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Convergence in the global economy. A broad historical viewpoint

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Abstract

This paper considers the issue of converging or diverging growth paths in a long-run perspective. In particular, available data are explored in order to investigate whether or not the convergence trend observed since the ending of the Second World War also holds for earlier time periods. The data are used to illustrate some theoretical insights on the question as to what determines convergence or divergence trends. A brief historical interpretation of the results is presented.

Keywords: Convergence; Economic growth; Economic history

JEL classification: O57; O33

1. Introduction

The issue of what are the sources of long-run growth is an important one, as it has a crucial impact on man's well-being. Long-run growth has a clear relative dimension: whether a particular growth regime is characterized as 'high-growth' or 'low-growth' depends both on the history of the country in question, and on the growth pattern observed in other countries. While this in itself is clearly a trivial statement, it does highlight the importance of one aspect of growth that has caught much attention in recent literature: the issue of converging or diverging growth paths.

It is by now fairly well established that at least parts of the world have been converging in terms of per capita income since the ending of the Second World War (see for example Maddison, 1991a; Abramovitz, 1992). This statement, however, contains two important reservations: it only holds for *parts* of the world, and for the

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postwar period. The aim of the current paper is twofold. First, it aims to explore some of the available data in order to investigate whether or not the convergence trend also holds for earlier time periods. Second, the data will be used to illustrate some theoretical insights into the question of what determines these convergence or divergence trends.

The approach used is mainly quantitative, with much emphasis on empirical results, and only a brief historical and institutional interpretation will be offered in the last section. It will therefore necessarily be disappointing for scholars who are used to dealing with economic problems in the broad historical or institutional sense. However, it is hoped that this paper will be able to isolate some interesting views on the issue of long-run convergence and divergence in growth, which can then be subjected to further historical research.

The rest of this paper is organized as follows. Section 2 will present and apply a method outlining the key diverging or converging trends in long-run growth. The method will be applied to several groups of countries, including the group that now forms the OECD, and Latin America. A first attempt (in the form of variance decomposition) to isolate some of the factors explaining the observed trends will also be presented. Section 3 will present some further factors explaining the patterns observed in Section 2. A discussion on the role of some of the most important factors will be given, focusing also on the ways in which these factors can (or cannot) be measured. Some statistical analyses will be applied to test the significance of these factors in various time periods. This statistical analysis cannot, however, provide a complete explanation for the convergence and divergence trends observed in Section 2. Therefore, Section 4 will provide a brief historical perspective, trying to interpret the results from the previous section. Section 5 will summarize the argument. The sources for the data used are outlined in an appendix.

2. Convergence and divergence in per capita income

In order to measure convergence or divergence trends in per capita income, a test proposed by Ben-David (1991) is applied. This test assumes the following relation between per capita income relative to some group average in different periods t and $t-1$.

$$\ln Y_t = \Psi \ln Y_{t-1} \tag{1}$$

Y is defined as $(Q/P)/(\Sigma Q/\Sigma P)$, and Q denotes GDP (in 1980 US$ purchasing power parities), P denotes population (in thousands), and Σ indicates the sum in some group of countries. The assumed relationship allows for converging (if $\Psi < 1$), diverging (if $\Psi > 1$), or stable (if $\Psi = 1$) differences in per capita income.

In order to estimate the value of Ψ for different periods of time, the following procedure is used. For each 'case' (defined as a combination of countries, years, and reference group), a pooled cross-country time series dataset is set up. In turn, Ψ is estimated by OLS for the subset for periods $t-2$ to $t+2$. This means that the number of observations in each OLS estimate is five times the number of countries

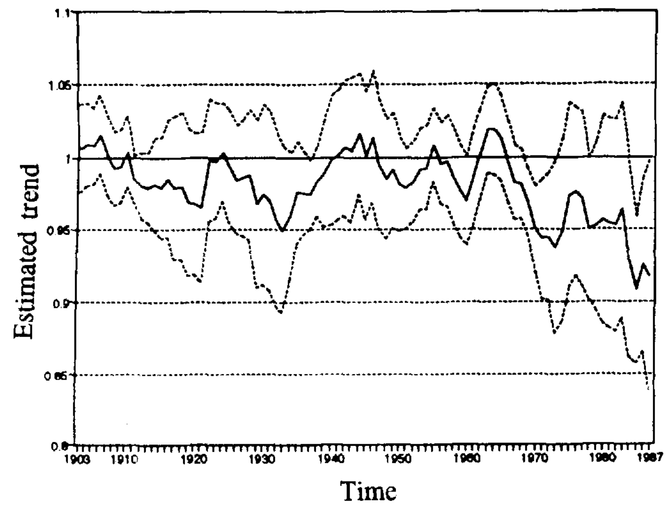

Fig. 1. Local convergence and divergence in Latin America, 20th Century. ——— Coefficient ------ ±2 SE.

in the analysis. The resulting estimate of Ψ is attributed to t, and plotted in a graph together with the estimates for other periods. The estimated coefficient plus/minus two times the estimated standard error is also plotted, so that a (reasonably wide) confidence interval is established. Whenever this confidence interval is completely below (above) unity, convergence (divergence) is said to be observed. Whenever the confidence interval embraces the unit line, no particular trend is found.

Convergence might be local or global. For example, if the average distance between Latin America and the OECD countries is getting smaller, one can speak of a global convergence trend. However, if Latin American countries are converging towards some Latin American mean, local convergence is taking place.

There are basically two sets of countries for which long enough time series are available in order to apply the above procedure. These are the six Latin American countries in Hofman (1992) (Argentina, Brazil, Chile, Colombia, Mexico, Venezuela) and the 16 present OECD countries[1] in Maddision (1991a) (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway. Sweden, Switzerland, United Kingdom, United States). These data are used to estimate convergence or divergence trends for three different groups: Latin America, Europe (12 countries in Maddison), and the OECD.

For Latin America, two cases are examined: local convergence towards the mean of the six countries, and global convergence towards the mean of the 16 other countries. The results of this analysis are in Figs. 1 and 2. For the local case, a mixed pattern is observed. In most cases, the solid line is below unity, indicating convergence. However, there are only a few isolated years for which this trend is

[1] The term 'OECD' is used in the sense of describing these 16 countries, rather than the present organization.

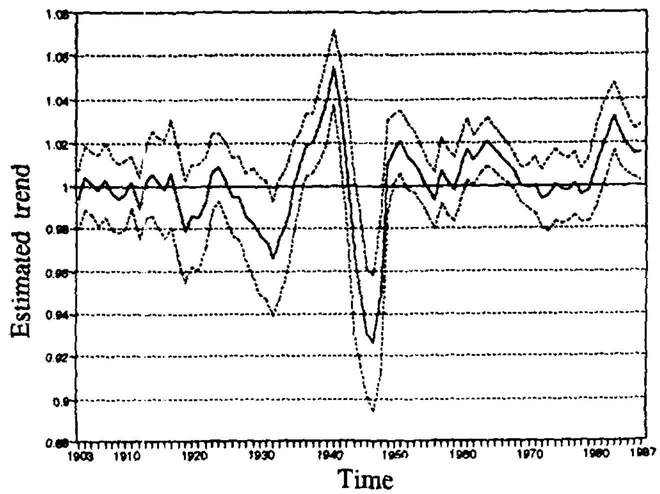

Fig. 2. Global convergence and divergence in Latin America, 20th Century. ——— Coefficient --------- ±2 SE.

significant. This indicates that although there is a weak trend for local convergence in Latin America, the growth behaviour of the individual countries is so erratic that the overall trend is insignificant.

For the case of global convergence, defined as convergence towards the mean of the OECD countries, a different picture is established. Before the 1940s, the trend was mainly flat, with occasional periods of weak convergence. The 1940s show large swings, but from the 1950s onwards, there are occasional periods of significant divergence, while the overall trend is one of insignificant divergence. The contrast is sharpest in the most recent period, with a local convergence trend, and a global divergence trend.

For Europe, the picture is quite different. Figs 3 and 4 show the local and global convergence and divergence patterns, respectively. In the local case, convergence prevails over the total period. However, significant convergence is only found in the late 1930s and the postwar period (with the exception of a brief period in the early 1960s). A similar picture is found for the case of global convergence, except that in this case the 1930s show a somewhat more significant convergence trend. In both cases, convergence seems to slow down in the 1970s and 1980s.

Fig. 5 gives the results for the 16 OECD countries. This is the case where postwar convergence is strongest, with significant convergence up to the 1970s. Also the 1930s show weak convergence. The slowdown of convergence in the 1970s and 1980s is also present in this case. Finally, Fig. 6 gives the trend for those countries for which longer time series (from 1860s onwards) are available. For the 20th Century, the trend for these countries is basically the same as the one for the OECD as a whole. The 40 years in the 19th Century show no significant trend, with the exception of a short period in the 1860s, where divergence is taking place.

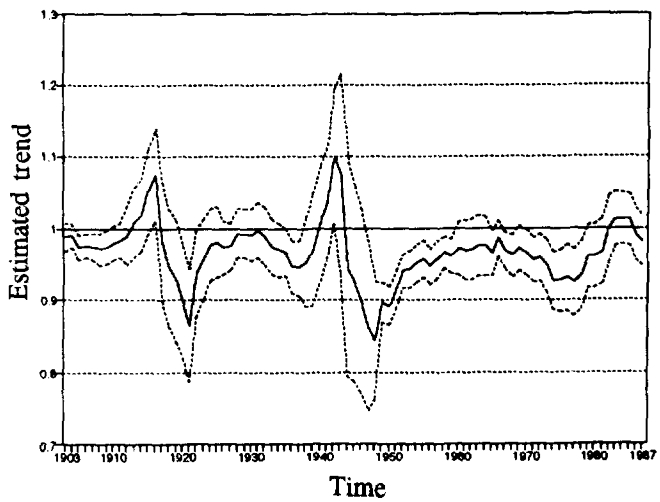

Fig. 3. Local convergence and divergence in Europe, 20th Century. ——— Coefficient -------- ±2 SE.

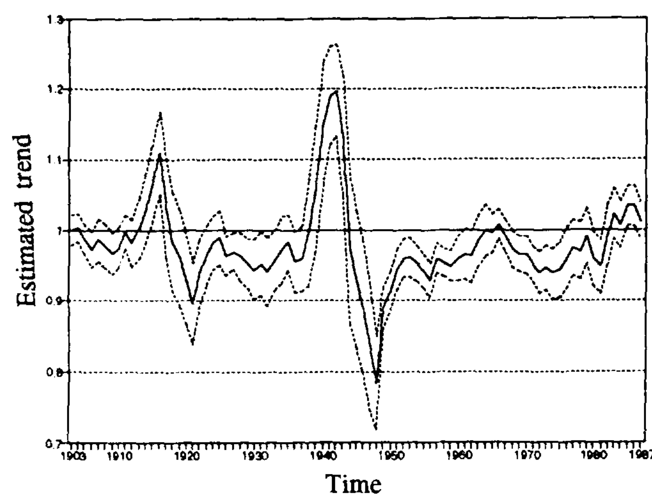

Fig. 4. Global convergence and divergence in Europe, 20th Century. ——— Coefficient -------- ±2 SE.

The conclusion from these pictures is that convergence is strongest in the total sample of OECD countries in the postwar period. The Latin American countries do not seem to take part in the convergence process at all. However, contrary to what other authors have stressed (for example, Abramovitz, 1992), convergence is present in the immediate pre-war period (i.e. the 1930s) too. This puts the argument about the influence of the war itself in a different light. For example, Dollar and Wolff (1993, pp. 4–5) argue:

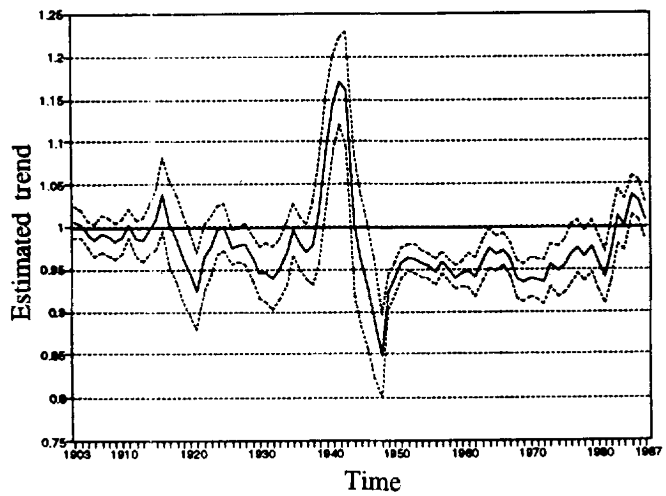

Fig. 5. Convergence and divergence in 16 OECD countries, 20th Century. ——— Coefficient -------- ±SE.

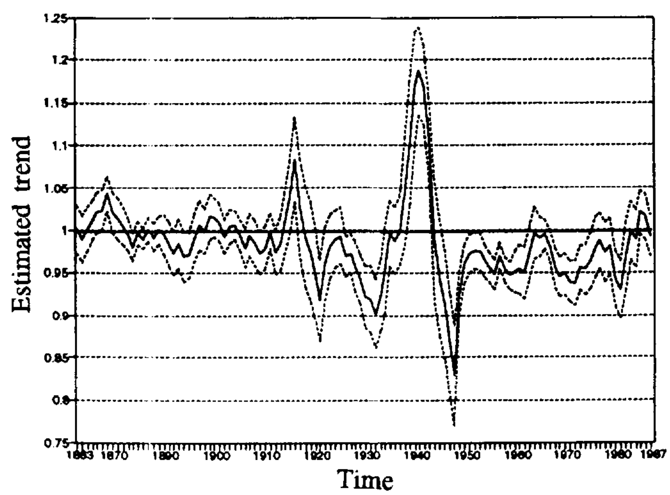

Fig. 6. Convergence and divergence in 11 OECD countries, 20th Century. ——— Coefficient -------- ±2 SE.

"The United States had a large labor productivity advantage over all other countries as the world emerged from World War II. This advantage was partly the result of the destruction of the capital stock in Europe and Japan during the war. In addition, as part of the war effort, U.S. industries had pioneered a wide range of new technologies in chemicals, aerospace, electronics, and other sectors. The rapid convergence of the other countries' productivity on the U.S. level in the 1950s partly reflects postwar reconstruction of the capital stock. Reconstruction had largely been completed by the end of the 1950s; however, it can be seen that convergence on the United States continued, though at a less rapid pace."

The results here seem to underline the last conclusion by Dollar and Wolff, stressing it, however, from a different angle: convergence had already set in before the war, and received a temporary stimulus through the effects mentioned by Dollar and Wolff, but after that continued at its 'natural' pace.

What are the factors leading to convergence or divergence, and why is their influence so different in different periods? A first attempt to establish some directions for the possible answers to these questions can be found by applying variance decomposition methods to the underlying data on per capita GDP in the above figures. In order to do so, one may start from the observation that the current dataset has two dimensions: countries and time. Then, assume that the growth rate of per capita income (denoted by g) can be described by the following function:

$$g(t, c) = \mu + \alpha(t) + \beta(c) + \gamma(t, c) \tag{2}$$

The three functions α, β, γ denote effects related to time (t), country (c) and an interaction between t and c, respectively. It is assumed that they have mean zero and variances σ_α, σ_β and σ_γ, respectively. This implies that μ is the average growth rate. The rest of the analysis in this section will attempt to give an explanation of the variance of the observed growth rates, by decomposing this variance into the three effects related to time, $\alpha(t)$, country, $\beta(t)$, and the interaction term, $\gamma(t, c)$. The technique applied to do this is described in Searle (1971), and was applied to the case of Chinese economic growth by Wang and Mody (1993).

First, assume that the covariances between the different effects determining g are zero. Then, the variance of g can be found as follows:

$$\sigma(g) = \sigma_\alpha + \sigma_\beta + \sigma_\gamma \tag{3}$$

Thus, the contribution of each component to the total variance of growth rates can be found by estimating the variances on the rhs of this equation. The approach to do this is to calculate a number of sums of squares, the expected value of which can be expressed as a known function of the variances to be estimated. These variances can then be found by solving the related equations, substituting the expected values of the sums of squares by the observed values.

More specifically, calculate the following sums of squares:

$$T_0 = \sum_{t=1}^{n_t} \sum_{c=1}^{n_c} g(t, c)^2,\ E(T_0) = n_c n_t(\mu^2 + \sigma_\alpha + \sigma_\beta + \sigma_\gamma) \tag{4}$$

$$T_1 = \frac{\left(\sum_{t=1}^{n_t} \sum_{c=1}^{n_c} g(t, c)\right)^2}{n_t n_c},\ E(T_1) = n_t n_c \mu^2 + n_c \sigma_\alpha + n_t \sigma_\beta + \sigma_\gamma \tag{5}$$

$$T_2 = \frac{\sum_{t=1}^{n_t} \left(\sum_{c=1}^{n_c} g(t, c)\right)^2}{n_c},\ E(T_2) = n_c n_t \mu^2 + n_t n_c \sigma_\alpha + n_t \sigma_\beta + n_t \sigma_\gamma \tag{6}$$

Table 1
The results from the variance decomposition analysis.

Effect	All countries (1900–1988) %	13 OECD countries (1870–1988) %	16 OECD countries (1900–1988) %	6 Latin American countries (1900–1988) %
Time	5	16	18	14
Country	2	0	5	1
Interaction	93	84	77	85

$$T_3 = \frac{\sum_{c=1}^{n_c}\left(\sum_{t=1}^{n_t} g(t,c)\right)^2}{n_t}, \; E(T_3) = n_t n_c \mu^2 + n_c\sigma_\alpha + n_t n_c \sigma_\beta + n_c\sigma_\gamma \tag{7}$$

The expected values of these expressions (denoted by E) can be confronted with the observed values in the sample, after which the values for the variances (and μ) can be solved for. The expressions that result from this procedure are the following.

$$\sigma_\alpha = -\frac{T_0 + T_1 n_c - T_2 n_c - T_3}{n_c(1 - n_c - n_t + n_c n_t)} \tag{8}$$

$$\sigma_\beta = -\frac{T_0 + T_1 n_t - T_2 - T_3 n_t}{n_t(1 - n_c - n_t + n_c n_t)} \tag{9}$$

$$\sigma_\gamma = \frac{T_0 + T_1 - T_2 - T_3}{1 - n_c - n_t + n_c n_t} \tag{10}$$

Table 1 shows the results from the analysis for four different groups of countries. In all cases, most of the variance (from 75% to more than 90%) is explained by the interaction between the factors time and country. The factor time also explains a substantial portion, while the country-specific factor explains little. This means that in this sample, growth of per capita income is not specifically strong in certain countries nor certain time periods. Instead, it is certain countries which grow fast (or slow) in certain periods. Moreover, there are no big differences between OECD and Latin American countries. However, if the two are grouped together, the impact of the time factor alone diminishes, while the variance component explained by the interaction term goes up. This indicates the differences in growth performance between these two groups.

The conclusion from this is that relatively high growth does not seem to be a persistent phenomenon in this sample. If one is going to try to explain growth, both time- and country-specific factors are important, but they should not be entered into the analysis in a form which does not allow any interaction between the two. This conclusion will be the starting point for a more elaborate (regression) analysis in the next section.

3. Suggested explanatory factors

Economic growth is a complex phenomenon. This paper can only touch upon some of the sources of this process, which as a whole is clearly beyond the scope of a single contribution of this size. However, most scholars in the field of long-run growth would agree that technological change is the primary force driving both long-run economic growth itself, and differences in long-run growth between nations and/or time periods (some, rather randomly chosen, references from various fields of economic analysis are Schumpeter, 1939; Nelson and Winter, 1982; Romer, 1986; Maddison, 1991a).

It has also often been recognized that technological change is a phenomenon not easily tackled by the traditional tools of the economist (see, for example, the references in the previous paragraph, or Dosi, 1988). In the era of modern capitalism, technological change is driven by economic motives. Research and development is being carried out in large laboratories in firms, universities and (semi-public) research institutes. In addition, smaller firms also invest significantly in various forms of technological change (see for example, Kleinknecht, 1987).

However, the main thing that makes innovation so hard to analyze at the aggregate level usually applied in studies of economic growth, is the fact that its impact and the way in which it is established varies tremendously from case to case. In many cases, measuring the impact of innovations is practically impossible, because it has an influence on such things as the quality of life, which are not taken into account in standard national accounting practices (think, for example, of improved health care). Sometimes, the impact of an innovation can be quite revolutionary, although limited to a specific field of economic activity (think, for example, of the many patents issued for lawn-mowing devices). In other case, however, an innovation (eventually) has an influence on virtually all economic activities (recent examples are computers and new materials, hisoric examples are electricity or the automobile).

What all these different degrees of impact have in common, however, is that the influence of an innovation only takes place after a significant diffusion lag. Diffusion of an innovation is never immediate, and always depends on a whole range of characteristics of the society in which it is supposed to diffuse. To a certain extent these characteristics are economic (firm organization, income distribution, etc.), but there are certainly institutional, political, geographical, sociological and other factors which play important roles. The question as to why the industrial revolution took place in Britain, for example, and spread to other countries at such different paces afterwards, can only be answered if these characteristics of the diffusion process are taken into account.

All of this underlines the limited use that can be made of purely economic tools in the field of long run growth. This conclusion, however, should not lead to a nihilistic methodology in which these economic tools are thrown overboard. It should rather lead the economic researcher to interpret the observed trends with care, and keep in mind that the theory developed cannot take into account, let alone explain, every aspect of the economic history of the last two centuries.

From this perspective, what are the economic factors related to technical change and its impact on long-run growth? One important factor is gross fixed capital formation (investment). Investment is related to technological change because most innovations rely upon embodiment in fixed capital for their influence on economic growth. There are different types of investment, and each has its own mode through which technology is fostered. After the illuminating contribution by De Long and Summers (1991), it has become fashionable to stress the effects of investment in machinery and equipment. While this is obviously related to technological change in a direct way, one should not underestimate the importance of, for example, investment in infrastructure.

There is an important problem with regard to the measurement of capital. Economists are used to thinking about capital as a stock of goods. While this notion is appealing from an intuitive point of view, it also introduces many problems on the measurement side. The famous debate on this issue between the two Cambridges on both sides of the Atlantic is still relevant in this respect.

Silverberg (1991) has outlined a number of problems of this type. His main objection against the traditional ways of measuring concerns the assumptions made about life times of various types of capital goods and about scrapping of parts of the capital stock. The central argument is that scrapping of capital goods is determined in an endogenous way, and strategies related to scrapping can therefore differ between entrepreneurs. For example, under pressure of growing real wages or faster technological competition, capital goods might be scrapped before the end of their technical lifetime. The practices used by the various national statistical offices (usually a fixed lifetime is applied to a series of investment data) are in sharp contrast with this. The recent efforts (by among others Maddison) to standardize life times, and thus capital stock estimates, between countries, are not a real improvement in this respect (see Wolff, 1994 for an application). In fact, to the extent that actual economic life times differ between countries, standardized capital stock estimates might make the problem worse.[2]

Of course, investment does not necessarily imply technological change. It is quite thinkable that entrepreneurs invest in pure capacity expansion, by simply buying more of the old equipment they already used. This problem, which is at the heart of many measurement problems discussed above, is one that is not easy to tackle. The central issue is quite well described in a quotation from Lewis (1978, p. 116):

> "The distinction [between] the functions of capital as a factor of production and a bearer of new technology (...) is difficult to sustain because the move from less to more capital almost always involves some change of technology. Yet it is a distinction which the econometricians have decided to pursue, and on which they will for some time be continuing to break their heads. For our purposes it suffices to note that in so far as each generation of machines is more productive than its predecessor, a country with a high investment ratio will, other things being equal, have higher productivity than a country with a lower investment ratio, because a higher proportion of its machines will be of the latest design."

[2] See Scott (1989) for additional arguments against the use of the capital stock as an economic concept.

Economies of scale form another major element of technological change. In the recent so-called new growth theory (see Verspagen, 1992 for an overview), the size of the population (given the level of education) is a main factor determining the number of innovations, and hence productivity growth. In a more general theoretical setting, the point that a larger production scale may allow for the introduction of more advanced techniques is also plausible. The 'demand pull' argument provided by Schmookler (1966) can be seen as one particular application of this insight. However, the classical notion of scale economies applies given a certain production technique. This indicates that certainly not all scale economies are related to technological change.

One particular form of scale economies is related to specialization. The argument about the scale economies of specialization goes back at least to Adam Smith's pin-factory, where the division of labour between workers created important productivity gains. Later on, Kaldorian theory stressed intertemporal scale economies, which might arise from specialization due to learning effects. In this theory, either specialization or fast growth of production is assumed to have a positive influence on the opportunities for learning-by-doing or learning-by-using. Models implementing these theoretical insights can be found in Dixon and Thirlwall (1975) and Verspagen (1993). The body of Kaldorian theories also provides an important framework for so-called export-based theories of growth.

Even within the economic domain, there are many more factors with an influence on technical change. The development of human capital and schooling, resources devoted to R&D, or the acquisition of knowledge from research institutes or (foreign) firms, are all important sources for productivity growth. However, given the historical and quantitative viewpoint in this paper, many of these factors fall outside the current scope, either because their role only recently gained importance (R&D), or because historical data necessary to assess their role in further detail are absent (human capital). The discussion here will therefore only focus on one additional factor, related to the international dimension.

Just as the impact of an innovation on the national level can only be established through diffusion in the national economy, the impact of technical change on the global economy can only occur through international diffusion. In other words, international knowledge spillovers are an important source for growth. An historical example of the importance of international diffusion is the case of the spread of the industrial revolution (see for example Lewis, 1978; Kenwood and Lougheed, 1992). The contribution of Gerschenkron (1962) to this literature has inspired many scholars studying postwar growth, leading to the so-called catching-up literature (for example Abramovitz, 1979; Fagerberg et al., 1994). This literature has focused on knowledge spillovers as a major source for convergence of per capita GDP in the postwar period. The idea in this literature is that relatively backward countries will be able to exploit a backlog of knowledge developed in the more advanced countries, and will therefore grow faster.

An important problem that seems central to most of these factors, however, is the distinction between growth due to growth of productivity, or growth due to the expansion of resources used. The neoclassical method of growth accounting (Solow,

1957) applied by the 'econometricians' Lewis is referring to, is devoted entirely to distinguishing between the contributions of the growth rate of inputs and other sources to the growth rate of output. The discussion of the role of capital in technological change above has shown that this is not an easy task. If an increase in the stock of capital is observed, which part can be seen as 'more of the same', and which part can be seen as enhancing technological change?

The neoclassical concept of total factor productivity (tfp), which is the central concept in the so-called growth accounting method, has provided an elegant answer to this question. However, this answer, which says that the growth rate of the capital stock should be weighted by the share of property in income in order to arrive at its contribution to output growth, relies heavily on such constructs as equilibrium and a competitive market. Keeping this in mind, the method loses much of its assumed general nature.

In order to avoid these sorts of problems, the approach chosen here will be somewhat different. The growth accounting approach basically assumes that the weights that give the growth rate of productivity as a function of the growth rates of certain inputs are known. These weights are then used to estimate the influence of these factors, after which the residual growth rate is attributed to the other factors (like technical change). Contrary to this, the analysis here will not assume any known weights, but instead will attempt to estimate these weights by means of a regression analysis. The factors not directly in the analysis are assumed to turn up in the regression constant and/or error-term.

The advantage of this approach lies in its more general nature. Compared with growth accounting, less restrictions on the contribution of certain factors are made. Given the nature of the assumptions underlying the construction of these restrictions, relieving them should provide the analysis with an additional number of degrees of freedom that could themselves prove quite useful for explaining long-run growth.

3.1. Regression analysis

The aim of the regression analysis applied here is to throw some more light on the variance–decomposition analysis applied above. While variance–decomposition is more or less a black box, which does not specify the nature of the time- and country-specific factors, regression analysis can do this. However, because of the long time span taken into account in this paper, many variables which should be included in a regression explaining growth, cannot be taken into account, because of data limitations (see the discussion above). The aim of this analysis is therefore not so much to estimate a specific growth model, but rather to investigate the robustness of some (partial) correlations in the field of long-run growth (see also Wang and Mody, 1993, for a justification for such an approach).

The following variables are used in the regression. The dependent variable is always the average annual growth rate of per capita GDP over a certain period. The periods used are 1870–1880, 1880–1892, 1892–1900, 1900–1914, 1918–1929, 1929–1939, 1950–1960, 1960–1973, 1973–1988. These periods are chosen on the basis of an examination of the series for aggregate output in the countries in the analysis, where the breakpoints relate to breaks in this series (except the break in 1960, which is made to take into account the building up of the European and Japanese economies after the war).

Independent variables are the investment output ratio (defined as the mean of the annual values in the period), the export to output ratio (defined similarly)[3], the initial (i.e. first year) value of per capita income, the initial size of the country (in thousands of population), and a constant. All variables are taken in natural logs, except for the dependent variable (which might take on negative values). The investment–output ratio is entered into the regression in order to take into account the effects related to capital investment discussed above. The export–output ratio and the initial population size are assumed to measure the effects related to the various forms of economies of scale, also introduced above. The initial per capita GDP is assumed to take into account the effect of knowledge spillovers.

In order to allow for the interaction between time- and country-effects, the sample is split up into different periods, for which separate coefficients are estimated. Two separate models are estimated. The first model is a simple linear equation, estimated for a pooled sample of all the OECD countries.[4] This model assumes that regression coefficients do not change over time, and serves as a reference for the second model. The second model has the following form.

$$g_{it} = \sum_{j=1}^{5} (\alpha_j + \alpha_{jt} + \alpha_{ji}) X_{ijt} \tag{11}$$

X stands for the five variables introduced above. The subscripts i, j and t denote a country, a variable and a time period, respectively. The αs are separate effects, associated with each variable. It is assumed that α_{ij} is equal for all OECD countries and for all Latin American countries, but may differ between these groups.[5] In order not to reduce the number of degrees of freedom too much, the sample has been split into three different time periods for which α_{tj} is estimated: 1870–1929, 1929–1939 and 1950–1988.[6] This periodization is not only intuitive from the point of view of economic history, it also links up closely to the results of the descriptive analysis in the previous section. All the signs (i.e. $\alpha_j + \alpha_{ij} + \alpha_{jt}$) are expected to be positive, except for the initial per capita income, which has an expected negative sign, and the constant, which might take on any sign.

[3] For the Latin American countries in the analysis, yearly export data are absent. The solution to this is to use the values of the export to GDP ratio for 1900 and 1913; 1913 and 1929; 1929, 1932 and 1938; 1950; 1973; 1973, 1980, 1986 for the periods 1900–1914, 1918–1929, 1929–1939, 1950–1960, 1960–1973 and 1973–1988, respectively.

[4] The OECD countries for which data are available for all variables are Australia, Canada, France, Germany, Japan, Netherlands, UK, USA, Sweden, Italy.

[5] Venezuela is not in the regressions, because export data are absent for this country.

[6] This periodization links up closely to Kenwood and Lougheed (1992) and Maddison (1991a), for example. The main difference is that usually the interwar is taken as one period. Regressions carried out under this alternative yield slightly worse results. These regressions are not documented, but available from the author on request.

Table 2
Regression results for explaining growth of per capita income, nine time periods 1871–1988, 16 countries[a]

Investment–output ratio	Export–output ratio	Initial per capita GDP	Initial population	Constant
Eq. 1, pooled OECD sample (73 observations, adj. $R^2 = 0.37$)				
0.0278 (4.91)	0.0089 (2.84)	−0.0164 (3.61)	0.0085 (4.01)	0.0245 (1.77)
Eq. 2, OECD and Latin America, 3 periods (103 observations, adj. $R^2 = 0.62$)				
1870–1929—OECD				
0.0162 (3.74)	0.0084 (2.70)	−0.0163 (3.73)	0.0034 (1.88)	0.0443 (2.93)
1900–1929—Latin America				
0.0040 (0.59)	0.0032 (0.65)	−0.0179 (4.61)	−0.0055 (2.41)	0.0744 (3.23)
1929–1939—OECD				
0.0122 (2.03)	0.0075 (1.70)	−0.0257 (6.33)	0.0070 (2.23)	0.0085 (0.34)
1929–1939—Latin America				
0.0000 (0.00)	0.0023 (0.35)	−0.0274 (6.06)	−0.0019 (0.58)	0.0386 (1.38)
1950–1988—OECD				
0.0234 (2.53)	0.0028 (0.86)	−0.0288 (7.37)	0.0088 (4.64)	0.0278 (1.51)
1950–1988—Latin America				
0.112 (0.98)	−0.0023 (0.38)	−0.0305 (5.74)	0.0000 (0.01)	0.0579 (1.94)

[a] Numbers listed in the cells are the sum of α values for the indicated categories. Numbers in parentheses are t-statistics. Standard errors are computed from a matrix corrected for heteroscedasticity.

Table 2 shows the results for the two different estimations. Given the large time span involved in the first regression, the results are quite reasonable. The proportion of the variance explained is reasonable (0.37), and all the coefficients are significant and have the expected sign. This indicates that the factors in the regression are quite robust factors explaining international growth rate differentials over time.

However, given the fast developments of the 20th Century, and the results from the variance decomposition analysis, the assumption of constant coefficients seems somewhat too restricting. This is why the second equation estimated allows for different coefficients on each of the variables in different time spans. In general, splitting up the sample increases the goodness of fit drastically, and brings the proportion of the variance explained up to 0.62. For the OECD countries, all the coefficients have the expected sign, and most are also significant, at least at the 10% level. The only coefficients which are clearly not significant are the constants in the 1930s and the postwar period, and the coefficient on the export–output ratio in the last period. This is quite different for the Latin-American countries. The only coefficients that are significant for this group, are the catching-up coefficients and the constants (the latter with the exception of the 1930s). The only conclusion that can be justified on the basis of these results is that the approach used does not have much to say on growth in Latin America.

With regard to the differences in magnitude of coefficients between time periods, there are some interesting conclusions in the OECD sample. The impact of the investment–output ratio is relatively high in the postwar period, when investment-output ratios increased. The impact of exports on growth is strongest in the early periods, and turns insignificant in the postwar period. The catching-up effect related to initial per capita income is significant in all periods, but increases in magnitude in the 1930s and the postwar period. The same increase is found for the case of scale economies, as indicated by the population size variable.[7] Finally, the constant is relatively high in the early period.[8] For the Latin American countries, it does not seem very useful to look for differences in the magnitude of coefficients between time periods.

In what respect can these results throw any light on the issue of the postwar convergence boom? In order to answer this question, assume two hypothetical countries. The first of these countries has the highest value of per capita income in the period under consideration. The value for the rest of the variables in this country is equal to those in the second country. The second country has a value for per capita income equal to the maximum value minus one sample standard deviation. Obviously, the second country will grow faster than the first (due to the negative coefficient on per capita income), implying convergence.

Now for each variable, ask the question by how many sample standard deviations the value in the second country should be decreased to achieve equal growth rates in the two countries. If this value is high, this means convergence is achieved relatively easily, because the backward country might have low values for the other variables than per capita income, and still be catching-up. The contrary holds for a low value of the computed number of standard deviations. Obviously, this value depends on the sample averages of all the variables, their standard deviations, as well as the estimated values of the coefficients in Table 2.

The results for the calculation for the OECD sample are presented in Table 3.[9] In general, it is seen that in the periods before the 1930s, the values are low, but slightly increasing. This indicates the low, but increasing, potential for convergence in the sample for the early years. In the 1930s, corresponding with the first period of convergence found in the previous section, the values rise. In the postwar period, the values are decreasing slowly again, and become quite low in the last period. This also corresponds with the evidence in the previous section.

[7] The combination of the results for the export–output ratio and the initial population size indicates that there might be some multi-collinearity between those two variables. In fact, the (negative) correlation between those two variables is quite well established both on theoretical and definitional grounds.

[8] Note that due to the logarithmic form of the variables, some of them have negative values, which makes the constant difficult to interpret.

[9] Note that some of the effects documented in Table 3 are dependent upon coefficients from Table 2 that are not statistically significant. For example, the effects related to the export–output ratio in the last three periods are in some cases rather large (e.g. 1950–1960), but are calculated on the basis of a non-significant coefficient (0.0028, with t-value 0.86).

Table 3
Catching-up opportunities offered by different variables, OECD sample, 1870–1988[a].

Period	Investment–output ratio	Export–output ratio	Initial population
1870–1880	0.79	1.17	1.28
1880–1892	0.87	1.28	1.53
1892–1900	1.21	0.99	2.01
1900–1914	1.23	1.10	1.96
1918–1929	1.10	1.12	1.86
1929–1939	3.12	1.75	1.27
1950–1960	1.83	6.50	1.38
1960–1973	1.12	4.76	0.91
1973–1988	0.94	2.13	0.44

[a] A low (high) absolute value indicates a relatively low (high) opportunity for catching-up by means of this variable.

4. A brief historical interpretation of the results

In a sense, the regression results are much more interesting because of the questions they raise, than the answers they provide. As the discussion of these results has shown, the regressions provide an interpretation of the postwar convergence boom by means of the magnitude of the parameters estimated, which differs between pre- and postwar periods. The recent convergence slowdown, on the contrary, seems to be due to a smaller standard deviation of per capita incomes, or, in more prosaic terms, a depletion of imitation possibilities.

The real question that comes out of this, is why the estimated coefficients in the regression equation would differ between pre- and postwar periods. This is the question that this section will, albeit briefly, address. A useful starting point is the distinction of different periods in economic growth. Kenwood and Lougheed (1992) distinguish three different periods: 1820–1913, 1918–1939, after 1945. These periods correspond closely to Maddison's phases of growth: 1870–1913, 1920–1939, 1950–1973, after 1973. They also correspond quite nicely, although not completely, with the periodization used in the regressions.

A review of some indicators for these three (or four) different periods, will yield some interesting features. A more complete discussion than is possible here is provided by among others Lewis (1978), Maddison (1991a), and Kenwood and Lougheed (1992). The main focus in this section will be at the sectoral level, discussing some of the available material on structural change and international trade.

From the perspective of structural change, the first period (before 1913) was characterized by the spread of manufacturing technology. The industrial revolution, taking part in the 18th Century in Britain, transformed the UK economy during the 19th Century, but only began to spread in a significant way to other countries in the period around 1870.

At the same time, the period 1870–1913 was the period in which the USA began to overtake the UK as the technological leader in the world. Among the factors that are generally mentioned as the causes for this process of overtaking, one finds the low investment rate in Britain, and the generally poor ability of the British to apply new technologies. In a sense, as is argued in for example von Tunzelmann (1994), this is paradoxical, because many of the new technologies (cars, steel, chemicals) were actually developed in Europe, including the UK. In the USA, however, the introduction of the new technologies was coupled with new organizational designs, such as Fordism, which appeared to be hard to implement in Europe. The USA is generally seen to have had some inherent advantages (such as a large domestic population and a society which was perceptive to change) that favoured this process. Lewis (1978) provides a nice overview of the arguments from the UK point of view, while Abramovitz (1994) focuses on the American side. (Also, see the article by Broadberry in this volume).

From the perspective of technological and structural change, the period after 1913 had a much less radical character. The spread of the industrial revolution within the sample of the core European countries and the USA had more or less been completed by 1913. This is indicated by Table 4, which gives the share of manufacturing in GDP for selected years. Although the quality of the data for the early years is generally poor, the table indicates that the share of manufacturing in total GDP had

Table 4
The spread of industrialization in selected countries. Share of manufacturing in GDP.

	1899[a]	1913[a]	1929[a]	1937[a]	1950[a]	1955[a]	1957[a]	1963[b]	1973[b]	1980[b]	1986[b]
Argentina	0.14	0.15	0.18	0.20	0.23	0.23	0.23	0.44	0.50	0.40	0.48
Australia		0.16	0.15	0.20	0.20	0.24	0.25	0.27	0.26	0.20	
Belgium	0.36	0.33	0.43	0.39	0.31	0.35	0.35	0.25	0.28	0.26	
Brazil				0.16	0.20	0.21	0.20	0.33	0.32	0.30	
Canada	0.22	0.19	0.26	0.28	0.29	0.28	0.28	0.28	0.28	0.21	0.21
Chile			0.18	0.13	0.17	0.22	0.24	0.27	0.44	0.23	
Colombia			0.06	0.09	0.16	0.16	0.16	0.19	0.21	0.21	0.19
Germany[c]	0.23	0.32	0.33	0.35	0.34	0.41	0.42	0.48	0.49	0.37	0.42
France	0.28	0.41	0.35	0.35	0.27	0.29	0.32	0.34	0.34	0.27	
UK	0.19	0.20	0.25	0.28	0.35	0.37	0.36	0.40	0.42	0.32	0.31
Italy	0.21	0.29	0.31	0.34	0.28	0.32	0.33		0.26	0.22	0.16
Japan	0.16	0.13	0.17	0.21	0.15	0.24	0.29	0.35	0.42	0.33	0.34
Mexico				0.17	0.23	0.24	0.26		0.22	0.22	0.21
Netherlands		0.21	0.27	0.24	0.27	0.31	0.31	0.21	0.25	0.18	
Norway	0.20	0.25	0.21	0.21	0.25	0.28	0.28	0.24	0.26	0.15	0.14
Sweden	0.27	0.34	0.30	0.35	0.36	0.35	0.35	0.28	0.33	0.26	0.27
USA	0.22	0.25	0.28	0.28	0.31	0.32	0.32	0.30	0.33	0.29	0.31

[a] Source: Maizels (1963, Table E1 and Table E3).
[b] Source: own calculations on the basis of UNIDO data and the sources for GDP mentioned in the appendix. The values for Argentina seem suffer from a systematic upward bias.
[c] West Germany from 1937 onwards.

Table 5
Structural change in international trade over the 20th Century. Share of commodity classes in total trade[a].

Commodity class	1899[b]	1913[b]	1929[b]	1937[b]	1950[b]	1955[b]	1957[b]	1970[c]	1980[c]	1990[c]
Subtotal Metals and Engineering	0.16	0.21	0.25	0.31	0.35	0.40	0.42	0.52	0.51	0.55
Metals	0.06	0.08	0.07	0.10	0.08	0.10	0.11	0.21	0.21	0.26
Machinery	0.04	0.06	0.09	0.10	0.14	0.15	0.17	0.10	0.08	0.05
Transport equipment	0.02	0.03	0.06	0.07	0.09	0.11	0.11	0.16	0.15	0.18
Other metal commodities	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.05	0.06	0.06
Chemicals	0.04	0.05	0.05	0.07	0.07	0.08	0.08	0.13	0.16	0.14
Textiles and clothing	0.21	0.19	0.16	0.13	0.11	0.08	0.08	0.07	0.05	0.05
Other manufacturing	0.11	0.12	0.13	0.12	0.11	0.12	0.12	0.10	0.10	0.10
Non manufacturing	0.48	0.44	0.40	0.38	0.36	0.32	0.31	0.18	0.19	0.15
Total manufacturing	0.52	0.56	0.60	0.62	0.64	0.68	0.69	0.82	0.81	0.85

[a] Total trade is defined as exports from Belgium France, Germany, Italy, Netherlands (not in 1899), Sweden, Switzerland, UK, Canada, USA, Japan). Foodstuffs are excluded from manufacturing trade.
[b] Source: Maizels (1963, Table E4).
[c] Source: own calculations or the basis of OECD data.

reached levels in 1913 that, for most countries, were more or less comparable with the levels that would be attained in the postwar period. The UK and Japan, as the prototypes of early and late industrializers (respectively), form an exception to this rule. Both countries have increased the share of manufacturing in GDP significantly after 1913. The table also shows the decreasing importance of manufacturing after 1973.

The most important characteristic of the interwar period is without doubt the generally low level of activity. Obviously, this is best illustrated with reference to the 1930s, in which the Great Depression hit economic activity almost worldwide. However, the 1920s were also characterized by low growth and utilization of productive capacities (see Maddison, 1991a).

The interwar years are also characterized by significant structural change within manufacturing, for example in the area of international trade. These structural changes were largely induced by the changing nature of manufacturing production under the influence of innovations that played a major role in the emergence of the USA as a technological leader. The old commodities (like textiles and coal) that characterized the early stages of industrialization, had to give way to new commodities, such as chemicals and new types of machinery. This process is illustrated in Table 5.

The table shows the gradual shift towards a larger share of metal commodities (machinery, basic metals, transport equipment) and chemicals in total trade. This causes the total share of manufacturing to go up significantly. Within manufacturing, the rise of these commodity classes is largely at the expense of textiles, which are reduced to a very small commodity class by the 1990s.[10] In general the picture of structural change that emerges from Table 5 seems to be one that is very gradual, showing also that structural change continues into the postwar period. This makes the features describe less likely candidates for explaining the differences in convergence.

The postwar period is one in which growth was generally high. Partly, this is caused by high investment. The level of investment as a fraction of GDP showed a major shift after the war. For some countries, the catching-up effect, which is the central element of the discussion here, also contributed significantly to high growth (see the regressions in the previous section). The period after 1973, however, seems to show that the 'golden age' of the years 1950–1973 was quite exceptional, because growth slowed down considerably during this period.

Are there any factors that come out of this general interpretation of the nature of the different epochs that can throw any light on the question why the catching-up effect was so much stronger after the war? Lewis (1978) has suggested that the period of low growth between the wars interfered with the spread of an important amount of innovations that were developed in the leading country, the USA, during that period. In the words of Abramovitz (1994), 'America's labor productivity lead had widened in two main phases, the first between 1870 and 1913, the second, another large step, during the wartime decade of the Forties', an intepretation based on the data developed by Maddison, which were also used for the present paper. In this interpretation, the potential for convergence was present in the interwar period, but due to a number of factors the potential was not realized. In terms of the results of the previous sections, this underlines again the importance of the question why the catching-up coefficient was so small during the early periods.

Lewis (1978) does not go into the matter in very much detail, but simply underlines that the exceptionally low capacity utilization led to the accumulation of a backlog of convergence potential which remained largely unused. In a more general interpretation, his argument can be taken to stress that catching-up is 'easier' in periods of high growth, than in periods with low growth. This fits the results found in this paper quite well, with a weak convergence trend in the 1930s, strong convergence during the golden age of the 1950s and 1960s, and a slowdown in convergence during the 1970s.

Abramovitz (1994) discusses a number of factors that might give a deeper understanding. First, he mentions the nature of the technologies available for imitation, after the US took over leadership from Britain. According to him, their scale-intensive nature made them more suitable for the large US market. Only when European markets themselves became larger after the war, did the mass-production methods become suitable for these smaller economies. Second, he mentions factors related to 'social capability to catch up' (such as managerial attitudes and education) which were generally weak in Europe during the interwar years.

Nelson (1991) focuses on some peculiarities of the postwar period in order to

[10] Note that most of the textiles production has been shifted to countries not in the table.

explain the observed differences. He stresses the openness of world markets after the second world war (as related to some well-known developments such as Bretton-Woods and increasing mobility) as the main source for the 'loss of American leadership'. This immediately offers an interpretation for the slowdown of convergence since the mid-1970s. While the oil crisis of 1973 is generally seen as having an influence on growth performance, it is not clear how it should have an immediate impact on convergence. The breaking down of the Bretton-Woods system, however, seems to be related to this in a direct way.

On the basis of the results in the previous section, the explanations related to the openness of the world economy and the 'social capability argument' seem more likely candidates than the first one. If scale economies were really much more important in the pre-war period, this would probably have turned up in the coefficient on population size. But what the regressions show is that scale economies became much more important in the 1930s and the postwar period, which is contrary to such an expectation.

5. Summary and conclusions

This paper has focused on convergence and divergence of per capita income levels over the 19th and 20th Centuries. In the second section, it has been shown that convergence has been taking place in OECD countries in the post-war period. Earlier periods and other countries generally led to the conclusion of more or less constant per capita income differences, or in some cases (Latin America) divergence. Using a variance decomposition analysis, it was shown that in general there is no trend for persistence in high or low growth in the sample considered. Instead, certain countries grow rapidly (slowly) in certain time periods.

The third section has implemented some empirical approaches to explaining growth. A regression analysis has shown that for OECD countries, investment–output ratios, export–output ratios, population size and catching-up potential all had a significant (positive) influence on per capita income growth. Population size, investment and the catching-up effect are particularly strong in the postwar period of high growth. For Latin America, the regression approach leads to worse results.

Section 4 has attempted to provide some explanations for the question as to why the catching-up potential was so much larger in the post-war period. Drawing on previous work by Nelson, Abramovitz and Lewis, it was concluded that factors such as the opening-up of the world economy, social capability to catch up, and the low activity in the interwar years are related to this trend.

Appendix. A note on sources

A.1. GDP

A.1.1. Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Sweden, Switzerland, UK, USA.

The principal source is Maddison (1991a). The data in Glissmann et al. (1981) for Germany (1850–1860) and the UK (1830–1860) are used to interpolate Maddison's data for the indicated periods. The method used to do this is to fit the trend in the data of Glissman et al. (1981) to Maddison's series. For comparison with Latin America and Asia, the series obtained this way (which were in 1985 US$ purchasing power parities (PPP)), were transformed to 1980 US$ PPP by using the 1980 and 1985 PPP indices and the GDP price indices for those years supplied by the OECD.

A.1.2. Argentina, Brazil, Chile, Colombia, Mexico, Venezuela.
The source for these data is Hofman (1992).

A.2. Population

A.2.1. Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Sweden, Switzerland, UK, USA.
Population data for these countries are taken from Maddison (1991a). Since these data are not adjusted for border changes, the information in Maddison (1991a, various appendices) was used to perform such a correction. For Germany and the UK, population data were interpolated for years that GDP was taken from Glissman et al. (1981) (see above). This was done by fitting a third-order polynomial time trend to the data in Maddison (1991a) for these years.

A.2.2. Argentina, Brazil, Chile, Colombia, Mexico, Venezuela.
The source for these data is Hofman (1992).

A.3. Investment

A.3.1. France, Germany, Netherlands, United Kindom, Australia, Canada, USA, Japan.
The data for investment and GDP used to calculate the investment–output ratio are taken from Maddison (1991b).

A.3.2. Italy, Sweden
Investment data for these countries are taken from Glissman et al. (1981). These data were transformed to 1980 US$ PPP by use of the Maddison data on PPP, and divided by data on GDP from Maddison (1991a).

A.3.3. Argentina, Brazil, Chile, Colombia, Mexico, Venezuela.
The source for these data is Hofman (1992).

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References

Abramovitz, M.A., 1979, Rapid growth potential and its realisation: the experience of capitalist economies in the postwar period, in: E. Malinvaud, ed., Economic growth and resources, vol. 1: the major issues, Proceedings of the Fifth World Congress of the International Economic Association (London, Macmillan) 1–51.

Abramovitz, M.A., 1992, Catch-up and convergence in the postwar growth boom and after, paper presented at the Workshop on Historical Perspectives on the International Convergence of Productivity, New York, April 23–24.

Abramovitz, M.A., 1994, The origins of the postwar catch-up and convergence boom, in: J. Fagerberg, B. Verspagen and N. von Tunzelmann, eds., The dynamics of Technology, Trade and Growth (Edward Elgar, Aldershot).

Ben-David, D., 1991, Equalizing exchange: a study of the effects of trade liberalization (NBER Working Paper, No. 3706).

De Long, J.B. and L.H. Summers, 1991, Equipment investment and economic growth, Quarterly Journal of Economics 106, 445–502.

Dixon, R.J. and A.P. Thirlwall, 1975, A model of regional growth-rate differences on Kaldorian lines, Oxford Economic Papers 11, 201–214.

Dollar, D. and E.N. Wolff, 1993, Competitiveness, convergence and international specialization, (MIT Press, Cambridge, MA).

Dosi, G., 1988, Sources, procedures and microeconomic effects of innovation, Journal of Economic Literature 26, 1120–1171.

Fagerberg, J., B. Verspagen and N. von Tunzelmann, eds. 1994, The dynamics of technology, trade and growth (Edward Elgar, Aldershot).

Gerschenkron, A., 1962, Economic backwardness in historical perspective (Harvard University Press, Cambridge, MA).

Glissmann, H.H. and H.W.F. Rodemer, 1981, Lange Wellen wirtschaftliches Wachstums, in: D. Petzina and G. Van Roon, eds., (Konjunktur, Krise, Gesellschaft, Klett-Cotta, Stuttgart), 66–106.

Hofman, A.A., 1992, Capital accumulation in Latin America: a six country comparison for 1950–1989, Review of Income and Wealth 38(4) 365–401.

Kenwood, A.G. and A.L. Lougheed, 1992, The growth of the international economy. 1820–1990: an introductory text, 3rd edn., (Routledge, London).

Kleinknecht, A., 1987, Measuring R&D in small firms: how much are we missing?, Journal of Industrial Economics 36, 253–256.

Lewis, W.A., 1978, Growth and fluctuations 1870–1913 (Allen & Unwin, London).

Maddison, A., 1991a, Dynamic forces in capitalist development, a long-run comparative view (Oxford University Press, Oxford).

Maddison, A., 1991b, A long run perspective on saving (Memorandum of the Institute of Economic Research, University of Groningen).

Maizels, A., 1963, Industrial growth and world trade (Cambridge University Press, Cambridge).

Nelson, R.R., 1991, Diffusion of development: post World War II convergence among advanced industrial nations, American Economic Review: Papers and Proceedings 81, 271–275.

Nelson, R.R. and S.G. Winter, 1982, An evolutionary theory of economic change, (Harvard University Press, Cambridge, MA).

Romer, P.M., 1986, Increasing returns and long run growth, Journal of Political Economy 94, 1002–1037.
Schmookler, J., 1966, Invention and economic growth (Harvard University Press, Cambridge, MA).
Schumpeter, J. A., 1939, Business cycles, vols. I and II (McGraw-Hill, New York).
Scott, M.F., 1989, A new view of economic growth (Oxford University Press, Oxford).
Silverberg, G., 1991, Dynamic vintage models with neo-Keynesian features, in: OECD, Technology and productivity. The challenge for economic policy (OECD, Paris) 493–508.
Solow, R.M., 1957, Technical progress and the aggregate production function, Review of Economics and Statistics 39, 312–320.
von Tunzelmann, N., 1994, Technology and industrial progress: the foundations of economic growth (Edward Elgar, Cheltenham).
Verspagen, B., 1992, Endogenous innovation in neo-classical growth models: a survey, Journal of Macroeconomics 14, 631–662.
Verspagen, B., 1993, Uneven growth between interdependent economies. The evolutionary dynamics of growth and technology (Avebury, Aldershot).
Wang, F.Y. and A. Mody, 1993, Industrial growth in coastal China: economic reforms... and what else? (Mimeo, The World Bank).
Wolff, E.N., 1994. Technology, capital accumulation, and long-run growth, in: J. Fagerberg, B. Verspagen and N. von Tunzelmann, eds., The dynamics of technology, trade and growth (Edward Elgar, Aldershot).