w^c} - \frac{\dot{w}^L}{w^L}\right) = 0$ or $\left(\frac{\dot{w}_i^c}{w_i^c} - \frac{\dot{w}_i^L}{w_i^L}\right) = 0$, i.e. where the growth rate of the wage rate is equal across industries and countries, one only has to take the dynamics of relative productivity movements into consideration to examine the dynamics of comparative advantages; this case was extensively discussed in section 2.

shifting production specialisation of goods from the advanced to the catching-up country is built on this assumption of the relative dynamics of productivity and the assumption of wage equalisation across industries.

If this assumption has some empirical relevance, this would mean - given the patterns of productivity convergence discussed above - that catching-up countries are gaining more and more competitive advantage in the sectors showing faster convergence. Whenever the term on the r.h.s. of equation (2.4) is positive the unit labour costs in the leader country are growing relatively faster than in the follower country. Thus, the evolution of relative unit labour costs across industries in the two countries is the difference of wage rate growth and the relative rates of decline of labour input coefficients in the different industries in both countries. Again various combinations of productivity and wage growth could be discussed. Here we shall single out a particularly interesting case: This case shows the evolution of unit labour costs in the neoclassical model of convergence (discussed above) with wage equalisation. In particular, we assume that the growth rate of the uniform wage rate is determined by the long term growth rates of the productivity levels in both sectors.[9] Figure 2.8, which shows the evolution of unit labour costs, depicts the situation where convergence takes place faster in the sector with the higher initial gap (sector 2). We assume, as in Figure 2.3, that $\beta_1^c = 0.025 < \beta_2^c = 0.075$. With

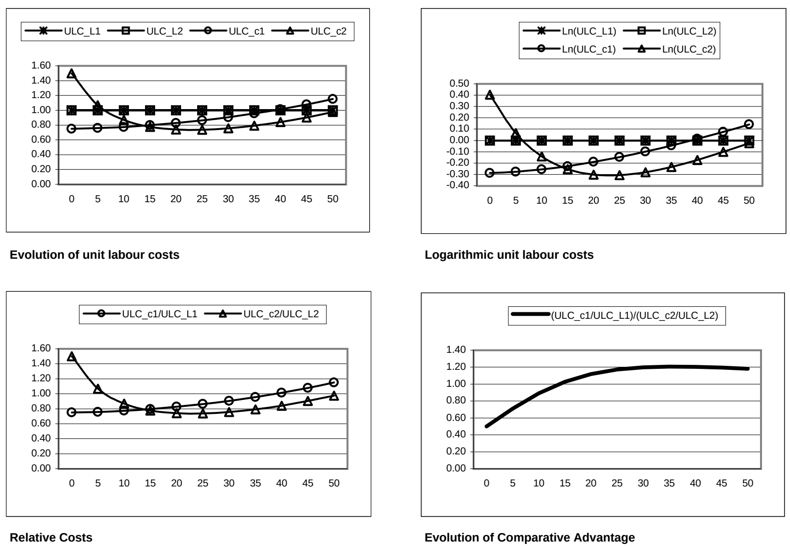


Figure 2.8: Evolution of unit labour costs

these parameter values, there occurs a switchover in the hierarchy of the productivity levels (as we have already seen in Figure 2.3). Panel A shows the evolution of the levels of unit labour costs in the two countries for sectors 1 and 2. Unit labour costs remain constant in the leader country as by assumption wage rates are growing with the same rate of growth as productivity. (Remember here, that the productivity growth rates are assumed to be equalised across sectors

[9]In the simulations underlying the figures we assumed that the growth rate of wages is the (unweighted) average of the long term growth rate of the productivity levels in the two sectors. This means that wages in the catching-up economy are growing relatively slower than productivity in the first phase and relatively faster in the second phase as the economy's industrial structure is shifting towards the higher productivity growth sector. This particular specification of general wage dynamics is not essential for the structural dynamics of comparative advantage discussed below.

in the leader country.) Panel B shows the logarithmic levels of the unit labour costs. With equal wage growth this also implies that relative unit labour costs show a switchover (see Panel C) and hence also a *switchover in the pattern of comparative advantages* (see Panel D when the curve rises above 1). Due to the long term evolution of wages and productivity the follower country can obtain a position of having comparative advantages in sector 2 (i.e. the sector in which the inital gap in productivity levels was higher).

Thus one can conclude, that with the described patterns of the dynamics of productivity convergence and the assumption of wage equalisation across sectors there can result an interesting variety of dynamics of comparative advantages and of shifting trade structures.

2.5 Skills, rents and prices

As we have pointed out above, the models discussed so far either assume (implicitly) a special development of prices (e.g. the Krugman model) or do not discuss the evolution of relative prices at all. Further we have not yet discussed the impact of relative factor use and factor prices (either capital or skill types). In this section we shortly discuss the impact of factor endowments and relative prices of factors by assuming two skill types of workers. Further we introduce the emergence of transitory (Schumpeterian) rents in the course of developments in certain industries.

These aspects are modeled explicitly in a theoretical multi-sectoral, multi-factorial and dynamic trade framework in Landesmann and Stehrer (2000). Here we shall shortly present the modeling strategy in a non-technical manner and especially further aspects of the evolution of unit labour costs and specialisation patterns which emerge from this extended framework. In the paper by Landesmann and Stehrer (2000) the price system in the steady-state is classical as cost (plus mark-up) prices

$$\mathbf{p}' = (1+\pi)\left(\mathbf{p}'\mathbf{A} + \boldsymbol{\omega}'\right)$$

where $\mathbf{p}$ is a (column) price vector, $\mathbf{A}$ is an input-output matrix, and $\boldsymbol{\omega}$ is a vector of unit labour costs with typical element

$$\omega_i = \sum_z w_i^z a_{Li}^z$$

where $z = 1, \ldots, Z$ denotes skill groups of workers. π is the long run mark up which is equal across sectors. In equilibrium this gives the price vector

$$\mathbf{p}' = \boldsymbol{\omega}' \left(\frac{1}{1+\pi}\mathbf{I} - \mathbf{A}\right)^{-1}$$

The unit costs are thus given by

$$\mathbf{c}' = \mathbf{p}'\mathbf{A} + \boldsymbol{\omega}'$$

Thus unit costs (and prices) depend on nominal wages, the labour input coefficients, the technical coefficient matrix and the wage structure in the economy. Changes in either of these components result in changes of the unit costs.[10] If prices do not adjust immediately to the costs (e.g. in

[10] Here we only discuss changes in prices and labour input coefficients and not changes in the input-output matrix. In general, prices depend strongly on the form of the input-output matrix, but we shall not discuss this further. Without any further discussion, we assume that the diagonal elements of $\mathbf{A}$ are relatively large relative to the off-diagonal elements.

case of changes in the labour input coefficients), there is a dynamic adjustment process simply modeled by a lagged adjustment of mark-up prices to costs[11]

$$\dot{\mathbf{p}} = \alpha_p \left(\mathbf{p} - \mathbf{c}\right)$$

In this case there emerge transitory rents defined by

$$\mathbf{r} = \mathbf{p} - (1 + \pi)\mathbf{c}$$

This formulation makes an explicit discussion on the distribution of rents necessary. Here we only discuss the impact of changes in the labour input coefficients (labour productivity) and changes in wage rates. We can distinguish two limiting cases:

CASE 1: The first case is if the rents are distributed immediately to the workers proportionally to the increases in their labour productivity. This would imply that $w_i^z a_{Li}^z$ remains constant and thus the vector of relative prices remains constant too. In this case there would be no changes in relative prices. Real incomes would rise with the different skill groups in the different industries earning exactly the benefits of productivity increases. In this case we cannot assure the same wage rates for the same types of skills across industries.

CASE 2: The second limiting case is, when wages remain constant and the increases in labour productivity work through only via changes in prices. With the same consumption structure for all workers, this means that real wages rise equally for all workers as only the price index changes (this is more complicated if demand structures differ across skill groups). Relative prices are declining for the industry having productivity increases. If all nominal wages w_i^z are rising at the same rate (with the relative wage structure remaining constant) this only has an impact on the absolute price level but not on the price structure.

The evolution of unit costs is also determined by the sectoral skill composition and relative wage rates of skill groups. If we assume constant (labour) productivities but changes in the wage rates of skill groups we get the common pattern that relative prices depend on relative factor prices and relative factor intensities (as in the Heckscher Ohlin model).[12] That is, if the relative wages of the skilled workers are rising, also the relative prices of the skill-intensive goods are rising (Stolper-Samuelson theorem).

In our model the dynamics of skill specific wage rates depend on the distribution of rents within sectors and economy-wide labour market conditions:

$$\dot{w}_i^z = f(\mathbf{r}, u^z)$$

The dynamics of the wage rate of skill group z in sector i depends on the development of the sector-specific rents and on the excess supply situation (unemployment rate u^z) for skill-group z in the economy as a whole. The model allows thus for changes in wage structures across skill groups and for the same skill groups across sectors. The latter changes are of a transitory nature; the former depend also on factor endowment changes or changes in the skill composition of the available labour force.

In a more advanced analysis one could also include reactions of sectoral factor intensities to changes in relative factor prices which shall not be discussed here. But the spirit of this extended framework should be clear. The model also implies that if prices are given exogenously

[11] For simplicity we assume the same speed of adjustment in all industries.

[12] This is true in general with reasonable assumptions on the input-output matrix, but we do not go into detail.

(assumption of a small open economy) the wage structure is not uniquely determined in one country across skill groups (for details see Landesmann and Stehrer, 2000).

With respect to ULC of catching-up countries relative to a leading country (US) some interesting cases could be discussed. For example if relative wages of the unskilled workers in the leading country are decreasing (through skill-biased technological progress, international competition from type-A catching-up countries or changes in relative factor endowments), this leads to changes in comparative advantages of the leader country towards the lowertech (lowskill intensive) sectors. On the other hand, if technological progress (catching-up) is biased towards the higher-tech sectors in the catching-up (type B) countries this could lead to gains in comparative advantages in the higher-tech (skill intensive) sectors. This pattern would be even more relevant if the catching-up economy shows a stronger lag in the wage-productivity dynamics and/or manages high rates of relative increases in the skill endowment which would help to lower the shortage of skilled labour, making skilled labour relatively cheaper and thus lowering the relative prices of the skill intensive goods. Of course the outcome depends further on income and price elasticities of demand and factor demand elasticities which are not discussed here.[13]

Following the theoretical considerations we now present an overview of the empirical and econometric research done so far.

3 Patterns of catching-up: cross-country/cross-sector evidence

In this section we present empirical results from studying the time trajectories of catching-up. Similar results were presented in Stehrer and Landesmann (1999) for a smaller country sample.

3.1 Data

The data set used is taken from the UNIDO industrial statistics data base at the 3-digit ISIC level, revision 2, which allows comparisons across a large country sample. The UNIDO industrial statistics provide data for output, value added, and employment (among others) for 28 industries which allows comparative analysis across countries (industrialized and developing countries). The period covered by these data is generally 1963-1997, although there are missing values for some countries in some industries. For PPP and exchange rates we use data from the Penn World Tables (PWT 5.6a) which covers the period up to 1992.

Of course there are limitations concerning the quality of the data. We encounter the same difficulties as in the aggregate applied growth literature, which is reviewed e.g. in Heston (1994) and Temple (1999). The main problems are that countries report only combinations of two or more 3-digit ISIC codes. Further output data can be reported at factor costs or in producer prices. The reported employment data can either be the number of persons engaged (employees plus self-employed) or the number of employees. Furthermore, there are no data available (especially for the developing countries) to account for the effects of differing working hours. For a discussion of the implications of this issue for the convergence literature, see Wolf (1994).

The following variables are considered: output per employee (OUTPROD), value added per employee (VALPROD), and wages per employee (WAGEMP) and also unit labour costs (ULC) defined as WAGEMP/OUTPROD. The UNIDO data are expressed in current national

[13]For a fully specified model which is a special case of the framework described here and simulations for the outcome on the labour markets in developing and developed countries, see Landesmann and Stehrer (2000).

currencies. For the analysis we expressed all values at PPP-rates taken from the Summers-Heston data set covering the period up to 1992.

For the effects of using domestic prices, exchange rates or PPP-rates on convergence results see Nuxoll (1994), who discusses some effects pointed out by Gerschenkron (1952). Nuxoll (1994) shows that using international prices instead of using domestic prices (e.g. the Penn World Tables) leads to very different growth rates. He argues in favour of using national accounts data for growth rates and Penn World Table numbers for levels. Further Bernard and Jones (1996) report different results, using constant price output data, dependent on the benchmark year used in the regression analysis. Finally, it must be pointed out that the PPP-rates used are based on GDP measures; ideally one should use sectoral level PPP rates based on sectoral producer prices. Using PPP rates based on GDP measures introduces some distortions, especially if the non-trading sector is very inefficient and thus shows high relative prices compared to other countries. But sectoral price level comparison data are hardly available for a larger group of countries; for a comparison of Eastern Asian countries, see e.g. Timmer and Szirmai (1997). The caveats resulting from using GDP PPP rates instead of sectoral unit value ratios are discussed below.

In this paper we compare the catching-up processes of six particular industries in 32 countries over the period from 1963 onwards.[14] The industries which are included in the analysis refer to three typical low-tech sectors, textiles (ISIC321), wearing apparel (ISIC322) and footwear (ISIC323) and three typical medium to high-tech sectors, non-electrical machinery (ISIC381), electrical machinery (ISIC383) and instrument engineering (ISIC385).

All variables are expressed in percentages or as the ratios of the logarithmic levels relative to the US-level, which is assumed to be the technology leader over the whole period and in all industries.[15]

3.2 Methodology

In studying the patterns of catching-up different methods may be used. First the data can be analysed using cross-country estimations (reviewed extensively in the empirics of growth studies, e.g. in Barro and Sala-i-Martin, 1995). This concept is widely known as β-convergence. The concept has been criticized as the results are affected by Galton's fallacy; see e.g. Friedman (1992), Quah (1993b), and the discussion in Bernard and Durlauf (1996). Nonetheless this approach is still used in studying convergence issues (see e.g. Bernard and Jones, 1996) and we shall also do so in this paper. An alternative is to look at the evolution of the variance of the measures of the gaps or the levels of the variables. We shall also present the evidence of a measure of σ-convergence. Some other methods are also available. E.g. Ben-David (1993) and Bernard and Durlauf (1996) who proposes time series analyis (unit root tests) in studying convergence patterns across countries. Quah (1993b, 1997) further proposes the estimation of a transition matrix which sets up the probabilities of moving between particular ranges of the variable over given time periods.

In this paper we only present results on cross-country analysis (β-convergence) and σ-convergence. Time series analysis can be found in the Stehrer and Landesmann (1999), although a different country sample is used.

[14] The countries included are listed in the appendix, Table A.1.

[15] This assumption is problematic if there is a cross-over in the position of absolute productivity levels; e.g. if a follower country is overtaking the US in a particular industry. But in the cross-section analysis carried out below, only the gap at the beginning of the period and the growth rate is included.

3.2.1 Cross-country analysis

In the following we shall adopt the methodology presented in Verspagen (1992) at the manufacturing level. Similarly, Barro and Sala-i-Martin (1997) present a model of catching-up to the technology leader, where the growth rate of output per worker in the catching-up country depends on the growth rate of the leading country, the gap, and the steady-state level of the gap. For this we define the technology or wage gap as

$$G_{i,t}^{c} = \ln\left(\frac{v_{i,t}^{US}}{v_{i,t}^{c}}\right) \tag{3.1}$$

where v denotes the considered variables (OUTPROD, VALPROD, and WAGEMP), c is the country index and t represents time. The long run motion of the technology or wage gap $G_{i,t}$ (either for OUTPROD, VALPROD, WAGEMP) is estimated by OLS regression on a constant and a time trend t.

$$G_{i,t}^{c} = a_{i,0} + \phi_i^c t + \epsilon_i^c$$

separately for each country and industry. This procedure uses thus the whole time series information on G_t^c. Thus the OLS estimator is robust against short term effects of shocks and cycles. ϕ_i^c denotes the growth rate of the gap in country c over the period. The last step is then to regress the growth rate on the initial technology gap:

$$\phi_i^c = \beta_{i,0} + \beta_{i,1} G_{i,0}^c + \epsilon_i^c$$

3.2.2 Sectoral prices, purchasing power parities, and exchange rates

One of the most worrying issues in this sort of analysis is the fact, that we have to use GDP PPP rates instead of sectoral PPP rates in comparing sectoral productivity levels across countries. Here we discuss the possible distortions from this caveat.

In general there are several possibilities to express the levels of the variables in international comparison. The variables which can be observed are the nominal values of productivity and wages in NCU, a production index from which an implicit price index can be calculated, and the GDP PPP rate, and the exchange rate (EXR). The problem now arises if the price structure in the leader country (US) is different from the price structure in the follower country. The problem can be made clear in a small theoretical framework. We assume that the variable (e.g. output productivity) for industry i is growing at an exogenous rate:

$$q_i^c(t) = q_i^c(0) \exp^{g_{q_i}^c t}$$

Further the price *level* also grows at an exogenous rate:

$$P_i^c(t) = P_i^c(0) \exp^{g_{P_i}^c t}$$

The problem we face is, that we can only observe the nominal variable, i.e.

$$v_i^c(t) = q_i^c(t) P_i^c(t) = q_i^c(0) P_i^c(0) \exp^{(g_{q_i}^c + g_{P_i}^c)t}$$

The price *index* can be expressed as

$$P_i^c(t, t') = \frac{P_i^c(t)}{P_i^c(t = t')} = \exp^{g_{P_i}^c (t - t')}$$

Further the GDP PPP rate also evolves with an exogenous growth rate

$$PPP^c(t) = PPP^c(0) \exp^{g^c_{PPP} t}$$

Thus the PPP rate can grow with a different rate than the price of the individual industry (or the good), as it depends on the basket of goods included. The industry variable expressed at the current PPP rate is then given by

$$\ln\left(\frac{v_i^L(t)}{v_i^c(t)/PPP^c(t)}\right) = \ln\left(\frac{q_i^L(0)}{q_i^c(0)}\frac{P_i^L(0)}{P_i^c(0)}PPP^c(0)\right) + [(g^L_{q_i} - g^c_{q_i}) + (g^L_{P_i} - g^c_{P_i}) + g^c_{PPP}]t \quad (3.2)$$

Expressing the variable in real terms at time t' gives

$$\begin{aligned}\ln\frac{\left(\frac{v_i^L(t)}{P_i^L(t,t')}\right)}{\left(\frac{v_i^c(t)}{P_i^c(t,t')}\right)/PPP^c(t')} &= \ln\left(\frac{q_i^L(0)}{q_i^c(0)}\frac{P_i^L(0)}{P_i^c(0)}PPP^c(0)\right) + (g^L_{P_i} - g^c_{P_i} + g^c_{PPP})t' + [g^L_{q_i} - g^c_{q_i}] \\ &= \ln\left(\frac{q_i^L(0)}{q_i^c(0)}\frac{P_i^L(t')}{P_i^c(t')}PPP^c(t')\right) + [g^L_{q_i} - g^c_{q_i}] \quad (3.3)\end{aligned}$$

In the first case when evaluating the variables at current PPP rates,[16] one can see from equation 3.2 that the (observed) gap in the initial period depends also on the different price levels in the leader and follower countries and the PPP rates. In the ideal case the PPP rates (at an industrial level) would reflect completely the differences in price levels and one could study the convergence of the (physical) variable. Further, the growth rate also depends on the growth rates of the price levels and the PPP rate. When using real terms instead of current terms as in equation 3.3, the quantities (e.g. productivity levels) are valued at prices at time t'. One can see easily, that if the purchasing power parities match the price differences at the sectoral level exactly, i.e. $\frac{P_i^L(t')}{P_i^c(t')}PPP^c(t') = 1$ the choice of the reference year would have no impact on the analysis. Ideally this would imply that one uses sectoral PPP rates. Further the expressed levels of the gap depend not only on the physical variables but also on price movements.[17]

3.3 Results on β-convergence

In this section we present the results from the cross-country analysis. For a first overview Figure 3.1 presents the time trajectories of the means of the gaps defined in equation 3.1 for the variables OUTPROD, VADPROD, and WAGEMP where the lower (L) and the medium to higher-tech (H) industries are distinguished. Further the left side of Figure 3.1 shows the trajectories for the total sample and the right hand side for the subsample (16 countries) consisting of EUS, EUS2, JAP, NIC1, and NIC2.[18] As one can easily see, there are some remarkable characteristics of the catching-up process. First, the gaps in both kind of industries and for all three variables are higher for the subsample than for the total sample. Second, for the variable OUTPROD the gap is closed in both sample groups relatively faster in the medium to hightech industries than in the lower-tech industries and is closed much faster in the subsample relative to the

[16] One could of course also use current exchange rates, but these are more likely to reflect short-term or systematic over- oder undervaluations than the estimates of the PPP rates.

[17] Further one could include quality variables in this set up.

[18] The time trajectories are smoothed through a 3 years moving average. Figures B.1 to B.3 in the appendix present the trajectories for the three variables and some country groups.

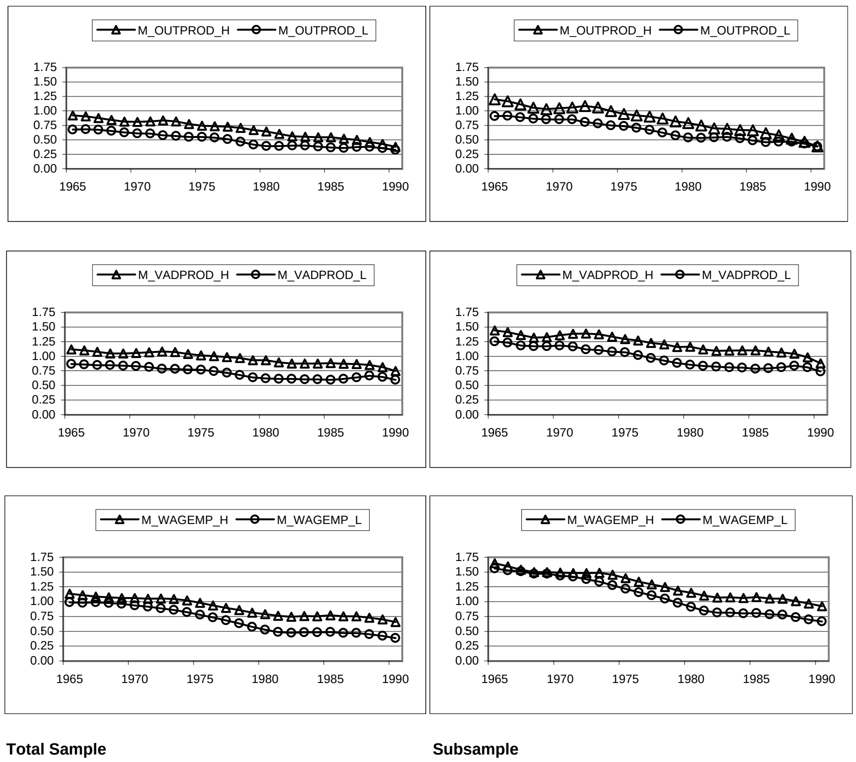


Figure 3.1: Time trajectories of logarithmic means

total sample reaching almost the same level at the end of the period. Third, for VADPROD the convergence process is slower than for OUTPROD and the average gap is higher. There is only slight evidence from the graphical inspection that the convergence process is relatively faster in the medium to higher-tech industries. Fourth, the variable WAGEMP shows a different convergence pattern: the gap is closed relatively faster in the lower-tech than in the higher-tech industries in both samples. The combination of these two facts - the relatively faster closure of the gap for OUTPROD in the medium to higher-tech industries and the relatively slower closure for WAGEMP - means that the competitive pressure for the US (and as the subsample is relatively faster catching-up than the total sample also for other advanced countries) is shifting towards the medium to higher-tech industries.

We now come to an econometric analysis of these tendencies. Table 3.1 presents the estimation results for the three variables OUTPROD, VADPROD, and WAGEMP again for the total sample and the subsample. In these estimations we pooled the three low tech sectors (ISIC 321, 322, and 323) and the three medium to high-tech sectors (ISIC 382, 383, and 385). Further, we estimated a separate constant for each of the six industries to capture industry specific effects (not reported in this paper) but common slope parameters for each of the two types of industries. The results are presented for the entire set of countries and a subsample consisting of EUS1, EUS2, JAP, NIC1, and NIC2.[19] The table presents the common regression statistics, the mean initial gap $\frac{1}{N}\sum_{c=1}^{N} G_i^c$ and the mean growth rate of the gap $\frac{1}{N}\sum_{c=1}^{N} \phi_i^c$ where $i = H, L$ denotes the industry type and N the number of countries in the sample and three tests for differences in the mean gap,[20] the mean growth rate, and coefficient of convergence. The test for the mean initial gap and mean growth rate of the gap is a t-test and the test of equality of the two coefficients a F-Test (Chow-Test).

We found significant convergence for all industries and variables in both sample groups. For the total sample the cofficient of convergence $\beta_{i,1}$ for OUTPROD is smaller for the lower-tech than for the higher-tech sectors $|\beta_{L,1}^{OUTPROD}| = 0.022 < |\beta_{H,1}^{OUTPROD}| = 0.031$; the difference is statistically significant at the 5.1 % level. There are are no significant differences in the convergence parameters for the other two variables VADPROD and WAGEMP between the two sets of industries. Further the average initial gap is significantly higher for the medium to higher-tech industries than for the lower-tech industries for all three variables.

Further, the average growth rate is significantly higher (in absolute values) for the medium to high-tech industries compared with the lower tech industries for OUTPROD, but not significantly different for VADPROD. For OUTPROD the higher average growth rate of the gap (in absolute values) is due to the larger initial gap and the higher coefficient of convergence. For the variable WAGEMP the average growth rate is (statistically significant at the 6.4 % level) higher (meaning that the gap is closed faster) for the lower-tech industries.

For the subsample we found again significant convergence parameters for all three variables and the two sets of industries. But for this sample of countries we did not find significant differences in the parameters of convergence between the two sets of industries. Further only the gaps for OUTPROD and VADPROD are significantly higher for the medium to higher-tech industries and there is no significant difference of the initial gap for WAGEMP.

Although the parameters of convergence are not different, the average growth rates are (significantly) higher (again in absolute terms) in the medium to higher-tech industries than in

[19] The results for the individual industries are reported in the appendix; see Tables C.1 to C.3.

[20] The mean initial gap reported in Table C.1 differs slightly from the initial gap in Figure 3.1 as in the regression analysis we take the first available year for each country and in the Figure we averaged across all the countries for which figures were available in 1965.

	Total Sample					
	OUTPROD		**VADPROD**		**WAGEMP**	
	321,322,323	**382,383,385**	**321,322,323**	**382,383,385**	**321,322,323**	**382,383,385**
$\beta_{i,1}$	-0.022	-0.031	-0.023	-0.026	-0.020	-0.019
p-value	0.000	0.000	0.000	0.000	0.000	0.000
Std.Dev.	0.004	0.003	0.002	0.003	0.002	0.002
F-Value	47.380	90.990	70.500	56.950	166.680	83.840
R^2	0.680	0.807	0.760	0.724	0.882	0.852
$\bar{R}^2$	0.666	0.798	0.749	0.711	0.877	0.846
N	93	91	93	91	93	91
Half-Time	32.017	22.158	30.239	26.877	34.431	37.126
Mean Gap	0.710	0.985	0.951	1.226	1.079	1.282
Mean Gr	-0.017	-0.026	-0.015	-0.019	-0.031	-0.026
Tests						
Δ **Gap** $(P > \|t\|)$	0.000		0.001		0.040	
Δ **Gr** $(P > \|t\|)$	0.005		0.215		0.064	
$\Delta\beta_{i,1}(P > F)$	0.051		0.448		0.603	

	Subsample					
	OUTPROD		**VADPROD**		**WAGEMP**	
	321,322,323	**382,383,385**	**321,322,323**	**382,383,385**	**321,322,323**	**382,383,385**
$\beta_{i,1}$	-0.019	-0.030	-0.019	-0.026	-0.014	-0.015
p-value	0.001	0.000	0.000	0.000	0.007	0.000
Std.Dev.	0.005	0.005	0.004	0.005	0.005	0.004
F-Value	32.870	64.140	50.440	34.750	92.780	80.870
R^2	0.749	0.854	0.821	0.760	0.894	0.880
$\bar{R}^2$	0.726	0.840	0.805	0.738	0.884	0.869
N	48	48	48	48	48	48
Half-Time	36.120	22.771	36.234	27.182	51.193	46.793
Mean Gap	0.882	1.881	1.266	1.497	1.596	1.752
Mean Gr	-0.022	-0.032	-0.023	-0.023	-0.043	-0.035
Tests						
Δ **Gap** $(P > \|t\|)$	0.004		0.034		0.140	
Δ **Gr** $(P > \|t\|)$	0.024		0.948		0.013	
$\Delta\beta_{i,1}(P > F)$	0.112		0.303		0.834	

Table 3.1: Cross-country regressions

the lower tech industries for OUTPROD, which can be explained by the much larger inital gap. The reverse is true for WAGEMP, where the average growth rate is higher for the lower-tech than the medium to higher-tech industries.

These results can now be compared to the stylised patterns of convergence in Section 2. The empirical pattern fits best to the stylised pattern in Figure 2.3, i.e. there is convergence in both sectors but relatively faster in the medium to higher-tech sectors. Further we should note here, that there is no general evidence in the sample of countries used for this study that countries are converging in one sector but falling behind in the other sectors (as was shown in Figure 2.4).

The convergence pattern for wages is very much like the one we discussed in relationship with the evolution of unit labour costs in Section 2.4. There is evidence for a wage drift across sectors, meaning that wages are converging with equal rates. As for wages gaps between the medium to higher and lower-tech sectors are very close (not statistically different) and the growth rates of wages across sectors are similar (in fact the closure of the gap is even a little faster in the lower-tech sectors), as we assumed in the theoretical discussion. The empirical pattern of the evolution of relative unit labour costs shall be discussed below (see Section 3.5).

3.4 Results on σ-convergence

As was mentioned above, the evolution of the standard deviation or coefficient of variation (CoV) can be used in studying convergence. If the standard deviation of a certain variable becomes smaller over time, the countries become more similar with respect to their productivity or wage levels. As is mentioned in Barro and Sala-i-Martin (1995) β-convergence does not imply σ-convergence (β-convergence is a necessary but not sufficent condition for σ-convergence). From our theoretical analysis above we cannot conclude that there should be σ-convergence. If the countries converge with different speeds or are starting the catch-up process at different points in time there could also be an increase in the CoV. For our pattern of comparative advantage switchovers, the convergence must take place relatively faster in the high-tech sectors.

In Figure 3.2 we report the development of the coefficient of variation (CoV) of the gap for the three variables and the two subsamples of countries. The CoV is in general lower in the medium to higher-tech than in the lower-tech industries. This means that the productivity or wage level relative to the leader is more similar across the countries for the medium to higher-tech than lower-tech industries although this difference is vanishing at the end of the period. Further there is a tendency that the CoV is rising over time and falling only for VADPROD from 1980 onwards. The CoV is also in general lower for the subsample than for the total sample in 1965. At the end of the period the two samples show almost the same CoV.

One reason for these patterns could be that, with a closure of the gap, other characteristics become more important. As we have only tested for *absolute* convergence, we have not yet captured this effect. In the case that there is in fact only *conditional* convergence, than it could be that countries are more differentiated in their productivity levels the closer they are to the technological frontier.[21] A second reason could be that countries in the sample are starting the convergence process at different points in time, which would also explain the rising trend of the CoV. Further in the case that these starting points are different across industries in one country (i.e. there is a sequence of industries catching-up, beginning with the lower-tech industries), this would explain the differences between the medium to higher and lower-tech

[21] This could also be an explanation for the finding in Bernard and Jones (1996). For a sample of 14 advanced OECD countries, they could not find (absolute) convergence for the manufacturing industry.

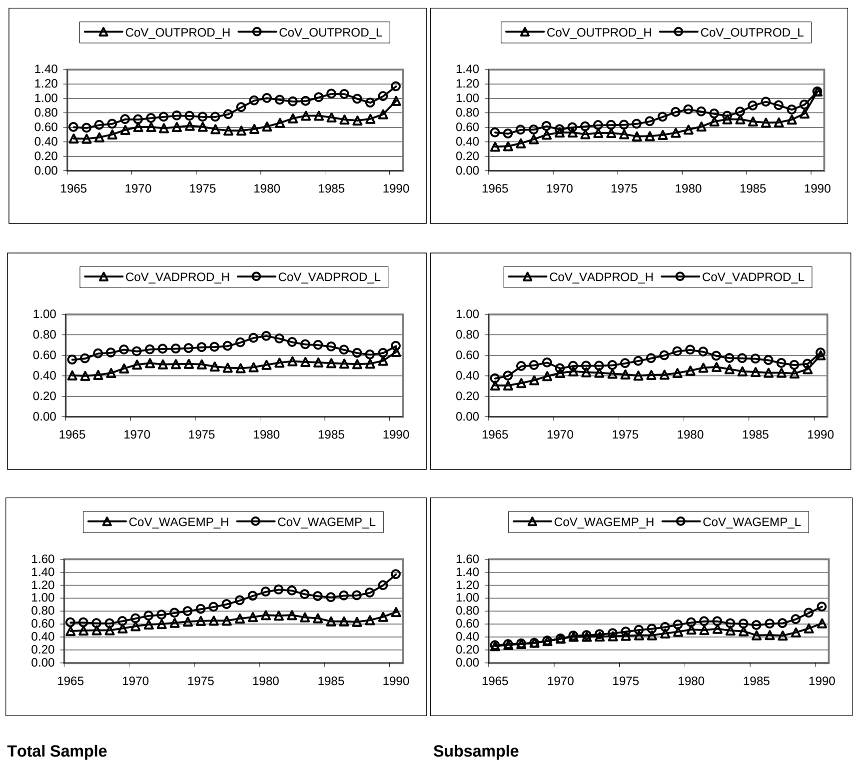


Figure 3.2: Coefficients of Variation

branches (see especially e.g. the time trajectories of OUPTPROD for the total sample over the period 1975-1990; Panel A in Figure 3.2).

Further one can observe some subperiods: From 1965 to the 1980's there was a rising trend with a larger increase at the end of the 1970's, after which the CoV was more or less stable for OUTPRD, even slightly falling for VADPROD and WAGEMP, with a sharp increase again at the end of the 1980's. These differences between the subperiods are hard to explain in the simple model of catching-up discussed in this paper as probably macroeconomic conditions (the general slowdown of aggregate growth in the 1980's) may be important and could not be discussed here.

Finally, for the variable WAGEMP the CoV is rising faster in the lower-tech than in the medium to high-tech industries. This could be due to some features of labor market conditions in catching-up economies which have not yet been introduced in the analysis so far. E.g. that the labour markets of those economies which are not following a 'switchover' pattern in catching-up show labour market features of the Lewis-type (Lewis, 1954) in that the wage developments of low-skilled workers are lagging behind and hence the differentiation across the catching-up economies as a whole is increasing leading to a higher CoV in the lower-tech industries.

3.5 Unit labour costs

The movements of sectoral productivities and wages result in different movements of unit labour costs (as discussed in section 2.4 above). In this section we discuss the dynamics of unit labour costs for the sample of countries and industries introduced above. The unit labour costs (ULC) are defined as $OULC_i^c = \frac{WAGEMP_i^c}{OUTPROD_i^c}$ and $VULC_i^c = \frac{WAGEMP_i^c}{VALPROD_i^c}$. Further the ULC's are expressed relative to the ULC level in the US ($ULC_i^{US} = 1$) $\frac{ULC_i^c}{ULC_i^{US}}$. As all variables are measured in current PPP here the problem of deviations discussed above does not matter any longer.[22] Figure 3.3 shows the time trajectories of the mean of the unit labour costs relative to the US for the total sample (Panel A and B) and the subsample (Panel C and D) using OUTPROD and VADPROD respectively.[23] At the beginning of the period the US had higher ULC than the average of the countries (note that we do not include quality adjustments in this analysis) but had a comparative advantage in the medium to higher-tech industries. Further the ULC's are much lower in the subsample than in the total sample. Then - due to the differential productivity and wage dynamics described above - there was a *switchover in the structure of comparative advantages* at the beginning of the eighties. As ULC were rising relative to the US in the lower-tech sectors (and even becoming higher than in the US in absolute levels in the total sample, thus meaning that absolute cost advantages were lost) the ULC's for the medium to high-tech industries were even falling relative to the US.

The evolution of the unit labour costs can be quite different across countries or country groups. Figure 3.4 presents the time trajectories for selected country groups given in Table A.1.

[22] Measuring both variables in current PPP_t^c (i.e. productivity and wages per employee in national currency units divided by the current PPP rate), the unit labour costs $ULC_{i,t}^c$ at time t are then calculated as $ULC_{i,t}^c = \frac{WAGEMP_{i,t}^c/PPP_t^c}{OUTPROD_i^c/PPP_t^c} = \frac{WAGEMP_{i,t}^c}{OUTPROD_{i,t}^c}$.

[23] Again we use a 3 year moving average for smoothing the time series in the figures.

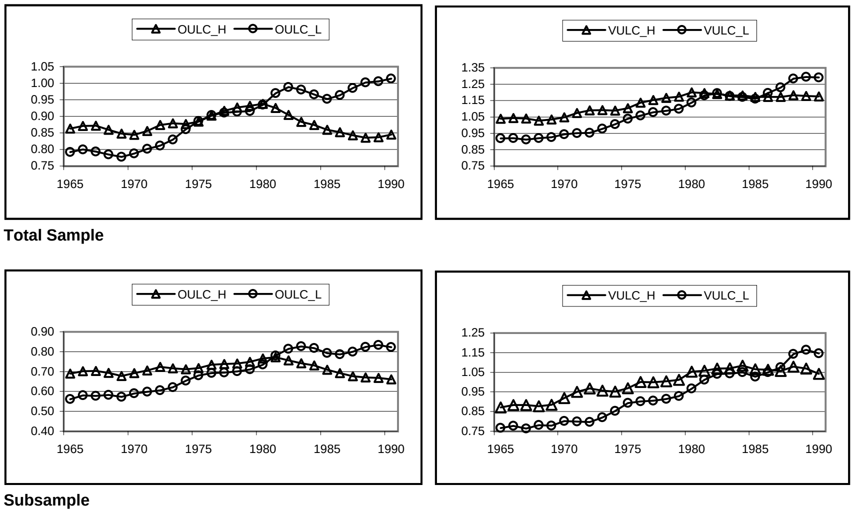


Figure 3.3: Relative ULC in high and low tech sectors

4 Conclusions

What can be concluded from this analysis? From the theoretical point of view there seems to exist some reasonable arguments that in the course of development and catching-up the competitive pressure of these countries can be directed more towards the medium to higher-tech sectors of the more advanced countries rather than remaining on the lower-tech sectors (as is the main concern in the recent debate on labour market implications of increasing trade integration between the 'North' and the 'South'). This was demonstrated by using simple convergence models and assuming wage drift (or relatively even wage growth) across sectors.

In the empirical part we found evidence for convergence at the industrial level. This result is at odds with the result of Bernard and Jones (1996) who found no convergence at the manufacturing level for 14 OECD-countries. But here we also have to take into account the problems discussed above (e.g. using current GDP PPP rates). Further detailed analysis using a time series approach will guide our future research agenda.

The second main finding of this paper is that there is some evidence for sectorally different convergence parameters where the medium to higher-tech sectors are converging relatively faster than the lower-tech sectors in productivity levels. For wages we do not see a similar pattern, which implies that there is a wage drift across sectors. These findings point towards the possibility of a comparative advantage switchover. This was then demonstrated for an average of catching-up countries relative to the US.

Although these results are in our view convincing we have to keep some caveats in mind which should be taken into account in further research: First the aggregation level of the sectors is already quite high for trade analysis. Second one should use ideally sectoral PPP rates instead of GDP PPP rates. Third we did not introduce proxies for improvements in product quality (see, however, the analysis in Stehrer and Landesmann (1999) where export unit values were used as indicators for product quality differences). Fourth, we only analysed labour productivity and not TFP convergence. Lastly, there could be a selectivity bias in the selection of economies included in our analysis (mainly for reasons of data availability at the industrial level). This selection has

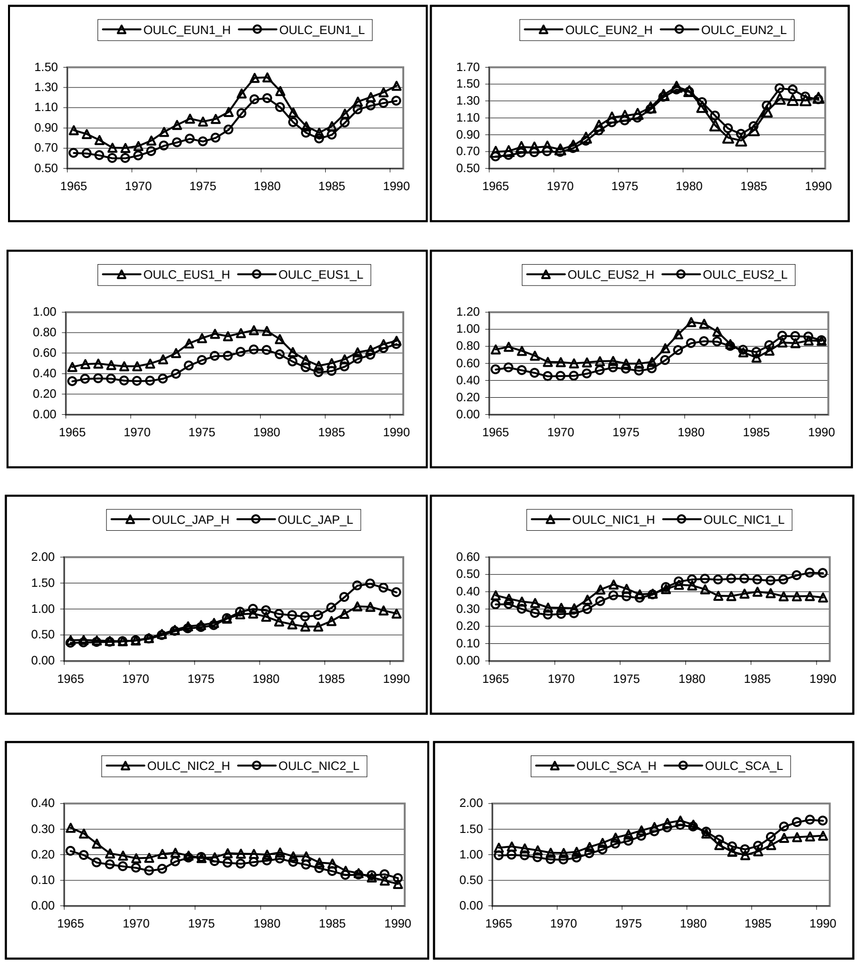


Figure 3.4: Relative ULC in high and low tech sectors - Selected country groups

most likely led to an inclusion of mostly countries in which catching-up has actually occurred. However, the emphasis in this paper has been to point to the possibility of a 'comparative advantage switchover' rather than focusing on the general question of why and when catching-up or falling-behind occurs.

A Countries

GROUP	NUMB	ABB	NAME
AMN	124	CAN	Canada
AMN	840	USA	USA
EUN1	250	FRA	France
EUN1	280	GWE	GermanyWest
EUN1	826	UKD	United Kingdom
EUN2	40	AUT	Austria
EUN2	56	BEL	Belgium
EUN2	208	DEN	Denmark
EUN2	352	ICE	Iceland
EUN2	372	IRE	Ireland
EUN2	528	NLD	Netherlands
EUS1	724	ESP	Spain
EUS1	300	GRE	Greece
EUS1	380	ITA	Italy
EUS1	620	POR	Portugal
EUS2	196	CYP	Cyprus
EUS2	376	ISR	Israel
EUS2	470	MAT	Malta
JAP	392	JAP	Japan
NIC1	344	HKO	China-HongKong
NIC1	410	KOR	Korea
NIC1	458	MAL	Malaysia
NIC1	702	SIN	Singapore
NIC1	158	TAI	Taiwan
NIC2	356	INA	India
NIC2	360	INO	Indonesia
NIC2	764	THA	Thailand
OCE	36	AUS	Australia
OCE	554	NZL	New Zealand
SCA	246	FIN	Finland
SCA	578	NOR	Norway
SCA	752	SWE	Sweden

Table A.1: List of countries

B Figures

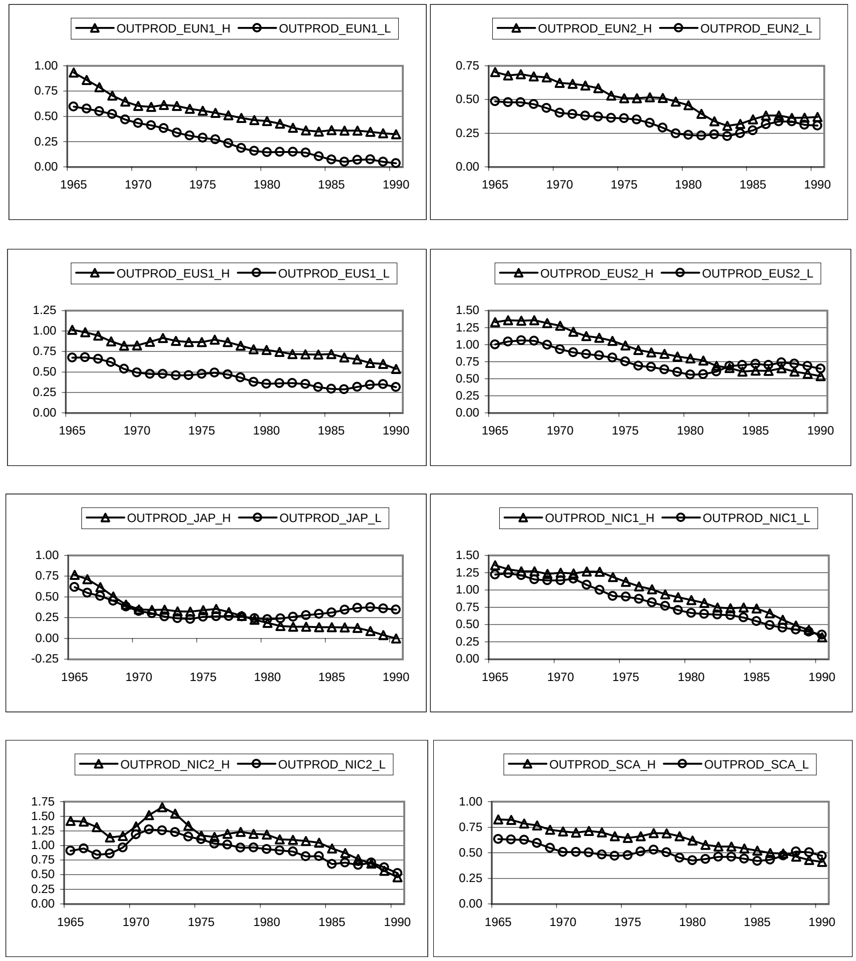


Figure B.1: Evolution of OUTPROD gap - Country groups

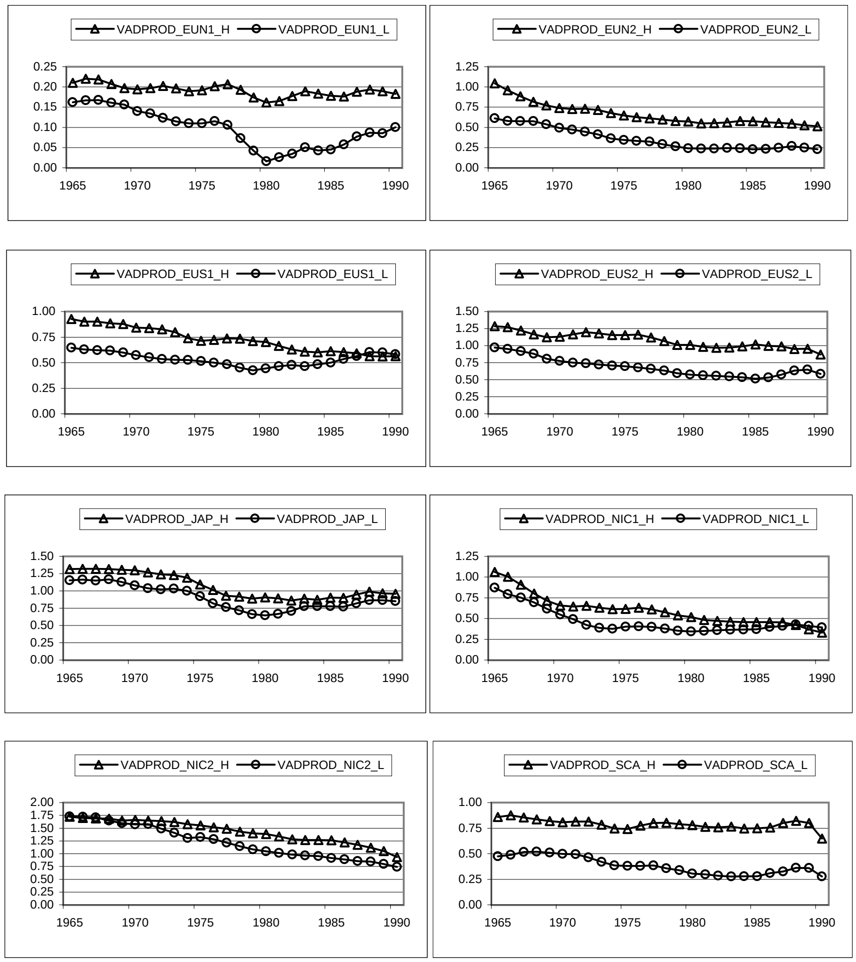


Figure B.2: Evolution of VADPROD gap - Country groups

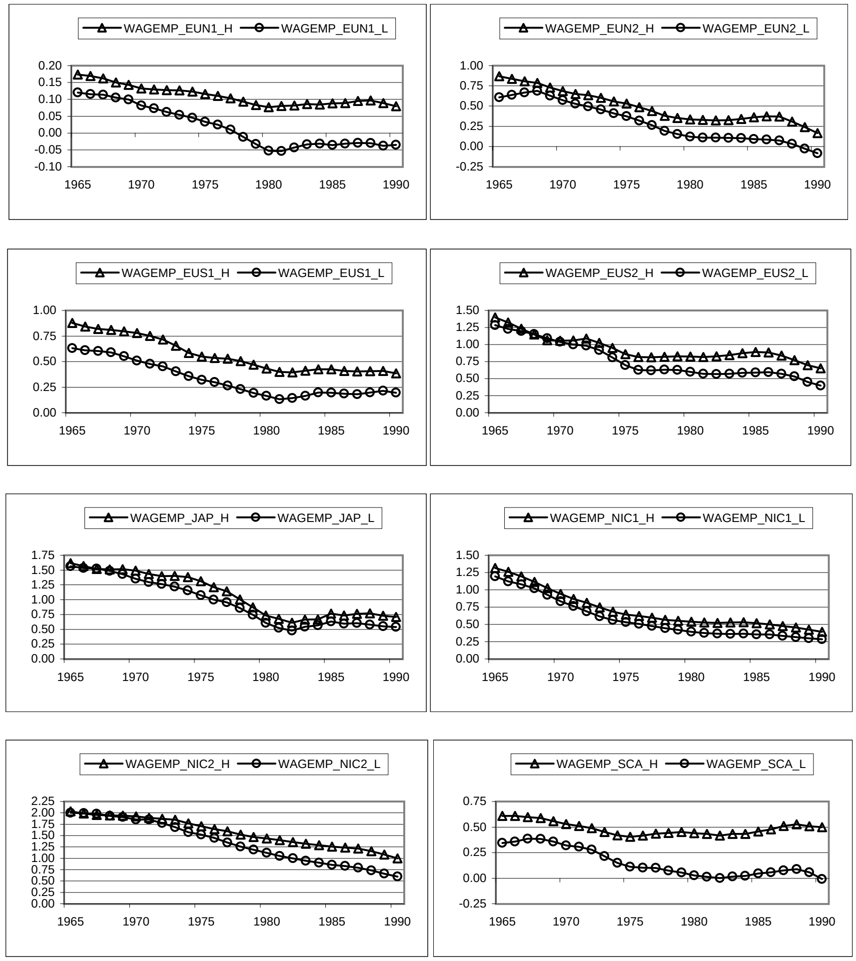


Figure B.3: Evolution of WAGEMP gap - Country groups

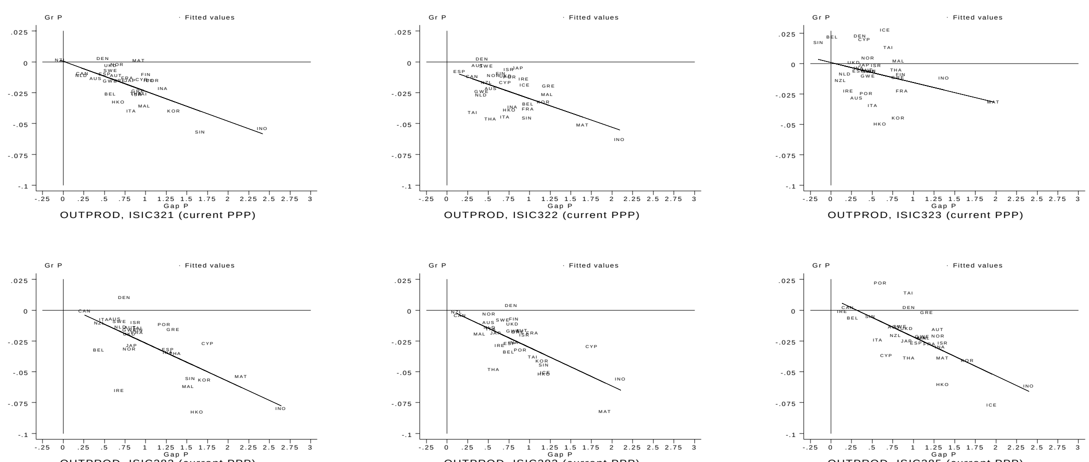


Figure B.4: Scatterplots for OUTPROD - Total sample

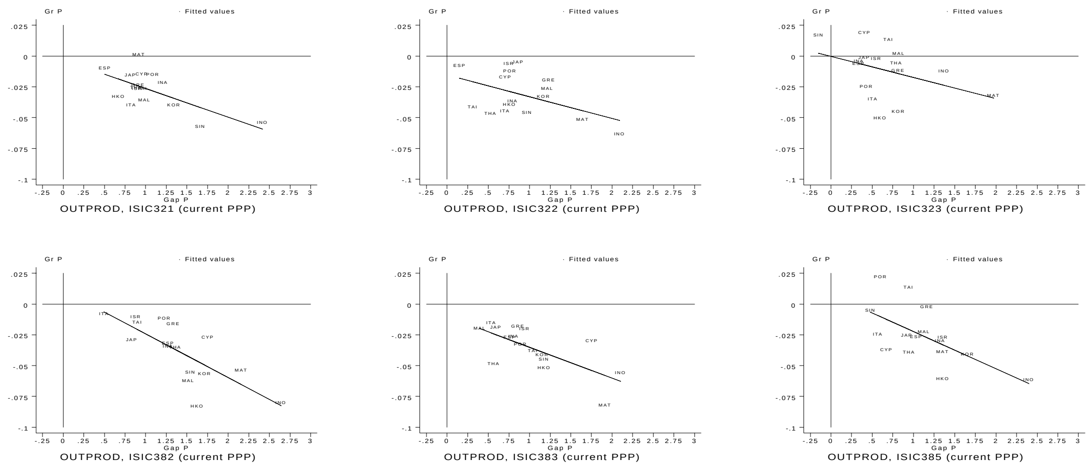


Figure B.5: Scatterplots for OUTPROD - Subsample

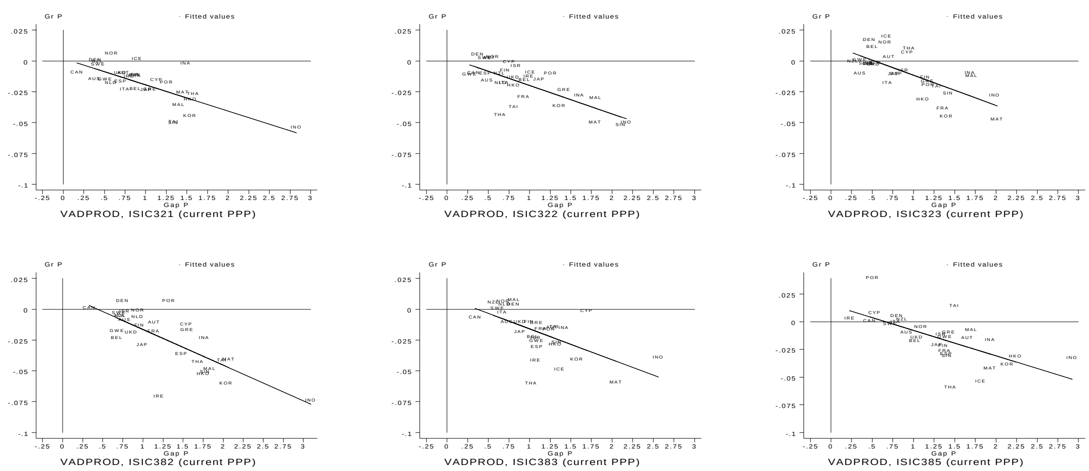


Figure B.6: Scatterplots for VADPROD - Total sample

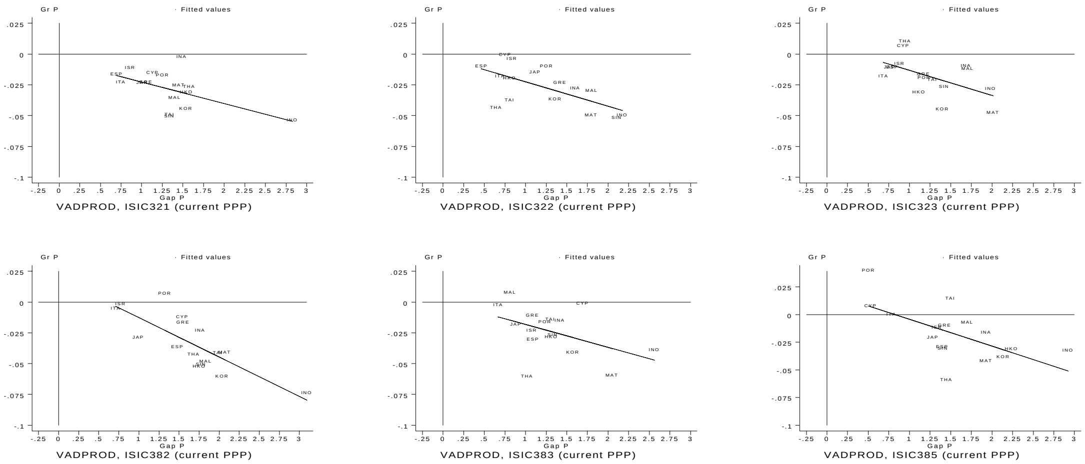


Figure B.7: Scatterplots for VADPROD - Subsample

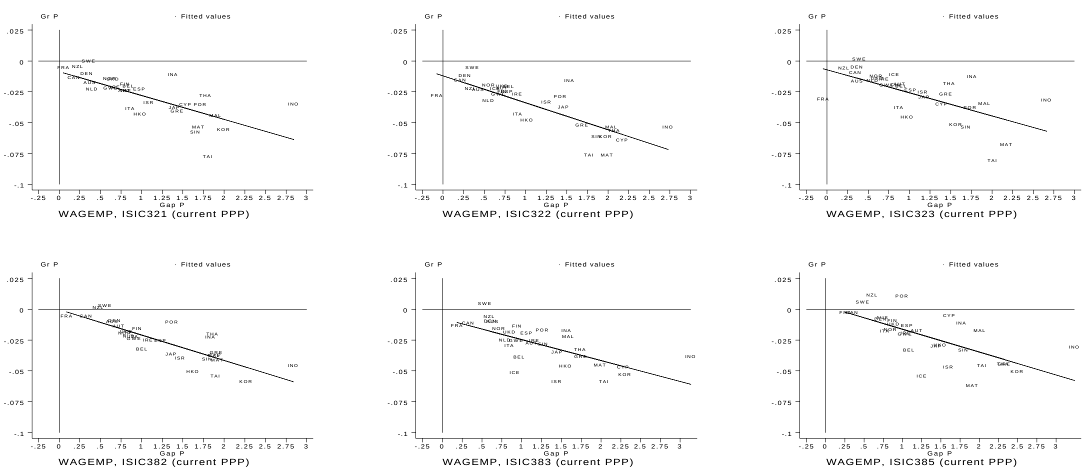


Figure B.8: Scatterplots for WAGEMP - Total sample

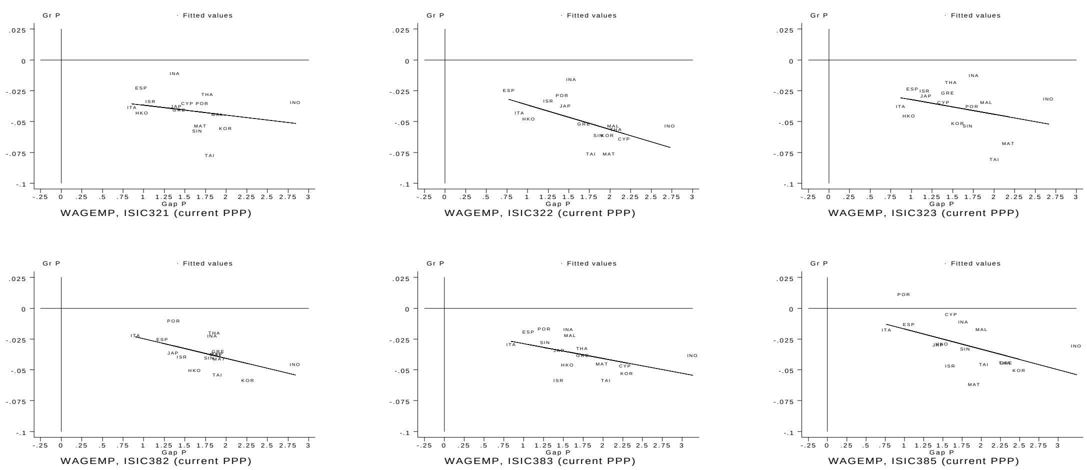


Figure B.9: Scatterplots for WAGEMP - Subsample

C Tables

	Total Sample					
	ISIC321	**ISIC322**	**ISIC323**	**ISIC382**	**ISIC383**	**ISIC385**
$\beta_{i,1}$	-0.024	-0.023	-0.016	-0.031	-0.031	-0.032
p-value	0.000	0.001	0.058	0.000	0.000	0.000
Std.Dev.	0.004	0.006	0.008	0.006	0.005	0.006
F-Value	33.51	13.80	3.88	28.68	33.08	28.89
R^2	0.536	0.322	0.118	0.506	0.533	0.508
$\bar{R}^2$	0.520	0.299	0.088	0.488	0.517	0.490
N	31	31	31	30	31	30
Half-Time	28.419	29.749	42.265	22.360	22.089	22.005
Mean Gap	0.820	0.768	0.541	1.070	0.866	1.023
Mean Gr	-0.019	-0.024	-0.008	-0.028	-0.025	-0.022

	Subsample					
	ISIC321	**ISIC322**	**ISIC323**	**ISIC382**	**ISIC383**	**ISIC385**
$\beta_{i,1}$	-0.023	-0.018	-0.017	-0.035	-0.025	-0.030
p-value	0.004	0.065	0.136	0.001	0.003	0.010
Std.Dev.	0.007	0.009	0.011	0.008	0.007	0.010
F-Value	11.43	4.02	2.51	19.68	13.29	8.90
R^2	0.450	0.223	0.152	0.584	0.487	0.389
$\bar{R}^2$	0.410	0.168	0.091	0.555	0.450	0.345
N	16	16	16	16	16	16
Half-Time	29.751	39.029	40.440	19.542	27.648	22.952
Mean Gap	1.064	0.914	0.668	1.406	1.041	1.117
Mean Gr	-0.028	-0.032	-0.012	-0.039	-0.036	-0.026

Table C.1: Cross-country regressions: Output productivity

	Total Sample					
	ISIC321	**ISIC322**	**ISIC323**	**ISIC382**	**ISIC383**	**ISIC385**
$\beta_{i,1}$	-0.021	-0.023	-0.025	-0.029	-0.025	-0.023
p-value	0.000	0.000	0.000	0.000	0.000	0.000
Std.Dev.	0.004	0.004	0.005	0.005	0.006	0.005
F-Value	31.32	34.10	27.61	38.35	16.56	21.63
R^2	0.519	0.540	0.488	0.578	0.364	0.436
$\bar{R}^2$	0.503	0.525	0.470	0.563	0.342	0.416
N	31	31	31	30	31	30
Half-Time	32.512	30.058	28.263	23.926	27.626	30.202
Mean Gap	0.981	0.943	0.928	1.270	1.108	1.305
Mean Gr	-0.019	-0.019	-0.010	-0.024	-0.019	-0.015

	Subsample					
	ISIC321	**ISIC322**	**ISIC323**	**ISIC382**	**ISIC383**	**ISIC385**
$\beta_{i,1}$	-0.017	-0.020	-0.020	-0.032	-0.019	-0.024
p-value	0.021	0.007	0.027	0.000	0.072	0.010
Std.Dev.	0.007	0.006	0.008	0.006	0.010	0.008
F-Value	6.70	9.75	6.13	24.76	3.79	8.97
R^2	0.324	0.411	0.305	0.639	0.213	0.391
$\bar{R}^2$	0.275	0.369	0.255	0.613	0.157	0.347
N	16	16	16	16	16	16
Half-Time	39.747	35.185	34.011	21.729	37.326	28.607
Mean Gap	1.326	1.226	1.245	1.646	1.318	1.528
Mean Gr	-0.028	-0.027	-0.018	-0.033	-0.024	-0.017

Table C.2: Cross-country regressions: Value added productivity

	Total Sample					
	ISIC321	**ISIC322**	**ISIC323**	**ISIC382**	**ISIC383**	**ISIC385**
$\beta_{i,1}$	-0.019	-0.022	-0.019	-0.021	-0.017	-0.019
p-value	0.000	0.000	0.000	0.000	0.000	0.000
Std.Dev.	0.003	0.003	0.004	0.003	0.003	0.004
F-Value	32.34	53.78	21.74	57.46	24.85	22.31
R^2	0.527	0.650	0.428	0.672	0.462	0.444
$\bar{R}^2$	0.511	0.638	0.409	0.661	0.443	0.424
N	31	31	31	30	31	30
Half-Time	35.766	31.651	37.067	33.681	40.773	37.366
Mean Gap	1.055	1.110	1.072	1.263	1.244	1.339
Mean Gr	-0.029	-0.036	-0.027	-0.026	-0.029	-0.022

	Subsample					
	ISIC321	**ISIC322**	**ISIC323**	**ISIC382**	**ISIC383**	**ISIC385**
$\beta_{i,1}$	-0.008	-0.020	-0.012	-0.016	-0.012	-0.017
p-value	0.342	0.017	0.230	0.310	0.063	0.037
Std.Dev.	0.008	0.007	0.009	0.007	0.006	0.007
F-Value	0.97	7.31	1.57	5.75	4.09	5.34
R^2	0.065	0.343	0.101	0.291	0.226	0.276
$\bar{R}^2$	-0.002	0.296	0.037	0.241	0.171	0.224
N	16	16	16	16	16	19
Half-Time	86.212	34.849	58.395	43.430	57.907	42.009
Mean Gap	1.561	1.665	1.562	1.751	1.704	1.801
Mean Gr	-0.041	-0.050	-0.039	-0.037	-0.037	-0.030

Table C.3: Cross-country regressions: Wages per employee

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