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Abstract

This paper develops a two-country two-sector endogenous growth model with a dual labour market based on efficiency wages. Growth is driven by Research done in the (high-tech) tradeable sector. The follower country tends to grow faster the greater the productivity gap from the leader country, but differences in unemployment benefit systems can lead to relative convergence, i.e. a steady state with the backward country lagging behind the leader country. The reason for this is that high social welfare benefits generate high unemployment and reduce the amount of labour employed for R&D purposes. Furthermore, it is shown that a shift in preferences towards non-tradeables can explain a global slowdown in economic growth.

JEL classification: O41, F12, J41, J64.
Keywords: endogenous growth, catching up, efficiency wages, dual economy.

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Relative Convergence in a Dual Economy with Tradeable and Non-Tradeable Goods

Henri de Groot and Anton van Schaik

1. Introduction

After World War II, the European countries drastically increased their productivity levels relative to the United States. In the 1980s, however, convergence slowed down or even has come to an end (cf. Dollar and Wolff 1993, OECD 1993). This observation, i.e. that European productivity levels might be stabilizing at some distance from their U.S. counterparts (both on a macro-economic and sectoral level) is clearly underexposed in the empirical literature on economic growth. The recent appearance of data sets for more than 100 countries in the post World War II period (e.g. Summers and Heston 1991) have spurred multivariate tests of single equation macroeconomic growth models on large cross-country samples, including both developed and developing countries. The regression results worsen, however, when only OECD countries are included (cf. Mankiw, Romer and Weil 1992, Table I). Obviously, the macroeconomic variables commonly used (viz. the growth rate of labour input and the investment ratio) are of no great use to explain inter-country differences in growth rates within the OECD area. Moreover, the estimation of a single-equation model is an activity to which there are now sharply diminishing returns. One way to remedy this would be to test more complete models, not only reduced forms, with a sharper focus on sectoral and institutional structures (cf. Fagerberg 1994). This may reveal that the process of catching-up with the US not only depends on the extent of the productivity gap, but also on the interaction of labour-market institutions with the sectoral structure of the economy. Comparing the post-war economic performances of the European Union and the United States, there are strong indications that labour market institutions do matter very much (e.g. Bean 1994, OECD 1994). In the 1950s and 1960s, the period of catching-up with the United States, European unemployment rates reached historically unprecedented low levels, but afterwards they were steadily rising, whereas the U.S. unemployment rate periodically returned to its "natural rate".

The answer to the intriguing question, why European countries do no longer increase their productivity level relative to the United States, is still a very open one. This paper develops a two-country endogenous growth model with tradeable and non-tradeable goods, to shed some light on
this question. The presence of a dual labour market, due to an efficiency wage relation that is operating in the high-tech sector only, is an important characteristic of the model. This wage relation can be considered as an institutional factor that is the most important in determining the distribution of labour across the sectors of the economy. Within this context, the question whether sectoral structures can differ among countries in such a way that they hamper or speed up economic growth is dealt with. Thereby we will mainly focus on the role unemployment benefits play in determining the sectoral allocation of labour. In distinguishing Europe from the U.S., it is evident that these systems differ a lot between the two regions, both in duration and in height. It will be argued that the generosity of benefits in Europe led to a society with relatively few people from the total work force employed in the high-tech sector of the economy. As, in our model, technological progress stems from this sector, there is a direct link between the generosity of the unemployment benefit system and economic growth.

The introduction of a two-country model raises the question about the external relatedness of sectors, that is, how the productivity of the tradeables sector in one country does affect the productivity of that sector in another country. In general, technological progress can be conceived either as a "free good", as a by-product of other economic activities, or as the result of intentional R&D activities in private firms. It is now increasingly accepted that the third source (innovation, as the outcome of intentional activities in private firms) is one of the most important sources of technological progress in OECD economies (cf. Dosi 1988, Fagerberg 1994). Recently, Van de Klundert and Smulders (1994) have incorporated the accumulation of firm-specific knowledge and the idea that firms can learn from each other in a two-sector two-country model, distinguishing traditional and high-tech goods, which can both be traded between regions. We follow these authors by assuming that the backward country can learn from the advanced country but not the other way around. In other words, the backward country can copy production processes at a relatively low cost and has an opportunity to catch-up (cf. Krugman 1990, Barro and Sala-i-Martin 1995). However, in contrast with the usual assumptions in the literature on trade and endogenous economic growth, we allow labour market institutions and unemployment to play a prominent role in our model. In addition we assume that the production of traditional goods only takes place in the non-tradeables sector. The inclusion of a non-tradeable sector has various reasons. First of all it is important from an empirical point of view, as sheltered sectors constitute a large part of the

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1 Empirically, this question has been studied by Dollar and Wolff (1993). Empirical studies that try to test for Kaldor’s Law can also be seen as studies that explicitly take into account the relatedness of different sectors, in casu the relatedness between the manufacturing sector and the non-manufacturing sector. For a discussion on this growth law see for example the Symposium on Kaldor’s Growth Laws in the Journal of Post Keynesian Economics (1983) and McCombie and Thirlwall (1994).
Secondly, we want to focus - among others - on the dual character of the labour market. In order to be able to do so we need two substantial sectors that make up the economy. Tradeability of traditional goods has therefore to be excluded as this makes possible full specialization (e.g. Van de Klundert and Smulders 1994). Finally, the distinction between a tradeables and a non-tradeables sector is important in relation to the knowledge spill-overs in our model. It seems reasonable to assume that these spill-overs are most strong in the tradeables sector. We will take the most extreme position by assuming that there are no spill-overs whatsoever in the non-tradeables sector.

We proceed as follows. Section 2 presents the model. Equilibrium unemployment and the allocation of labour over sectors is discussed in section 3. The sectoral structure of employment turns out not to depend on the dynamics of the model, which will be presented in section 4. The model predicts that (almost) identical countries, only differing in their initial labour productivity levels in the high-tech sector, will fully converge. However, if sectoral structures differ between countries, this will no longer hold. In this case there are possibilities for leapfrogging or relative convergence, i.e. steadily lagging behind the leader country. The results will be used to shed some more light on the development of the countries of the European Union and the United States in the post World War II period. Thereby, we will focus on differences in the system of unemployment benefits between the two regions and on demand factors that might explain the observed global slowdown in economic growth. We conclude in section 5.

2. A dual economy

The world consists of two almost identical regions with two differences only. Firstly, the backward region (the European Union, labelled region 2) initially has a substantially lower labour productivity in the high-tech sector compared with the leader region (the United States, labelled region 1). The initial positions are inherited from the past. Secondly, the rate of unemployment may differ between both regions. Each region produces two types of goods, viz. non-tradeable traditional goods and tradeable high-tech goods. The factors of production are labour, firm-specific knowledge and firm-specific efficiency of workers. In each region there are \( n \) firms \((i=1,\ldots,n)\) in the high-tech sector, which compete monopolistically on the world market for \( 2n \) varieties of the high-tech products \((n\) is assumed to be sufficiently large). Each firm is assumed to produce a unique brand.

In the non-tradeables sector there is unitary labour-productivity
where \( L_N \) stands for the number of workers employed in the non-tradeables sector and \( y \) is the production of non-tradeables. Assuming perfect competition in the non-tradeables sector, the price of a non-tradeable good equals labour-costs

\[
(1) \quad y = L_N,
\]

where \( p_N \) denotes the price of non-tradeables and \( w_N \) is the wage rate in this sector.

High-tech firms employ (direct or productive) labour \( (L_{xi}) \) for production of goods that has labour productivity \( h \) and efficiency \( e \), leading to \( x_i \) units of output

\[
(3) \quad x_i = h_e L_{si}.
\]

The efficiency of a high-tech production worker is a variable that can be affected by the wage setting behaviour of the firm. The variable \( h \) on the other hand is dependent on international forces and the Research and Development intensity chosen by the firm (\( h \) will be further explained in section 4). Thus a high-tech firm also hires workers for R&D activities. To simplify the analysis, we assume that each firm employs a fixed proportion \( \beta(>0) \) of the production workers in R&D-activities

\[
(4) \quad L_{ri} = \beta L_{si},
\]

where \( L_{ri} \) is labour employed in R&D-activities. The fruits of employing labour in R&D can be made explicit but this is not necessary for our purpose right now\(^2\). Besides employing workers for direct productive purposes and in R&D, firms have to incur a fixed cost \( (L_f) \) before being able to produce. This fixed cost is expressed in terms of labour.

Total nominal income \( (I) \) consists of labour income and profits \( (n\pi_i) \)

\[
I = w_N L_N + n w_{ri} (L_{si} + L_{ri} + L_f) + n\pi_i,
\]

where

\[
\pi_i = p_{Ti} x_i - w_{Ti} (L_{si} + L_{ri} + L_f).
\]

Here \( p_{Ti} \) is the price of the tradeable good \( i \) and \( w_{Ti} \) the wage rate of firm \( i \). Substituting \( \pi_i \) and eqs.

\(^2\) In a model with fully optimizing behaviour, a firm would allocate its labour among the two activities in such a way that the marginal productivity of labour in the two activities would be equalized (cf. Smulders, 1994, chapter 3). Alternatively, we could state eq. 4 as a rule of thumb. The main justification for this would be that the future fruits of doing R&D are inherently uncertain, not justifying the use of a perfect foresight model to derive R&D inputs. It can thus be argued that the use of rules of thumb by firms deciding on R&D-input is closer to the truth than the use of perfect foresight. There is however large debate on this issue.
1 and 2 results in

\[ I = p_N y + n p_{TI} x_I. \]  

Based on a two-step optimization procedure where consumer-preferences are specified according to a Cobb-Douglas consumption index, we derive that consumers spend a fraction \( \sigma \) of total nominal income on high-tech (tradeable) goods and a fraction \((1-\sigma)\) on traditional (non-tradeable) goods. Preferences between traditional and high-tech goods are assumed to be identical across regions. For the non-tradeables it can then be derived that

\[ (1-\sigma)I = y p_N. \]

Preferences over varieties are also uniform across regions and are given by a CES-function (cf. Dixit and Stiglitz 1977, Krugman 1990, Chapter 9) with an elasticity of substitution equal to \( \varepsilon(>1) \). Consequently, world demand for any variety of region 1 relative to world demand for any variety of region 2 (assuming symmetry within a region) depends on the relative price of these varieties

\[ \frac{x_1}{x_2} = \left( \frac{p_{T1}}{p_{T2}} \right)^{-\varepsilon}. \]

This relation holds for both regions and will only occur once in the fully specified model.

High-tech firms decide about labour-input and the wage rate. They fix a mark-up over labour-costs and put the wage such that they minimize labour-costs used for production (yielding the so called Solow-condition). This is equivalent to stating that firms maximize operating profits. The mark-up relation is written as

\[ p_T = \frac{\varepsilon}{\varepsilon-1} \frac{w_T}{eh}. \]

This relation shows that real wages in the tradeables sector increase with labour productivity \( h \). Unit real labour costs \( (w_T/ehp_T) \) equal \((\varepsilon-1)/\varepsilon \) and are therefore invariant with respect to labour productivity growth.

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3 For a formal statement and solution of the consumer problem we refer to Appendix A.

4 As there are no international capital flows in the model, trade must be balanced at every moment in time. This requires that the value of spending equals national income.

5 Because of this assumption we will omit the brand-indices i from this point on.

6 See Appendix B for a formal statement and solution of the producers maximization problem.
The efficiency-wage relation is operating in the high-tech sector only. The concept of efficiency wages has been studied widely by - among others - Stiglitz (1976), Salop (1979), Akerlof (1982) and Shapiro and Stiglitz (1984). Akerlof and Yellen (1986) and Layard, Nickell and Jackman (1991) provide good overviews. What all these models have in common is that they can be used to explain the existence of involuntary unemployment. The mechanism that is underlying all these models is that there is a reason for a (profit-maximizing) firm to pay a wage that is higher than the wage that clears the labour-market. The reason for this is either to retain (Salop 1979), recruit (Stiglitz 1976, Weiss 1980) or motivate (Akerlof 1982, Shapiro and Stiglitz 1986) workers. Within this last class of models there are again different explanations. Akerlof (1982) gives a sociological explanation and deals with 'fairness'. He assumes that worker’s have a norm of a fair day’s work and by paying a higher wage this norm can be increased by the firm. Shapiro and Stiglitz (1984) on the other hand assume firms to pay a high wage in order to prevent workers from shirking in case the monitoring system does not work appropriately. Because the firm is willing to pay a wage that is higher than the market clearing-wage, there exists an equilibrium in which there are workers willing to work at a lower wage than the wage paid by the firm. Nevertheless, these workers are not employed because it is not in the interest of the profit-maximizing firm to hire them. That is why unemployment can be said to be involuntary.

The idea that an efficiency wage relation is only operating in the high-tech sector can be based on various reasons (e.g. Layard et al. 1991). We will assume here that there is a relation between the fact that firms possess market power in the high-tech sector and the operation of the efficiency wage relation. The reason being that in case a firm makes profits, workers expect to be paid more. In terms of Akerlof, the wage that is considered as being fair by the workers increases as profits rise. Workers in the high-tech sector can thus be said to receive a non-competitive rent. Other reasons for the efficiency relation only operating in the high tech sector might be related to the fact the monitoring system in the sector does function not perfectly as the kind of work in the high-tech sector is difficult to monitor. In order the prevent the workers from shirking the firm might be induced to pay a wage premium.\footnote{Also empirically, the relation between the existence of efficiency wage considerations on the one hand and firm size, product-market power or capital intensity on the other hand has been established (e.g. Brown and Medoff 1989, Gera and Grenier 1994, Krueger and Summers 1988). What these studies conclude is that, after having controlled for differences in skills, working conditions, etc., there still remains a significant difference in wages paid by firms in different industries. These differences can be explained by the existence of non-competitive rents.}

With respect to the efficiency of a worker we follow Akerlof (1982) and state that the efficiency of a worker in the one sector (tradeables) depends on the wage he earns related to the wage of a worker in the other sector (non-tradeables)
This formulation guarantees an interior solution of the profit-maximization-problem for the firm (see Appendix B). Invoking the constraints on the parameters implies that $w_T > w_N$ at the optimum. As said above, the idea behind this formulation is that each worker has a certain perception of the amount of work that a 'fair' employer can ask from him. This fair amount of work can be affected by the employer by changing the wage he pays. The more he pays, the higher the notion of the worker of the fair amount of work to be supplied to the employer\(^8\).

In case of the Akerlof-specification for the efficiency-wage relation the Solow-condition is

\[
(9) \quad e = -a + c \left( \frac{w_T}{w_N} \right)^\gamma, \quad \text{where} \quad \frac{1}{c} < \gamma < 1, \quad a > 0 \quad \text{and} \quad c - a = 1.
\]

This Solow-condition states that the firm will increase its wage as long as a one-percent increase in wages leads to a more than one percent increase in effort. It turns out that the model exhibits relative nominal wage rigidity\(^9\) (note that the real wage rate in the traditional sector equals one, so that relative real wages come down to real wages in the tradeables sector). Substitution of eq. 10 in eq. 9 gives the optimal effort by employees in the tradeables sector, \(v\i\)

\[
(10) \quad \frac{w_T}{w_N} = \left[ \frac{a}{c(1-\gamma)} \right]^{\frac{1}{\gamma}}.
\]

An increase in the parameter \(a\) for instance, which can be seen as an upgrading of labour requirements in the tradeables sector, will increase relative wages. In this case employers in the tradeables sector pay higher wages to invoke more effort.

The labour-market consists of three segments, \(v\i\) employment in the tradeables sector, employment in the non-tradeables sector and unemployed labour. This leads to

\[
(11) \quad L = L_T + L_N + U,
\]

where \(U\) is the number of unemployed. We will normalize total (exogenous) labour at one \((L=1),\)

\(^8\) It should be noted that eq. 9 could be modified by introducing the unemployment rate as an argument in the function. The idea behind this is that a higher unemployment rate makes getting unemployed less attractive and hence increases the effort of an employee. This is worked out in Appendix C, but turns out not to affect the qualitative results of the model, so that it is not necessary to take this modification further into account here.

\(^9\) Stability of the interindustry wage differentials is confirmed by empirical studies (e.g. Krueger and Summers 1988, Gera and Grenier 1994).
so that \( L_T, L_N \text{ and } U \) can further be seen as ratios. Labour allocated in the tradeables sector consists of

\[
L_T = n(L_x + L_r + L_p) .
\]

We assume that labour is immobile over regions and perfectly mobile within a region. A high-tech firm that needs workers faces a pool of homogeneous labour, partly being unemployed and partly working in the non-tradeables sector. Unemployed people receive a real unemployment-benefit equal to \( b \), expressed in terms of the non-tradeable good. Consequently, the nominal unemployment benefit equals \( bp_N \). This benefit is paid out of lump-sum taxes on labour income, so that total income available in the economy is still described by eq. 5. It is assumed that the net real wage earned in the non-tradeables sector is higher than the real unemployment benefit, so that the unemployment benefit \( b \) must be sufficiently smaller than 1. (To simplify, one could take the borderline case where \( b = 0 \), because this does not affect the qualitative results, as can be easily verified later on.) In principle, all the people being unemployed or working in the non-tradeables sector would like to be employed in the tradeables sector because they can get a higher payment in that sector than what they get now.

With respect to the unemployed we assume that in equilibrium they are indifferent between accepting a job in the non-tradeables sector and remaining unemployed\(^{10}\). This is an assumption that can also be found in Bullow and Summers (1986). According to them this assumption is justified both theoretically and empirically. If the percentage of jobs which will open up in the tradeables sector is denoted by \( \delta \), the probability for an unemployed of finding a job in the tradeables sector equals

\[
\frac{\delta L_T}{U} .
\]

The numerator of this expression describes the number of jobs that falls free in the tradeables sector every period. The denominator gives the number of people that is waiting for a job in this sector. This means that a worker is indifferent between remaining unemployed and accepting a job in the non-tradeables sector if

\(^{10}\) This is equivalent to saying that a person employed in the non-tradeable sector is indifferent between becoming unemployed and remain working in the non-tradeable sector.
Basically, this relation says that the expected pay-off from accepting a job in the non-tradeables sector (left hand side) is the same as the expected pay-off from waiting until a job in the tradeables sector falls free and remaining unemployed in the meantime (right-hand side).

For each region the model counts 12 equations and 12 unknowns, viz. \( L_s \), \( L_r \), \( L_p \), \( L_N \), \( x \), \( y \), \( U \), \( e \), \( w_N/p_N \), \( w_T/p_T \), \( w_T/w_N \) and \( I/p_N \). Eq. 7, which determines the terms of trade \( p_T^1/p_T^2 \) applies for both regions. Labour productivity \( h \) will be explained later on by two dynamic equations. For the moment we have 25 equations and 25 unknowns in total, so that the model can be solved. According to Walras’ Law one equation should be redundant, but we already left an equation (stating that total income is spent on consumption) out. The model is only solved for real variables. Real income has been denoted in terms of non-tradeables, but given the solution for all relative prices, real income in terms of tradeables can easily be derived.

3. The allocation of labour

The solution of the model is quite straightforward. After substituting eqs. 2 and 10 into eq. 13 we get

\[
U = \left[ \frac{\delta (A - b)}{1 - b} \right] L_T, \text{ where } A = \left[ \frac{a}{c (1 - \gamma)} \right]^{1/\gamma}.
\]

Note that \( A = w_T/w_N > 1 \) and by definition \( b < 1 \), so that \( U/L_T \) will rise if one of the parameters \( a \), \( b \) or \( \delta \) increases. Combining this result with the labour constraint, eq. 11, yields

\[
(A) \quad L_N = 1 - \left[ 1 + \frac{\delta (A - b)}{1 - b} \right] L_T.
\]

What this equation basically says is that a rise of employment in the high-tech sector and the accompanied increase in the number of unemployed people leaves less workers to be employed in the traditional sector. The second relation between \( L_N \) and \( L_T \) follows from the other equations of the model.
Note that $0 < \sigma < 1$, $\beta > 0$ and $\epsilon > 1$, so that $P > 0$. This equation shows that, for the circular flow to be in equilibrium, an increase in employment of the high-tech sector must be accompanied with an increase in employment of the traditional sector.

Equating (A) and (B) gives the solution of the model in terms of $L_T$. Note that in equilibrium the sectoral division of labour is fixed, i.e. independent of the development of labour productivity ($h$) over time. This will be explained later on.

The solution of the model can easily be shown in a picture, which decomposes total labour over employment in the non-tradeables sector, employment in the tradeables sector and unemployment (see figure 1). In the figure it holds that

$$\tan(\xi) = AP \text{ and } \tan(\eta) = 1 + \frac{\delta (A-b)}{1-b}. $$

In the figure we have also drawn the full-employment line, which describes all possible divisions of labour over sectors for $\delta = 0$. In this case there is no reason for people to remain unemployed as no new jobs will open up in the tradeable sector. If $\delta > 0$, however, there is unemployment as $\delta (A-b)/(1-b) > 0$. The level of unemployment is determined by confronting the solution of the model, i.e. the intersection of line $A$ and line $B$, with the full-employment line. Note that $L_T$ is at least equal to $nL_f$, which is trivial because no matter how much the high-tech sector produces, it must always incur its fixed cost.
The comparative-static analysis will focus on changes in the parameter $\sigma$ which describes preferences for tradeable versus non-tradeable goods, the parameter $b$ which is a measure for generosity of the unemployment benefit system and an exogenous change in labour-productivity in one region in the high-tech sector ($h$). The results are summarized in table 1, where we look at the effects for region 2. Besides (un)employment levels, we also consider the wage-ratio between sectors

$$\frac{w_T}{w_N} = \left[ \frac{a}{c(1-\gamma)} \right]^{\frac{1}{\gamma}}$$

the price-ratio between tradeables and non-tradeables

$$\frac{p_T}{p_N} = \frac{w_T}{w_N} \frac{1-\gamma}{\gamma} \frac{1}{a} \frac{1}{h},$$

and the price-ratio in the high-tech sector, i.e. the terms of trade

$$\frac{p_T^2}{p_T^1} = \left( \frac{x^1}{x^2} \right)^{\frac{1}{\varepsilon}} = \frac{w_T^2 e^1 h^1}{w_T^1 e^2 h^2}.$$ 

The wage ratio is known from eq. 10. The ratio of prices of high-tech and traditional goods (i.e. the intraregional terms of trade) follows from combination of eqs. 2 and 8 and the optimal
efficiency of high-tech workers. The *(inter)*regional terms of trade is explained by eq. 7. This equals the price-ratio in the high-tech sector, obtained by applying eq. 8 to each region separately and then dividing.

It is important to note that preferences *(i.e. the parameter σ)* do not show up (directly) in these ratios. Relative prices are determined by relative wages (which in turn are fixed by the parameters of the efficiency wage relation) and the development of relative labour productivity in course of time. The productivity ratio within a region, *i.e. between traditional and high-tech goods*, is $1/h$, whereas the productivity ratio in the high-tech sector, *i.e. between the backward region and the leader region*, is $h'/h'$. The latter ratio will further be denoted by the small letter $d$.

Another important characteristic of the model follows from the assumption that the regions are symmetric with regard to the parameters of the efficiency-wage relation (and the strength of competition captured by the parameter $ε$), so that relative nominal wages ($w_T/w_N$) and the effort levels are the same in both regions. This implies that

$$\frac{w_N^2}{w_N^1} = \frac{w_T^2}{w_T^1} = \frac{P_N^2}{P_N^1} = d \frac{P_T^2}{P_T^1}.$$  

The interregional wage ratios equal each other and (as $ε > 1$) these ratios will rise if the productivity ratio $d$ increases. These ratios can be rewritten as

$$d = \frac{P_N^2}{P_T^1} \cdot \frac{P_T^2}{P_N^1} = \frac{w_T^2}{w_T^1} \cdot \frac{P_T^2}{P_T^1},$$

showing that relative productivity levels are reflected in both the ratio of the *(intraregional)* terms of trade and the relative real wages in the high-tech sector.

Now, turning to the comparative statics, we see that a world-wide shift in preferences towards high-tech goods, *i.e. a rise in the fraction of nominal income spent on tradeables (σ)* rotates line B in figure 1 to the right, so that production shifts away from traditional towards high-tech goods. This raises employment in the tradeables sector, whereas employment in the non-tradeables sector decreases. Unemployment also goes up, which is due to the fact that the number of jobs falling free in the tradeables sector is rising, so that waiting for a job in the tradeables sector becomes more attractive than accepting a job in the non-tradeables sector. Note that in the opposite case, *i.e. a world-wide shift in preferences towards non-tradeables*, employment shifts away from the high-tech sector to the traditional sector, whereas unemployment falls. These results of course hold for both countries as the shift in preferences is assumed to occur in both countries.
Next we look at the effects of an increase in the real unemployment benefit ($b$) in region 2. In the figure (see figure 2) line A turns clockwise around its intercept with the $L_N$-axis. Higher unemployment benefits make people more willing to wait until a job in the high-tech sector falls free. This reduces employment in the non-tradeables sector, so that total income diminishes. Accordingly, demand decreases. As a result, unemployment increases. The share of employed workers who are employed in the high-tech sector increases as well. So, increasing welfare benefits looks like it is making a society more "high-tech" at first blush. However, labour becomes more expensive relative to labour in the rest of the world. The (interregional) terms of trade improves so that output and employment in the high-tech sector decrease. Thus a more generous unemployment benefit results in higher unemployment and reduced employment in both sectors.

\[\text{Table 1 Comparative static results (for region 2)}^{11}\]

<table>
<thead>
<tr>
<th>Increase of</th>
<th>Effect on</th>
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<tbody>
<tr>
<td>$U$</td>
<td>$L_T$</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>+</td>
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<tr>
<td>$b^2$</td>
<td>+</td>
</tr>
<tr>
<td>$d$</td>
<td>0</td>
</tr>
</tbody>
</table>

$^{11}$ The increase of $\sigma$ occurs in both regions, whereas the increase of $d$ is due to an exogenous increase of $h^2$. 
Finally we consider an (exogenous) increase of labour productivity in region 2, which implies a rise of the productivity ratio in the high-tech sector \((d)\). The sectoral structure of employment does not change, because there is no incentive to change the demand for labour in the tradeables sector if the productivity ratio increases. (This is due to pricing behaviour of high-tech firms (cf. eq. 8), which makes unit real labour costs insensitive for productivity changes.) The increase in productivity is followed by a rise of high-tech real wages relative to high-tech real wages in the other region. The terms of trade deteriorates, so that output of the tradeables sector in region 2 increases. Thus, in general, the model predicts that output of the high-tech sector in the backward region is growing faster than output of the high-tech sector in the leader region, if the productivity ratio increases. The dynamics behind the process of catching-up will be described in the next section.

4. Relative Convergence

The technology-gap approach to economic growth conceives technological differences as the primary cause for differences in productivity levels across regions. Backward economies may catch-up by learning from the experience in the leader region. As Gerschenkron (1952) has pointed out, catching-up is not conceived as being automatic, but requires adequate preconditions to imitate
the technological leader, which often contains an element of innovation in its own. A certain level of R&D, for instance, is a necessary condition for successful imitation (cf. Fagerberg 1994). Barro and Sala-i-Martin (1995) describe this leader-follower mechanism as follows (p.281):

"The diffusion of technology from leading economies to followers involves costs of imitation and adaptation. We assume that these costs are lower than those for innovation when very little has been copied, but rise as the pool of uncopied ideas gets smaller. This cost structure implies a form of diminishing returns to imitation and thereby tends to generate a pattern of convergence. Follower countries tend to grow faster the greater the gap from the leaders. This process is, however, conditional, in that the growth rate depends, for a given technological gap, on government policies and other variables that influence the rate of return to imitation in a follower economy."

To model this we follow Krugman (1990, Chapter 7) and Van de Klundert and Smulders (1994) and assume that the dynamics of labour productivity in the two regions are given by

\[ \frac{\dot{h}_1}{h_1} = \xi L_r^1, \quad \text{and} \]

\[ \frac{\dot{h}_2}{h_2} = \frac{\xi L_r^2}{d^a}, \quad \text{with } \alpha > 0. \]

Here \( \xi(>0) \) stands for an (exogenous) productivity parameter in the R&D sector and \( L_r \) is the number of workers employed in the R&D sector. (As total labour \( L \) is normalized at one, we can call \( L_r \) the R&D employment-ratio.) High-tech firms improve their labour productivity by investing in R&D. In addition, firms in the backward region (region 2) can also learn from firms in the other region (region 1), for example by transferring or copying technologies from the leader firms, which don’t have to be developed by the followers on their own. The parameter \( \alpha \) measures the strength of these (one-sided) spill-overs in knowledge between regions. This parameter is highly institutionally determined and contains for instance investments in physical infrastructure, education, the quality of the legal system in the backward region and the preparedness or capability (in terms of e.g. technological congruence) of poor countries to adapt new technologies.

Subtracting eq. 14 from eq. 15 yields

This equation shows that the productivity ratio may increase, decrease or remain constant,
depending on the R&D employment-ratios, the strength of spill-overs and the initial productivity ratio. Thus the model can explain that an initial leading region becomes a backward region (compare this with the leapfrogging-idea of Brezis, Krugman and Tsiddon 1991), that regions diverge or that there is tendency for regions neither to converge nor to diverge. In the latter case (a constant productivity ratio) the wealth of nations measured in absolute productivity levels still increases, because high-tech productivity is (steadily) growing. All these cases are relevant from an empirical point of view, as has been widely documented in literature (e.g. Abramovitz 1989, Barro 1991, Baumol 1986, Brander 1992, Dowrick 1992, Maddison 1991, Nelson and Wright 1992, Parente and Prescott 1993 and Barro and Sala-i-Martin 1995).

The process of catching-up will come to an end if $\dot{d}=0$, which comes down to

$$\frac{d}{d} = \frac{\bar{h}^2}{h^2} \cdot \frac{\bar{h}^1}{h^1} = \frac{L_r^2}{d^a - L_r^1}.$$ 

Here the R&D employment-ratios have been rewritten in terms of $L_T$ and $nL_f$ (using eqs. 4 and 12). This result shows that persisting differences in productivity levels between regions can be explained by persisting differences in employment shares of the tradeables sectors. As we have seen in the previous section, interregional differences in high-tech employment shares (and in thus R&D employment-ratios) crucially depend on differences in social welfare benefits. Higher welfare benefits decrease the fraction of workers in the high-tech sector relative to the total labour force, so that there is less R&D.

The dynamic evolution of the two economies in the model can easily be understood when looking at the formula for $d'$. The benchmark is the case of equal R&D employment-ratios in both regions, which shows up in full convergence ($d'=1$). In this case, in the long run, both regions end up with an equal level of high-tech labour productivity. The backward region does not fully catch-up with the leader region, which can be called relative convergence ($d'<1$), if the number of high-tech workers (relative to total labour) in this region is smaller than in the leader region. In case of leap-frogging the initial advantage of a region of being backward changes into the disadvantage of becoming the leader after some time ($d'>1$). Leap-frogging will take place if the backward region has a larger tradeables sector than the leader region. Thus the model predicts that interregional differences in R&D employment-ratios (which depend on the allocation of labour over the various sectors of the economy) determine interregional differences in the pace of economic growth and
relative productivity levels. Backward regions with a relatively large tradeables sector grow faster than regions with a comparable productivity level but a smaller tradeables sector.

The predictions of the model fit in rather well into recent econometric evidence. First, there is the prediction that the sectoral structure of an economy is of crucial importance for understanding variations in economic growth, both over time and between countries (cf. Dollar and Wolff 1993). As documented by Maddison (1991) for a number of advanced countries since 1870 the share of sectors in the total economy shows a great variation between countries and over time. Maddison decomposes total employment into three sectors, viz. agriculture, industry and services. The evidence, starting at the second industrial revolution in 1870, reveals that the process of economic growth has been accompanied by massive changes in economic structure, whose long-run pattern has been similar in all the advanced countries (cf. Chandler 1990). The agricultural employment share strongly declined, whereas the service share climbed from one-quarter to approximately two-third. In contrast, industry shows a bell-shaped pattern of relative industrialization and de-industrialization, which has affected all of the countries, though its timing has varied. In 1950, most country industry shares were higher than in the United States, but in the eighties the variation between them has become much smaller\(^1\). This structural change has been accompanied by increasing productivity ratios relative to the United States in the fifties and sixties, a process which strongly slowed down afterwards.

One of the differences between Europe and the United States that might explain this difference in performance can be related to the system of unemployment benefits or, more generally, to the social welfare benefit system. It is widely agreed upon (e.g. Layard et al. 1991 and OECD 1994) that the benefit systems in most European countries are more or less open ended and that benefits are relatively easy to obtain. In our model the benefit system is captured by the parameter \( b \). The result of a generous benefit system is a large fraction of the population being unemployed and only few people working in the R&D-sector. This situation hampers economic growth during the process of catching-up and leads to a steady state with a lasting (high-tech) productivity gap between the follower region (the Europe Union) and the leader region (the United States). At the same time, the country with the generous benefit system looks relatively industrialized, looking at the ratio of the number of employed people working in the tradeables and the non-tradeables sector.

The model can also account for the empirically observed slowdown in economic growth in virtually all OECD-countries since the middle of the seventies (e.g. Maddison 1991, McCombie

\(^1\) A recent OECD study (1994) shows that in 1991 the employment share of high-technology manufacturing in European countries was lower than the U.S. share.
What happened in that period was an increase in the share of labour employed in the service sector, largely at the expense of labour in the industrial sector. In our model this can be conceived as a decrease in the parameter $\sigma$. This factor in explaining the growth slowdown has recently been emphasized by Cornwall and Cornwall (1994). They essentially argue that demand factors and distributional shifts of both output and labour should be taken into account when explaining overall macroeconomic growth rates. In their reasoning, higher levels of income per capita are associated with a higher share of the (low productivity) service sector and as this sector increases in size (relatively), the macroeconomic growth rate is depressed. A similar conclusion is drawn by A. Young (1994) on the basis of a growth accounting study for the Asian NIC’s. For those countries, intersectoral reallocations of labour appear to be an important factor in explaining the growth performance of these countries.

5. Conclusion

The model developed in this paper suggests various (hypothetical) reasons that can be given to explain why European countries were catching-up with the United States in the fifties and the sixties and staggering behind afterwards. The model predicts that backwardness and high employment shares of manufacturing were the driving forces behind European economic growth in the fifties and sixties. Presumably the process of catching-up has been reinforced by a world-wide shift in preferences towards high-tech goods, increasing the tradeables employment shares. Afterwards an opposite shift in preferences has occurred, first in the United States (which explains the early US-productivity slowdown) and later in the countries of the European Union. This global shift in preferences towards non-tradeable goods (services) can explain the observed global slowdown in productivity growth. In European countries, a generous unemployment benefit system emerged in the late sixties. This system can be characterized by relatively open-ended provision of benefits and easy access to the system. This change in system lead to an increase in unemployment in the European countries and reduced employment in the tradeables sector. The accompanied adverse effect on the number of people working in Research can explain the subsequent lagging behind (relative convergence) of Europe.
Appendix A. Consumer Behaviour

Each consumer in the world is confronted with two problems. First he has to decide how to divide his total income between high tech goods on the one hand and traditional goods on the other hand. Second, he has to decide how to divide the money he wants to spent on the high-tech goods among the \(2n\) varieties he is confronted with. The optimization problem the (representative) consumer faces is formulated as follows. Firstly, he has to decide how to divide his income (equation 5 in the text) between high-tech and non-tradeable goods. He does so by maximizing the following composite-good-index (\(\Gamma\))

\[
(C1) \quad \Gamma = X^\sigma y^{1-\sigma}.
\]

Here, \(X\) represents the bundle of all varieties of the high-tech good (\(2n\)) that are available in the world. It is defined as

\[
(C2) \quad X = \left[ \frac{1}{2n} \sum_{i=1}^{2n} c_i^{(e-1)/e} \right]^{1/(e-1)},
\]

where \(c_i\) is the consumed quantity of variety \(i\). We can solve this maximization problem with a two-step procedure where the constraints for this maximization problem are, respectively

\[
(C3) \quad X P_X + y P_N = I,
\]

\[
(C4) \quad \sum_{i=1}^{2n} c_i P_N = X P_X.
\]

Maximizing (C1) subject to (C3) yields the following Lagrangian

\[
L = X^\sigma y^{1-\sigma} - \lambda (X P_X + y P_N - I),
\]

with the corresponding following First Order Conditions

\[
\frac{\partial L}{\partial X} = \sigma X^{\sigma-1} y^{1-\sigma} - \lambda P_X = 0
\]

and
Eliminating $\lambda$ results in

$$\frac{\partial L}{\partial y} = (1-\sigma) X^{\sigma} y^{\sigma} - \lambda p_N = 0.$$ 

This equation tells us that a fixed fraction $(1-\sigma)$ of total consumption expenditure is spent on non-tradeable goods and a fixed fraction $(\sigma)$ is spent on high-tech goods (see equation 6 in the text).

Next, maximizing (C2) subject to (C4) gives the following Lagrangian

$$L = \left[ \sum_{i=1}^{2n} c_i^{\frac{\sigma}{\sigma+1-x}} \right]^{\frac{\sigma+1-x}{\varepsilon}} - \lambda \left[ \sum_{i=1}^{2n} c_i p_{\pi} - P_X X \right].$$

The First Order Condition to this problem for variety $i$ is

$$\frac{\partial L}{\partial c_i} = X \left( \sum_{i=1}^{2n} c_i^{\frac{(\sigma-1)/\varepsilon}{\sigma+1-x}} \right)^{-1} c_i^{\frac{1}{\varepsilon}} - \lambda p_{\pi} = 0.$$ 

For variety $l$ we can derive

$$\frac{\partial L}{\partial c_i} = X \left( \sum_{i=1}^{2n} c_i^{\frac{(\sigma-1)/\varepsilon}{\sigma+1-x}} \right)^{-1} c_i^{\frac{1}{\varepsilon}} - \lambda p_{\pi} = 0.$$ 

Eliminating $\lambda$ gives

$$c_i = c_i \left( \frac{p_{\pi}}{p_{\pi}} \right)^{-\varepsilon}.$$ 

Substituting this expression into (C2) results in

$$X = \left[ \sum_{i=1}^{2n} c_i \left( \frac{p_{\pi}}{p_{\pi}} \right)^{\frac{1-\varepsilon}{\sigma}} \right] = c_i p_{\pi} \left[ \sum_{i=1}^{2n} p_{\pi}^{1-\varepsilon} \right]^{\frac{\sigma+1-x}{\sigma}}.$$ 

Solving $c_i$ from this equation finally results in the demand for a single variety (in a single country):
or

\[ c_i = X \left( \frac{p_{n_1}}{P_X} \right)^{-\varepsilon}, \]

where

\[ P_X = \left( \sum_{i=1}^{2n} p_{n_i}^{1-\varepsilon} \right)^{-\frac{1}{1-\varepsilon}}, \]

which gives the demand for a single variety of the high-tech good.

If we now invoke the symmetry assumption for goods produced within a country, we can derive that

\[ \frac{c_1}{c_2} = \left( \frac{p_1}{p_2} \right)^{-\varepsilon} \quad \text{and} \quad \frac{c_1^2}{c_2^2} = \left( \frac{p_1}{p_2} \right)^{-\varepsilon}, \]

where \( c_i \) denotes the quantity consumed in country \( j \) of a single variety from country \( i \), where \( j \) and \( i \) equal 1 or 2. Goods-market equilibrium requires that

\[ c_1^1 + c_1^2 = x^1 \quad \text{and} \quad c_2^1 + c_2^2 = x^2. \]

Combining this with the previous relations yields

\[ \frac{x^1}{x^2} = \left( \frac{p_1}{p_2} \right)^{-\varepsilon}. \]

This is equation (7) in the text.
Appendix B. Producer Behaviour

In this appendix we will describe the behaviour of the firm that operates in the high tech sector. Each firm maximizes its operating profits by choosing \( w_{i1} \) and \( L_{i1} \) optimally. Formally, this problem can be written as

\[
\max_{L_{i1}, w_{i1}} \Pi = p_{i1} e_i \left( \frac{w_{i1}}{w_{N}} \right) h_i L_{i1} - L_{i1} w_{i1}.
\]

subject to the efficiency wage relation (9) and the demand function for the variety the firm produces (see Appendix A). The first order conditions for this optimization problem are

\[
\frac{\partial \Pi}{\partial L_{i1}} = \left( \frac{\epsilon - 1}{\epsilon} \right) p_{i1} h_i e_i - w_{i1} = 0, \quad \text{and}
\]

\[
\frac{\partial \Pi}{\partial w_{i1}} = p_{i1} h_i L_{i1} \frac{\partial e_i}{\partial w_{i1}} \left( \frac{\epsilon - 1}{\epsilon} \right) - L_{i1} = 0.
\]

From (A) we can derive the mark-up relation

\[
p_{i1} = \frac{\epsilon}{\epsilon - 1} \frac{w_{i1}}{h_i e_i}.
\]

Combining equation (B) with (A) yields the familiar Solow-condition

\[
\zeta = \frac{\partial e_i}{\partial w_{i1}} \frac{w_{i1}}{e_i} = 1.
\]

This Solow-condition is depicted in the figure. If we now use the Akerlof-specification as has been specified in the text (eq. 9) for the efficiency wage relation (and the symmetry assumption) we arrive at

\[
\frac{w_{T}}{w_{N}} = \left[ \frac{a}{c (1 - \gamma)} \right]^{\frac{1}{\gamma}}.
\]
Appendix C.

In this appendix we will derive the solution of the model in case we include the unemployment rate as an argument in the efficiency wage relation. The reasoning behind this introduction is that a higher unemployment rate makes workers in the high-wage sector more scared of becoming unemployed and consequently makes it possible for an employer to 'extract' a certain effort at a lower relative wage (e.g. Bulow and Summers 1986, Van de Klundert 1990).

Looking at the basic model, the effort-function (9) changes into

\[ e = -a + c \left( \frac{w_T}{w_N} \right)^{\gamma_1} u^{\gamma_2}, \]  

where \( u = \frac{U}{L_T} \) and \( 0 < \gamma_1 < 1, \gamma_2 > 0 \).

This yields the following Solow-condition (see Appendix A for the way this can be derived)

\[ \left( \frac{w_T}{w_N} \right)^{\gamma_1} - \frac{a}{c (1-\gamma_1) u^{\gamma_2}}. \]

According to this condition, the profit maximizing firm will set a lower wage relative to the wage in the tradeables sector in case of high unemployment. This is because in that case workers already supply large effort, reducing the incentive for an employer to increase effort even further by setting a high relative wage. The Solow-condition can again be combined with the mobility condition (13), yielding a relation between \( L_T \) and \( U \). (Here we have assumed for simplicity that the
unemployment benefit equals zero but this assumption does not change the results qualitatively.)

\[
U = \delta^{\frac{\gamma_1}{(\gamma_1 + \gamma_2)}} \left( \frac{a}{c(1-\gamma_1)} \right)^{\frac{1}{(\gamma_1 + \gamma_2)}} L_T.
\]

The model can now be solved along the lines set out in section 3. Again this results in two relations between \(L_N\) and \(L_T\)

\[
1 = L_N + \left( \delta^{\frac{\gamma_1}{(\gamma_1 + \gamma_2)}} A' + 1 \right) L_T, \quad \text{and}
\]

\[
L_N = P A' \delta^{\frac{\gamma_2}{(\gamma_1 + \gamma_2)}} (L_T - nL), \quad \text{where} \quad A' = \left[ \frac{a}{c(1-\gamma_1)} \right]^{\frac{1}{(\gamma_1 + \gamma_2)}}.
\]

The solution of the model is shown graphically in figure 1 of section 3. In this figure we now have

\[
\tan(\xi) = A' P \delta^{\frac{-\gamma_2}{(\gamma_1 + \gamma_2)}} \quad \text{and} \quad \tan(\eta) = 1 + A' \delta^{\frac{\gamma_1}{(\gamma_1 + \gamma_2)}}.
\]

Compared with the basic model in section 3, the most important distinction is that the slope of line (B) is now also dependent on the parameter \(\delta\). The reason for this is that the unemployment rate is a variable that the firm now takes into account when determining the relative wage. This can be seen in the Solow-condition (equation (10')). Consequently, the relative wage in this model is a function of the labour-turnover rate (contrary to the basic model). The main change in comparative static results therefore occurs in case of a change in the labour turnover rate, \(\delta\). In the basic model it can be concluded that an increase in the labour-turnover rate decreases employment in both sectors and increases unemployment. In the model with unemployment entering as an argument in the effort function we get that unemployment increases and employment in the non-tradeables sector decreases. With respect to employment in the tradeables sector the effect is ambiguous. In the figure this is clear as an increase in \(\delta\) results in a downward shift of line (B) and line (A) becoming steeper. To be more precise, an increase in employment in the tradeables sector can occur if for example \(\gamma_2\) is relatively large, that is if workers react strongly by increasing their effort in case of an increase in unemployment. In the figure a large value of \(\gamma_2\) results in a strong downward shift of line B after an increase in \(\delta\), making possible an increase in \(L_T\).
References


