On the Historical Continuity of the Process of Economic Growth

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Abstract

Pooled regressions first of 8 and then of 16 countries show a steady and robust process of endogenous growth since 1870, interrupted only by the events of World War II and the impact of convergence towards US levels of performance in the 1950s and the 1960s. This result contrasts with that of Maurice Scott, who finds that growth accelerated after the second world war. Catching up is no longer relevant in the 70s and the 80s of this century, despite a still existing gap in productivity levels *vis a vis* the US. It was neither relevant in the pre-WW II era. Growth is therefore characterized by the device "back to normal". Even so, a few countries underperform in terms of economic growth.

Non-technical summary

In neoclassical growth theory diminishing returns with respect to capital accumulation imply that the long-run rate of economic growth is independent of the macroeconomic savings ratio. Endogenous growth theories show how diminishing returns can be counterbalanced by externalities or internalities so that long-run growth of output depends on intertemporal preferences. There is now a large variety of models along these lines, each emphasizing particular aspects of accumulation and innovation. Maurice Scott takes a short-cut by postulating a fundamental growth equation relating output growth to the investment ratio and the growth rate of employment. Empirical testing of the theory is facilitated by approximating the fundamental growth equation by a linear relationship. If growth is fully engodenous the constant term in this linear equation should be equal to zero.

In this paper we want to investigate two main questions. First, is growth endogenous in the sense that the investment ratio and the rate of growth of employment explain differences in growth of output across countries and across time periods satisfactorily? Second, is there historical continuity or are there indications that growth has accelerated after major events such as for instance WW I and WW II? To answer these questions regressions are run on a sample of observations borrowed from Maddison. The period of observation is 1870-1989 and the number of countries is eigth in the core sample and 16 in an extended sample. Because countries differ with respect to the level of knowledge applied in producing goods, as may be inferred from differences in labour productivity, international spillovers may lead to catching up. This can be accounted for by introducing as an additional explanatory variable the ratio of labour productivity of followers to that of the leader, which is the US for most of the time.

Pooling of time-series and cross-section data gives a core sample of 57 observations. Pooling calls for testing of stability with respect to sub-periods and countries. The tests reveal that country-specific influences can only be assigned to Australia. More important, it is found that the catch-up variable is insignificant in the sub-periods before 1950 and after 1973. These results still hold (with an additional dummy for the Scandinavian countries) in case the Maddison sample is extended to 84 observations. Moreover, in all cases considered the constant term does not differ significantly from zero. It may therefore be concluded that endogenous

growth theory stands up to the facts. Historical continuity is observed if proper account is taken of the catch-up process in the 1950s and the 1960s. These periods are exceptional as they show a conditional convergence towards US productivity levels. After 1973 catching up is no longer significant and the industrialised countries are back on their pre-WW II historical track. The productivity slowdown observed since 1973 fits well into the picture. It should be noted that the idea of historical continuity contrasts with Scott, who finds an acceleration of growth after WW II. However, as shown in the paper this may be due to a rather special treatment of catching up in the post-war period.

The core sample with data starting at the second industrial revolution which according to Chandler started around 1870, includes a limited number of countries. Consistent pre-WW II data are hard to obtain. Missing data are of course no excuse for a selection bias, if there is reason to believe that this critique applies. However, Bradford de Long's critical assessment of the convergence hypothesis does not apply to our analysis. We find no convergence before WW II, and there is no *a priori* reason to assume that countries not included in the sample would have performed badly in terms of our fundamental growth equation. On the contrary, our results are robust as appears from estimating the growth equation using Summers and Heston data on post WW II-growth in 95 countries and three sub-periods. The total number of observations is now 245 as data for some countries are limited to the periods after 1960. The results confirm our main conclusions: endogenous growth theories fit the facts rather well and catching up is no longer an issue after 1973. The impact of the catch-up variable in the larger Summers and Heston sample is smaller than in the Maddison samples, as may be expected. As Abramovitz and Inkster, among others, have pointed out catching up requires adequate preconditions in terms of culture and institutions to be effective. Homogeneity in this sense is, of course, less in a large sample of 95 countries than in the much smaller Maddison country set.

The idea of a normal pattern of growth is reminiscent of the well-known *normal pattern* of sectoral development introduced by Chenery and Syrguin. Future research may explore this similarity by analysing growth at a sectoral level, applying the ideas developed in this paper.

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1. Introduction

From an empirical point of view economic growth is usually seen as a long-run process. Growth is conceived of as the trend in GDP over a substantial time span. Therefore, to explain growth by econometric techniques, one needs data for a large number of countries to apply cross-section analysis. The equation estimated contains the growth rate of GDP either in total or per capita as the dependent variable and a number of explanatory variables based on economic theory. There are basically *two* strategies that can be followed. First, the estimated equation may be derived from a theory of economic growth (e.g. Dowrick and Nguyen, 1989; Barro and Sala-i-Martin, 1992; Mankiw, Romer and Weil, 1992). Second, a pool of explanatory variables, which come from different macroeconomic theories, may be considered assuming that they can be entered independently and linearly (e.g. Kormendi and Meguire, 1985; Grier and Tullock, 1989; Barro, 1991; Levine and Renelt, 1992). In the latter case it is useful to sort out variables that really matter. As shown by Levine and Renelt (1992) by applying cross-section analysis for the period 1960-1989 to a sample of about 100 countries, the number of robust explanatory variables with respect to real per capita GDP is rather limited.

This paper looks at economic growth as a process of the medium as well as the long run. In studying growth, one has to eliminate the business cycle, but there is no compelling reason to assume that differences in growth rates across sub-periods must be averaged out to get the right picture. Therefore, the aim here is not only to show why growth rates differ between countries but also to investigate whether growth accelerates or decelerates over time. More specifically, we want to investigate whether there is historical continuity with respect to economic growth. Can economic growth before and after WW II be explained by the same growth equation? This approach calls for pooling cross-sectional data and time series data, going back in history as far as the availability of statistical sources allows. The equation estimated for this purpose is based on the growth theory of Scott (1989). The resulting equation is rather simple and could have been postulated right away, as implied by the results of Levine and Renelt (1992). However, for a proper understanding of the estimation results it seems desirable to make a short theoretical detour in section 2. The data, estimation procedures and statistical tests are dealt with in section 3, while the results of the regressions are discussed in section 4. The paper closes with some observations on the follow-up in our research programme.

2. Endogenous versus exogenous growth theory

Endogenous growth theories such as that of Scott (1989) intend to explain growth including technological progress, while exogenous theories leave room for an unexplained residual. The difference between these views can be illustrated by comparing Scott's theory with the neoclassical approach of Dowrick and Nguyen (1989), and Dowrick (1992).

Assuming a Cobb-Douglas specification, the neoclassical production function can be written in rates of change as

$$g = \alpha\, g_k + (1 - \alpha)\, g_{\ell} + \varepsilon, \tag{1}$$

where g, g_k and g_{ℓ} denote the growth rate of output, capital input and labour input, respectively. The parameter α stands for the production elasticity of capital. Technological change is constant and is equal to 100ε percent per year. Applying equation (1) to a cross section of countries leads to unsatisfactory results because total factor productivity varies substantially across regions. A way out is to assume that technological knowledge converges in the sense that countries with lower GDP per capita but broadly similar socio-economic characteristics catch up with the leader, which is the US in the 20th century. Equation (1) may therefore be extended by introducing a *catch-up* variable (*cu*) in the form of the ratio of the initial level of labour productivity in each country in the sample (y_0) and the initial labour productivity level in the US (y_{us}) (*cu/* y_0/y_{us}.)

The introduction of a catch-up variable gives rise to *additional* observations. First, as argued by Inkster (1990), who supplied ample historical evidence for his view, the international transfer of knowledge is an ongoing process with countries exchanging ideas, hardware and skilled people on a bilateral base. If countries differ substantially in their level of development, transfers from "leaders" to "latecomers" may dominate, thus giving rise to catch up, which can be identified by econometric methods. Second, a substantial difference in GDP per capita is a necessary but not a sufficient condition for catching up. In addition, the social and economic environment of the receiver should be similar to that of the source for the technology transfer to be fully "indigenised" and therefore successful (e.g. Ambramovitz 1989; Inkster, 1990). Adding a logarithmic catch-up variable and making the necessary transformations, Dowrick and Nguyen (1989) end up with the estimation equation

$$g = a_0 + \frac{a_1}{\kappa}\sigma + a_2 g_\ell - a_3 \ell ncu + \mu \qquad (2)$$

where μ denotes a random error term and the positive defined coefficients a_0, a_1, a_2 and a_3 depend on the parameters of the original production function, a coefficient introduced to account for the impact of the catch-up variable, and the length of the time period (T) for which growth rates are defined. Intuitively, one would expect the absolute extent of catch up to be stronger in the earlier years, so that the coefficient a_3 diminishes if T increases. There is a similar impact on the other coefficients. More specifically, as shown by the authors, the coefficient on the growth of capital a_1 is an underestimate of the Cobb-Douglas parameter α. Finally, it should be noted that because of missing estimates for the capital stock, the Harrod Domar identity $g_k=\sigma/\kappa$ is substituted in equation (1), with the share of investment in output denoted by σ and the capital-output coefficient denoted by κ. (Depreciation of capital is ignored to simplify the argument.) In estimating equation (2) the authors have to assume that κ is constant, which is inconsistent from a theoretical perspective.

The theory of endogenous growth of **Scott** (1989, 1991, 1993) is based on learning by doing and learning by watching. This places Scott's theory in line with endogenous growth theories developed independently (e.g. Romer, 1986). In Scott's theory, firms are conceived of as on-going concerns with sunk costs determining their position at each point in time. They have to decide how much will be invested to change the existing facilities and organizational capabilities and how much labour will be hired or fired compared with the volume of labour applied to run existing operations. In other words, firms have to decide on the volume of investment and the direction of technical progress simultaneously. In case of rationalisation, emphasis is put on labour saving, while in case of expansionary investment, labour demand will usually increase. Growth is never a repetition of the old but implies qualitative change as firms cumulate knowledge by investing. Every act of investment induces a change in production capacity as well as a rise in the stock of existing knowledge, which can be tapped later on. As Scott (1993) states it: "There are no diminishing returns to *cumulative* investment, because changing the world reveals fresh opportunities" (italics our own). Note that Scott uses a broad investment concept, including expenditure on R&D, outlays on organizational changes, some forms of advertising and the like. In this respect Scott's view parallels that of Chandler (1990), who points to the importance of "three-pronged investment" in the history of economic growth: (1) investment in production facilities large enough to achieve cost advantages of scale and scope; (2) investment in product-specific marketing, distribution and purchasing networks; (3) recruiting and organising of managers to coordinate and supervise production and distribution. With such a broad investment concept there is a measurement problem. However, as argued by Scott (1989, pp. 30-33), gross investment can be taken as a proxy for the true amount of investment because the omission of the outlays on R&D, marketing and improvement of the organisation, etc., is counterbalanced by the inclusion in the definition of gross investment of some expenditures that should be classified as "maintenance" instead of as true replacement investment. Maintenance and repair should be considered as current costs of production to prevent or offset physical deterioration of existing assets[2].

The options for firms can thus be summarised by a *fundamental growth equation*

$$g = f(\sigma, g_\ell) \quad , f_1, f_2 > 0, f_{11}, f_{22} < 0 \tag{3}$$

where the symbols have the same meaning as before. Forward-looking firms maximise the present value of the cash flow for given time paths of wages, prices and interest rates. Depending on these time paths economic growth will be predominantly expansionary, requiring additional labour to realize plans, or more defensive, rationalizing on variable labour input. The theory bears a certain resemblance to the model of Kamien and Schwartz (1969), which combines the Kennedy-Weizsäcker innovation possibility frontier with the idea that investment expenditure can shift this frontier outward[3].

There are three additional observations to be made. First, Scott's growth equation is concave in σ and g_ℓ, but when the curves are relatively flat a linear approximation may be acceptable in empirical work. Second, learning can be internal to the firm or can take the form of an externality. The theory can cope with externalities on a microeconomic level. The macroeconomic growth equation relates internal as well as external effects to gross investment as the primary engine of growth. Third, the growth equation may shift under the impact of special circumstances. The post WW II situation in developed countries provided an almost ideal situation to imitate superior American ways of producing and distributing commodities. For this reason a catch-up variable as in Dowrick and Nguyen (1989) should be added for relevant periods[4]. The equation to be estimated can therefore be written as

$$g = b_0 + b_1\sigma + b_2 g_\ell - b_3 \ell ncu + \mu, \tag{4}$$

where μ is a random error term and the constant b_0 is predicted to be zero, because technological change is fully endogenous in the model. In some studies convergence or catch up is measured by including initial GDP per capita instead of *cu* as an explanatory variable (e.g. Dowrick, 1992). This destroys the dimensional homogeneity of the estimation equation, so that the constant term cannot be interpreted as a pure measure for exogenous technological change. Consequently, Scott's theory of endogenous growth, implying that the constant term equals zero, cannot be properly tested. Equations (2) and (4) look similar, but the underlying theories differ substantially. Moreover, there is no need in Scott's theory to assume that the capital-output ratio is constant, because there is no need for a static neoclassical production function in the theory of economic growth. It should be noted that except for deviations caused by business cycles or temporary changes in X-efficiency for whatever reason, equation (4) applies for each sub-period within the entire period of observation[5]. There are no transitional dynamics apart from catching up, as is also true for some other macroeconomic models of endogenous growth with encompassing concepts of capital accumulation (e.g. Romer, 1986; Rebelo, 1991).

3. Estimation: data, procedure and statistical tests

For all 16 countries the data on GDP and employment levels come from Maddison (1991). In the core sample the investment ratios are from Maddison (1992)[6]. The investment series covers eight countries, which constrains the pool of observations of the core sample. Elimination of cyclical fluctuations is performed by calculating average exponential growth rates of output and labour input from peak to peak level[7]. Maddison reports employment levels for 1870, 1890, 1913, 1929, 1938, 1950, 1960, 1973 and 1989. For most countries these years show peaks in the level of output, so that it is justified to use them for this purpose. It is therefore possible to split the observation period (1870-1989) into eight subperiods. Thus, in principle, the core sample consists of 64 observations. The series for Australia, the United Kingdom, Canada and the United States covers the whole period from 1870 onwards. Data are missing, however, for Germany, Japan, France and the Netherlands for the "war period" 1938-1950, whereas the Japanese series starts in 1890 and the Dutch series starts in 1913. This reduces the core sample to 57 observations. Contrary to Scott (1989), the observations are not weighted for country size or reliability. The growth rate of labour input is captured by two different measures: man-hours and persons. For the investment ratio, we take the mean value of annual observations. The catch-up variable is defined as GDP per man-hour (respectively per person) relative to (corresponding) labour productivity in the US.

The core sample of g, σ, g_ℓ and cu recapitulates briefly the medium- and long-run tendencies in capitalist development[8]. Since 1870, all 8 countries have been involved in a process of substantial growth measured in hours[9]. Output growth amounted to 3.3% a year on average, whereas employment, measured in hours, grew by 0.7%, and measured in persons by 1.2% a year. The average investment ratio was 13.4. Apart from inter-country differences, output and labour productivity growth have varied significantly over time. Compared with the inter-war era, all countries experienced an acceleration in the 1950s and the 1960s. After 1973, there has been a substantial and general deceleration, but not dramatic compared with pre WW I evidence.

Estimation proceeds as follows. First, we tested the significance of country-specific factors by introducing country dummies. Stability over time of the coefficient of the investment ratio and the constant term was tested by adding dummies for all sub-periods with the exception of the 1950s and the 1960s. Stability over time of the coefficient of the catch-up variable was tested for all sub-periods. The test reveals that country-specific influences can only be assigned to Australia and that the coefficient of the investment ratio is stable over time, with the exception of the "war period" 1938-1950. Further, it appears that the catch-up variable is insignificant in the periods before 1950 and after 1973. This is illustrated by the equation in Table 1, where labour input growth is measured in man-hours. The catch-up variable is highly significant in the sub-periods 1950-1960 and 1960-1973. For all other sub-periods the catch-up variable can be eliminated.

Table 1

Test on the significance of the catch-up variable, 1870-1989

OLS estimation of output growth g on		
	Coefficient	t-value
Constant	0.35	0.72
Investment ratio (σ)	0.13	2.95
Growth rate of labour input (g_ℓ)*	0.87	8.93
Catch up (ℓncu_{1870})	-0.09	-0.12
Catch up (ℓncu_{1890})	-0.13	-0.31
Catch up (ℓncu_{1913})	-0.58	-1.41
Catch up (ℓncu_{1929})	-0.14	-0.35
Catch up (ℓncu_{1938})	-1.74	-1.08
Catch up (ℓncu_{1950})	-2.32	-6.18
Catch up (ℓncu_{1960})	-3.38	-5.64
Catch up (ℓncu_{1973})	-0.22	-0.23
$\sigma Dummy_{1938-1950}$	0.16	2.49
$\sigma Dummy_{Australia}$	-0.06	-2.71
Number of observations (N)	57	
R-Bar-Squared	0.86	

* Measured in hours worked.

Table 2

Pooled regression with labour input in man-hours, 1870-1989

OLS estimation of output growth g on	(1)	(2)	(3)	(4)
Constant	0.34	0.39	0.79	0.50
	(0.73)	(1.00)	(2.79)	(1.73)
Investment ratio (σ)	0.14	0.14	0.10	0.13
	(3.46)	(4.33)	(4.78)	(5.82)
Growth rate of labour input (g_{ℓ})	0.83	0.83	0.85	0.81
	(9.04)	(9.57)	(11.37)	(11.26)
Catch up 1950-1960 (ℓncu_{1950})	-2.19	-2.22	-2.02	-2.03
	(6.37)	(7.10)	(9.16)	(9.64)
Catch up 1960-1973 (ℓncu_{1960})	-3.13	-3.19	-3.37	-3.27
	(5.76)	(7.07)	(11.42)	(11.58)
Catch up 1973-1989 (ℓncu_{1973})	0.19			
	(0.21)			
$\sigma Dummy_{1938-1950}$	0.21	0.21	0.20	0.21
	(5.13)	(5.18)	(5.14)	(5.55)
$\sigma Dummy_{Australia}$	-0.06	-0.06	-0.05	-0.06
	(3.09)	(3.11)	(2.89)	(3.42)
$\sigma Dummy_{Scandinavia}$				-0.04
				(2.98)
Number of observations (N)	57	57	84	84
R-Bar-Squared	0.87	0.87	0.86	0.87
S.E. of Regression	0.72	0.71	0.69	0.66
Serial Correlation (F-statistic)	0.16	0.17	0.04	0.62
Functional Form (F-statistic)	1.18	1.25	0.00	0.37
Heteroscedasticity (F-statistic)	0.20	0.22	0.06	0.00

Table 3

Pooled regression with labour input in persons, 1870-1989

OLS estimation of output growth g on	(1A)	(2A)	(3A)	(4A)
Constant	-0.07	-0.13	0.20	-0.09
	(0.15)	(0.33)	(0.68)	(0.32)
Investment ratio (σ)	0.11	0.12	0.09	0.13
	(2.68)	(3.68)	(4.23)	(5.44)
Growth rate of labour input (g_ℓ)	1.07	1.06	1.09	1.05
	(8.36)	(8.89)	(11.03)	(11.09)
Catch up 1950-1960 (ℓncu_{1950})	-2.77	-2.73	-2.60	-2.59
	(6.95)	(7.53)	(10.46)	(11.02)
Catch up 1960-1973 (ℓncu_{1960})	-3.72	-3.62	-3.54	-3.44
	(5.60)	(6.51)	(10.15)	(10.41)
Catch up 1973-1989 (ℓncu_{1973})	-0.30			
	(0.28)			
$\sigma Dummy_{1938-1950}$	0.14	0.14	0.13	0.14
	(3.15)	(3.23)	(3.21)	(3.63)
$\sigma Dummy_{Australia}$	-0.07	-0.07	-0.07	-0.07
	(3.39)	(3.43)	(3.42)	(4.03)
$\sigma Dummy_{Scandinavia}$				-0.04
				(3.22)
Number of observations (N)	57	57	84	84
R-Bar-Squared	0.86	0.86	0.85	0.88
S.E. of Regression	0.76	0.75	0.71	0.67
Serial Correlation (F-statistic)	0.47	0.45	0.09	1.50
Functional Form (F-statistic)	0.84	0.74	0.01	0.10
Heteroscedasticity (F-statistic)	0.28	0.31	0.01	0.67

The equations (1) in Table 2 and (1A) in Table 3 summarise the regression results after elimination of insignificant variables[10]. However, the post 1973 catch-up variable is shown to emphasize one of our *main conclusions:* catching up after 1973 is not significant. Deletion of this insignificant explanatory variable hardly changes the results as can be seen by comparing the equations (1) and (2) in Table 2 and the equations (1A) and (2A) in Table 3. Labour input growth is measured by man-hours (1) and persons (1A) respectively. Absolute t-statistics are shown in brackets[11]. Joint tests of zero restrictions on the coefficients of the deleted dummy variables yield F-values below the critical F-value at a 5% significance level. The remaining variables appear to be robust in the sense defined by Levine and Renelt (1992). The t-statistics show that all coefficients are highly significant (at the 0.005 probability level on a one-tailed test), with the exception of the constant term and the catch-up variable of the period 1973-1989[12]. Additional tests indicate little or no evidence of serial correlation and heteroscedasticity. The equations explain about 87% of the variance of the dependent variable, so that there is no compelling reason to introduce additional explanatory variables.[13]

The distinction between the Tables 2 and 3 has to do with the fact that annual hours worked per person have been approximately halved since 1870 (see Appendix). When hours of work are long, a reduction can generally be expected to result in some offsetting increase in output per man-hour. Scott (1989) mentions several studies showing that such an offset exists. Authors disagree, however, as to how much should be allowed for increased productivity as hours fall. That is the reason we present both tables here. The equations in Table 2 implicitly assume that the offset is absent, whereas the equations in Table 3 imply a complete compensation for change in hours. It is to be expected that the truth lies somewhere in between these extremes. As things stand now, statistical tests favour equation (1) over (1A)[14].

It is interesting to see whether our results are robust in case the core sample is extended or the growth equation is fitted to observations from a different data set. First, we extended the core sample by including eight additional countries as in Maddison (1991, 1992): Italy, Austria, Belgium, Denmark, Finland, Norway, Sweden and Switzerland. For Italy, we used the investment series of Rossi, Sorgato and Toniolo (1992), which starts in 1890[15]. For the other countries the investment ratios are derived from the OECD National Accounts, which begin in 1950[16]. Altogether, the core sample is extended to 84 observations. The results are presented in equations (3) and (4) of Table 2 and the equations (3A) and (4A) of Table 3. In equations (4) and (4A) a common dummy variable is applied to all Scandinavian countries. This dummy variable appears to be significant. Separate dummies for the Scandinavian countries give grosso modo the same outcome. As appears by comparing equations (2) and (4), with respectively, equations (2A) and (4A), the results obtained for the core sample are robust with respect to an extension of the sample along the lines set forth by Maddison.

Second, the fundamental growth equation was tested applying the post-WW II data set by Summers and Heston (1991). Oil producing countries were eliminated, as were small countries (less than 1 million inhabitants) resulting in a sample of 245 observations (95 countries and three time periods if available). Applying OLS results in:

$$g = \underset{(-0.24)}{-0.16} + \underset{(5.66)}{0.12\sigma} + \underset{(5.45)}{0.77 g_{\ell}} - \underset{(-3.41)}{0.79 \ell n cu_{1950}} - \underset{(-4.33)}{0.80 \ell n cu_{1960}} + \underset{(0.46)}{0.09 \ell n cu_{1973}}$$

$\overline{R}^2 = 0.25\,,\ N = 245$

Absolute t-statistics are shown in brackets. Labour input is measured in persons, so that the result should be compared to equations (2A) and (4A) in Table 2. Here again the main results of our analysis stand upright: (1) technological change is endogenous; there is no indication of an autonomous factor; (2) catching up is limited to the fifties and sixties; there is no catch up after 1973. The impact of the explanatory variable *cu* from 1950 to 1973 is less than in the Maddison samples, as may be expected in a sample with very heterogeneous countries. Moreover, the equation explains only 25% of the variance of the dependent variable. A distinction between different growth clubs would undoubtedly improve these results (e.g. Dowrick and Gemmell, 1991; Dowrick, 1992). However, for our purpose there is no need to go into so much detail.

The robustness of our results can also be investigated by introducing a measure of investment in human capital as an additional explanatory variable. Investment in human capital or schooling differs substantially before and after WW II and may thus explain part of the acceleration in economic growth from 1950-1973[17]. To account for this possibility equation (4) of Table 2, which now includes the catch-up variable for the last sub-period, is reestimated by including a proxy for human capital investment:

$$g = 0.17 + 0.13\sigma + 0.82 g_{\ell} - 2.12 \ell ncu_{1950} - 3.45 \ell ncu_{1960} - 0.47 \ell ncu_{1973}$$
(0.45) (4.94) (11.17) (-8.81) (-9.92) (-0.80)

$$+ 0.22\sigma D_{38\text{-}50} - 0.05\sigma D_{Aus} - 0.04\sigma D_{Scandinavia} - 0.13 \ell nSEC$$
(5.79) (-2.49) (-3.02) (-1.58)

$\bar{R}^2 = 0.87$, $N = 84$ 2

Investment in human capital is approximated by *SEC*, the Secondary School Enrollment Ratio as used by Barro (1991) and Levine and Renelt (1992)[18]. It appears that our claim about the insignificance of the constant term (endogenous growth) and the significance of catching-up from 1950-1973 stands up to this additional test very well. The human capital variable P*nSEC* is not statistically significant at the 10% level and does not improve the overall fit of the equation. For this reason we do not go further into the subject.

4. Discussion of the results

As appears from regression equation (2) in Table 2 we found the process of economic growth to be steady over eight countries and eight distinct sub-periods since 1870, interrupted only by some events like WW II and the impact of convergence towards the US in productivity and lifestyle during the fifties and sixties. As observed before, the explained variance of our growth equation (2) is 87%[19], while the coefficients on the investment ratio (0.14) and the growth rate of working hours (0.83) are highly significant and robust[20]. The constant term does not differ significantly from zero, so that the hypothesis of endogenous growth cannot be rejected.

The robustness of the growth equation over time and across countries is a remarkable phenomenon. It points towards a **normal pattern** of investment and growth since the second industrial revolution, which started around 1870 (Chandler, 1990). As exceptions confirm the rule, it is rewarding to look at deviations from the normal pattern. There are two minor deviations. First, it is evident that the period including the second world war was one of high turbulance. It should be recalled in this connection that data for this period refer only to countries which did not suffer from foreign occupation (Australia, Canada, UK, USA). The higher productivity of investment during this period can, therefore, be explained in terms of an increase in X-efficiency. Second, the growth performance of the Australian economy is below the mark. Although this underperformance should be studied in more detail to warrant definitive conclusions, our rough estimate is that the isolated geographical location, protectionist policies and small domestic market size may have hampered a full integration in the industrializing world economy.[21]

The major exception with respect to continuity in the process of economic growth was of course the process of catching up **vis a vis** the US economy in the fifties, which became even somewhat stronger in the sixties. As documented in Maddison (1991), Ambramovitz (1989) and others, this golden era of economic growth in Western Europe is quite unique. It is not necessary to recapitulate the factors that caused this exceptional development in detail. However it is remarkable that catching up in the sixties was more pronounced. Post-war relocations and adjustments were completed by then and massive foreign investment from the US to Europe speeded up the transfer of technological and managerial knowledge. However, what needs to be stressed is that the European economies were back on the historical track after 1973. Catching up is no longer a relevant issue, despite a remaining gap in productivity levels compared with the US, as presented in the Appendix. There are at least two factors which may be of some help explaining this robust result. First, catching up should not be regarded as a linear and mechanical process. Before WW II, European countries like France and Germany had substantially lower productivity levels than did the US, but the catch-up variable is insignificant for this period, as shown in section 3. This result confirms the view of Ambramovitz (1989) and Inkster (1990) that catching up requires adequate preconditions in terms of institutions and cultures to be effective. Moreover, countries may grow differently by choosing specific technological trajectories, as shown for instance by Chandler (1990) in his description and comparison of economic growth in the UK and the US from 1870 to 1948. Second, looking at the post-WW II experience, macroeconomic stability differs in the period before and after 1973. According to Boltho (1982) and Maddison (1991), this may explain to a large extent the difference in growth performance across these periods, leaving less mileage for the catch-up hypothesis. Although this proposition seems exaggerated and the causality could perhaps be reversed, business cycles and the resulting uncertainties after 1973 may be partly responsible for a failure to realize what may have been left in terms of a potential for catch up. Uncertainty may lead to a lower investment ratio, but that would not be enough to explain the irrelevance of catching up after 1973. To explain what is at stake one has to assume that firms invested relatively less heavily in risky up-front technological improvements in times of higher uncertainty.

Extension of the core sample by including post-war data for another eight countries as in Maddision (1991)[22] leads to a significant but still small constant term as shown by regression equation (3) in Table 2. The coefficient of the investment ratio declines compared with that of equation (2), so that investment is less productive in the larger sample (N=84). Inspection of the residuals reveals that the problem is mainly due to the relatively weak growth performance of the Scandinavian countries.

Introducing a dummy variable for the set of Scandinavian countries brings the result more in line with the smaller sample (N=57), as appears to be the case in equation (4)[23]. The question of why the Scandinavian countries underperform must here, to a large extent, be left unanswered. Boltho (1982) explains sharply above-average investment ratios in Finland and Norway by their very low population densities which require much higher infrastructure investment and by the composition of their industrial output, heavily concentrated in highly capital-intensive semi-manufactures. However this may be, our growth equation (4) compares well with the result obtained for a smaller sample of countries, equation (2). This reinforces our earlier conclusion that economic expansion in the West can be characterized by a normal pattern of investment and growth, which is robust over time and across countries.

If employment is measured in persons instead of in hours, the results are not fundamentally different (see Table 3). The coefficient on the growth rate of labour input is somewhat higher, because the effects of structural labour time reductions are now not taken into account. The growth rate of persons employment correlates almost perfectly with the growth rate of output. The higher coefficient on g_P has a slightly depressing effect on the productivity of investment, while the constant term is much lower in this case. There is, consequently, no indication for exogenous technological change. Endogenous growth theory explaining technological change as a cumulative learning process fits the facts satisfactorily. It remains to be seen which measure of labour input is most suitable for explaining economic growth. Ideally, one would like to have a quality-adjusted standard of hours worked. However, lacking such data the robustness of results for changes in the measurement of labour input is reassuring, as one would expect that a correct measure of labour input sits somewhere between labour input in hours and in persons.

The question may be raised whether our analysis is vulnerable to the critique of De Long (1988) with respect to applying the Maddison data set. According to De Long, there may be selection bias with respect to countries, because countries with relatively high GDP per capita levels in 1870 that did not make it in terms of economic growth afterwards are excluded from the sample (for instance Argentina, Chile, Spain, Portugal). The original sample is therefore biased, because it favours convergence. Moreover, measurement errors of GDP per capita in 1870 create the appearance of convergence where it does not exist in reality. Both points are well taken but do not seriously affect our analysis. Selection bias is not relevant, because we do not study convergence since 1870 but rather present an estimate of the fundamental growth equation showing that catch up became relevant only after WW II. Measurement errors may play a role, but it is unlikely that by taking these into account the conclusion of no catch up in the pre-WW II period would be changed.

It is instructive to compare our results with the outcomes obtained by authors studying catching up in similar terms, i.e. Scott (1989), Dowrick and Nguyen (1989), and Crafts (1992) (see Table 4). Scott's results are mainly based on his own data for the US, the UK and Japan starting at different years in the 19th century for different countries and ending the estimation period in 1973. There is a strong emphasis on US data because weights are applied based on country size, length of the sub-periods and statistical reliability[24]. The insignificant constant term is suppressed in the regression equation preferred by Scott. An important difference with our results is that we found the coefficient of the investment ratio to be stable over time, while Scott introduces a dummy variable on σ for the post-WW II period. According to Scott there was an autonomous increase in technological change (an upward shift of the fundamental growth equation) after 1950. This shift can be explained by pointing to an increase in communication between both sides of the Atlantic after the war. Such an increase in communication and exchange of information could have stimulated international knowledge spillovers, thus raising the productivity of investment on a world-wide scale. However, there seems to be no need for such an interpretation if one considers a longer post-war time period and if catching up is treated in the usual way. Multiplication of the catch up variable by σ as in Scott (1989) detracts from catching up[25]. This is compensated for by the post-war time dummy on σ. Apart from this, the post-war regression coefficients of Scott's equation are remarkably close to the results we found, as appears from Table 4.

Table 4

Comparion with other regression results

OLS estimation of g on	Table 2 (2)	Scott (1989)	Table 3 (2A)	Dowrick (1989)	Crafts (1992)
Constant	0.39		-0.13		6.10
	(1.00)		(0.33)		(5.23)
Investment ratio (σ)	0.14	0.05	0.12	0.06	0.09
	(4.33)	(2.01)	(3.68)	(2.54)	(4.69)
Labour input (g_ℓ)	0.83	0.90	1.06	0.58	0.86
	(9.57)	(8.11)	(8.89)	(3.74)	(7.75)
Catch up (ℓncu_{1950})	-2.22		-2.73	-2.01	-1.35
	(7.10)		(7.53)	(9.67)	(4.94)
Catch up (ℓncu_{1960})	-3.19		-3.62		
	(7.07)		(6.51)		
$\sigma Dummy_{1950-1973}$ (Scott)		0.08			
		(3.61)			
$\sigma \ell ncuDummy_{1950-1973}$ (Scott)		-0.05			
		(3.23)			
Dummy 1950s (Crafts)					1.45
					(5.27)
Dummy 1960s (Crafts)					2.28
					(8.24)
Reconstruction (Crafts)					1.28
					(1.72)
Reconstruction squared (Crafts)					-1.28
					(2.51)
Number of observations	57	26	57	24	70
R-Bar-Squared	0.87	0.89	0.86	0.83	0.83

Dowrick and Nguyen (1989) obtain different but significant coefficients for the investment ratio and the growth rate of labour input by applying cross-country data from the Summers and Heston data set for the period 1950-1985. The constant term is not reported. Catching up relates to the entire period under consideration. In addition, Dowrick and Nguyen (1989) test for parameter stability by splitting the sample period into three sub-periods: 1950-1960, 1960-1973 and 1973-1985. The catch-up variable appears to be significant in all sub-periods, but the coefficient of the investment ratio becomes insignificant for the last sub-period if coefficients are not restricted to being equal across sub-periods.

Crafts (1992) extends the analysis of Dowrick and Nguyen by including data for the sub-periods 1900-1913 and 1923-1938 (11 countries) based on Maddison (1982). Labour is measured in hours worked, which compares with our equation (2) in this respect. Catch up extends over the entire post-war period from 1950 to 1988. The catch-up variable has a smaller impact than in Dowrick and Nguyen, but part of the higher post-WW II growth performance is explained by reconstruction variables à la Dumke (1990). Despite this extension, dummies for the 1950s and 1960s are required in order to get a good fit. Crafts explains this increase in productivity by referring to the possibility of long swings in economic growth, on the one hand, and by the impact of trade liberalization in those years, on the other hand. Here, as in Scott, the problem seems to be how to reconcile pre-war and post-war data on economic growth. However, the problem may well be that catching up in the 1950s and 1960s is not given proper weight by the procedure chosen.

The idea of "back to normal," as implied by our regression results, explains the growth slowdown after 1973 in the European countries and Japan rather well, as inspection of the residuals in Table 5 shows. The slowdown in the US remains nevertheless partly unexplained. We predict a US growth rate of 3.5% for the period after 1973, which is too high compared with the actual growth rate of 2.7%. In contrast, our predictions for the fifties and sixties are too low. A hint of an explanation may be found in the relevance of mutual technological spillovers analysed in a different historical context by Inkster (1990). According to this view the US economy may have profited from feedback effects related to the catch up in other countries. When catching up came to an end the US may have suffered a decline in international technological spillovers. There may of course be different reasons for a productivity slowdown in the US, but it remains to be seen whether the negative residual in the last period foreshadows a structural deviation from the general pattern of economic growth. What this example reveals is that it is rewarding to study in detail country-specific and period-specific deviations from the normal growth pattern, even if these deviations are not statistically significant. This holds *a fortiori* in case genuine outliers are found. Fortunately, there are very few of them in the post-war period. The main exception is German output growth in the 1950s, which is underexplained in our main equation (6.1% versus 8%). This "reconstruction" effect for the German economy is well documented in Dumke (1990). Looking at a clustering of negative or positive residuals for the post-war period as a whole, it can be concluded that France does very well, while UK performance lies below average. These results correspond with the findings of Dowrick and Nguyen (1989) and Crafts (1992).

Catching up set aside, the relative contribution of investment and employment varies greatly between countries and periods. In general the investment ratio has a larger impact than the growth rate of employment. In the post-war period, the influence of g_ℓ is most marked for Australia, Canada, the US and Japan. Demographic factors (population growth, migration and rising participation rates) may be held responsible for this difference with the European countries (see Appendix). These observations merely make a start in explaining why growth rates differ. A more comprehensive explanation should include institutional factors as well as differences in national economic policies. Our econometric analysis could serve as a framework for a more detailed description of economic growth in individual countries and single periods, especially so if the sample for estimating the fundamental growth equation can be extended by including more nations as well as additional pre-WW II data.

5. Conclusion

This paper makes the case for the idea of a normal pattern of economic growth, which is robust over time and across nations if proper account is taken of exceptional situations and special circumstances. This idea is reminiscent of a normal pattern of sectoral development analysed by Chenery and Syrguin (1975). The advantage of these models is that idiosyncratic developments can be detected in a rigorous way. However, too much idiosyncracies may spoil normality. There is a delicate balance between exceptions and the rule in our analysis as well as in

Chenery's approach of sectoral developments. From these observations follow two important lessons, which set the agenda for further research. First, additional effort should be spent to refine the estimation of the fundamental growth equation. This requires improvement and extension of data, especially with respect to growth before WW II. It could be worthwhile, moreover, to consider different subdivisions of time with respect to countries, for which the initial and terminal points of business cycles are not synchronized. Second, our analysis could be applied to explain sectoral growth rates and deviations from the normal pattern at a disaggregated level. As developments on a sectoral level may differ substantially from the aggregate picture (e.g. Wolff, 1992), such an extension shows great promise.

Table 5

The proximate causes of growth (equation 2) in percentages

	Period	Actual growth rate (g)	Explained by σ	g_ℓ	other factors	unexplained
GERMANY						
1	1870-1890	2.384	1.553	.412		.028
2	1890-1913	3.177	1.908	1.076		-.196
3	1913-1929	1.203	1.612	-.145		-.653
4	1929-1938	3.779	1.324	1.136		.928
5	1950-1960	7.966	2.196	.854	2.684	1.841
6	1960-1973	4.373	2.388	-.675	2.513	-.242
7	1973-1989	2.051	1.977	-.493		.177
JAPAN						
8	1890-1913	2.505	1.548	.617		-.050
9	1913-1929	3.698	1.973	.207		1.127
10	1929-1938	3.594	1.842	1.002		.360
11	1950-1960	8.827	2.720	2.476	4.239	-.998
12	1960-1973	9.606	3.609	.393	5.102	.110
13	1973-1989	3.927	3.242	.557		-.262
FRANCE						
14	1870-1890	1.281	1.312	-.083		-.338
15	1890-1913	1.658	1.413	-.082		-.061
16	1913-1929	1.865	1.521	-.419		.372
17	1929-1938	-.394	1.645	-2.641		.211
18	1950-1960	4.566	1.864	-.010	2.023	.299
19	1960-1973	5.408	2.308	.101	2.256	.351
20	1973-1989	2.324	2.025	-.603		.513
NETHERLANDS						
21	1913-1929	3.647	2.017	.619		.620
22	1929-1938	.327	1.893	.372		-2.328
23	1950-1960	4.611	2.469	.359	1.729	-.337
24	1960-1973	4.832	2.686	-.331	1.961	.125
25	1973-1989	1.991	1.988	-.289		-.098
AUSTRALIA						
26	1870-1890	4.495	.950	3.611		-.456
27	1890-1913	2.561	.797	.544		.828
28	1913-1929	1.291	.938	.009		-.045
29	1929-1938	2.057	.801	.765		.099
30	1938-1950	3.481	.773	1.053	2.194	-.930
31	1950-1960	4.043	1.454	1.024	.891	.283
32	1960-1973	5.210	1.521	2.148	1.183	-.032
33	1973-1989	3.125	1.405	1.264		.066
UNITED KINGDOM						
34	1870-1890	2.048	.905	.513		.238
35	1890-1913	1.763	.951	.588		-.167
36	1913-1929	.7051	.719	-.614		.209
37	1929-1938	1.895	.806	.805		-.106
38	1938-1950	1.626	.754	-.508	1.173	-.183
39	1950-1960	2.865	1.530	.460	1.250	-.766
40	1960-1973	3.159	1.930	-.579	1.850	-.431
41	1973-1989	1.949	1.896	-.099		-.237

CANADA						
42	1870-1890	3.061	1.516	1.220		-.065
43	1890-1913	4.952	2.068	1.640		.853
44	1913-1929	2.797	1.848	.999		-.440
45	1929-1938	-.035	1.407	-.127		-1.705
46	1938-1950	5.779	1.454	.379	2.263	1.293
47	1950-1960	4.581	2.373	1.205	.653	-.041
48	1960-1973	5.446	2.408	2.115	.746	-.212
49	1973-1989	3.601	2.174	1.498		-.460
UNITED STATES						
50	1870-1890	3.983	1.327	1.974		.292
51	1890-1913	3.897	1.484	1.364		.658
52	1913-1929	3.100	1.533	.544		.632
53	1929-1938	-.708	1.333	-1.760		-.671
54	1938-1950	5.076	1.360	1.525	2.117	-.316
55	1950-1960	3.252	1.703	.637		.522
56	1960-1973	3.951	1.764	1.222		.574
57	1973-1989	2.671	1.799	1.265		-.783

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Appendix

I Observations (1870-1989) with labour input man-hours

	Period	g	g_ℓ (hours)	$g-g_\ell$	σ	cu
GERMANY						
1	1870.0	2.3841	.49382	1.8903	11.4690	.50664
2	1890.0	3.1777	1.2895	1.8881	14.0838	.53747
3	1913.0	1.2037	-.17426	1.3780	11.9000	.49533
4	1929.0	3.7793	1.3616	2.4177	9.7778	.41991
5	1950.0	7.9662	1.0239	6.9422	16.2100	.29890
6	1960.0	4.3739	-.81003	5.1839	17.6308	.45520
7	1973.0	2.0517	-.59095	2.6426	14.5933	.64432
JAPAN						
8	1890.0	2.5055	.74031	1.7652	11.4261	.20537
9	1913.0	3.6986	.24828	3.4503	14.5688	.18454
10	1929.0	3.5948	1.2009	2.3939	13.6000	.21589
11	1950.0	8.8279	2.9677	5.8602	20.0800	.14849
12	1960.0	9.6061	.47124	9.1349	26.6385	.20236
13	1973.0	3.9275	.66769	3.2598	23.9333	.45784
FRANCE						
14	1870.0	1.2814	-.099901	1.3813	9.6900	.55896
15	1890.0	1.6585	-.099296	1.7578	10.4315	.53757
16	1913.0	1.8650	-.50290	2.3679	11.2312	.48387
17	1929.0	-.39467	-3.1654	2.7707	12.1444	.47990
18	1950.0	4.5667	-.013043	4.5798	13.7600	.40235
19	1960.0	5.4083	.12156	5.2868	17.0385	.49334
20	1973.0	2.3247	-.72308	3.0478	14.9467	.70299
NETHERLANDS						
21	1913.0	3.6475	.74220	2.9053	14.8890	.68950
22	1929.0	.32759	.44612	-.11853	13.9778	.73975
23	1950.0	4.6110	.43036	4.1806	18.2300	.45934
24	1960.0	4.8323	-.39691	5.2293	19.8308	.54112
25	1973.0	1.9910	-.34683	2.3378	14.6800	.76820
AUSTRALIA						
26	1870.0	4.4953	4.3279	.16740	12.7800	1.3228
27	1890.0	2.5610	.65284	1.9082	10.7217	.99820
28	1913.0	1.2919	.011004	1.2809	12.6125	.92655
29	1929.0	2.0571	.91795	1.1392	10.7780	.77321
30	1938.0	3.4814	1.2624	2.2190	10.4083	.75265
31	1950.0	4.0439	1.2279	2.8160	19.5600	.66969
32	1960.0	5.2100	2.5742	2.6359	20.4615	.69037
33	1973.0	3.1255	1.5149	1.6106	18.9000	.70084
UNITED KINGDOM						
34	1870.0	2.0480	.61521	1.4328	6.6850	1.0446
35	1890.0	1.7631	.70562	1.0575	7.0261	1.0129
36	1913.0	.70519	-.73580	1.4410	5.3125	.77619
37	1929.0	1.8953	.96470	.93060	5.9556	.66544
38	1938.0	1.6262	-.60890	2.2351	5.5667	.63590
39	1950.0	2.8657	.55225	2.3134	11.3000	.56964
40	1960.0	3.1595	-.69452	3.8541	14.2462	.56031
41	1973.0	1.9497	-.11963	2.0693	14.0000	.67095
CANADA						
42	1870.0	3.0619	1.4632	1.5987	11.1900	.64243
43	1890.0	4.9520	1.9660	2.9861	15.2652	.64180
44	1913.0	2.7977	1.1983	1.5993	13.6437	.75124
45	1929.0	-.035769	-.15312	.11735	10.3889	.65725
46	1938.0	5.7797	.45457	5.3251	10.7333	.58444
47	1950.0	4.5812	1.4444	3.1368	17.5200	.74516
48	1960.0	5.4467	2.5346	2.9122	17.7769	.79167
49	1973.0	3.6018	1.7955	1.8063	16.0467	.83166

UNITED STATES

50	1870.0	3.9836	2.3656	1.6180	9.7950	1.0000
51	1890.0	3.8979	1.6351	2.2627	10.9565	1.0000
52	1913.0	3.1007	.65237	2.4484	11.3187	1.0000
53	1929.0	-.70822	-2.1101	1.4019	9.8444	1.0000
54	1938.0	5.0766	1.8276	3.2490	10.0417	1.0000
55	1950.0	3.2527	.76402	2.4887	12.5700	1.0000
56	1960.0	3.9517	1.4648	2.4869	13.0231	1.0000
57	1973.0	2.6713	1.5170	1.1543	13.2800	1.0000

II Observations (1870-1989) with labour input persons

	Period	g	g_ℓ (persons)	$g-g_\ell$	σ	cu
GERMANY						
1	1870.0	2.3841	.80437	1.5797	11.4690	.50271
2	1890.0	3.1777	1.5881	1.5895	14.0838	.53284
3	1913.0	1.2037	.59869	.60506	11.9000	.49134
4	1929.0	3.7793	1.2050	2.5743	9.7778	.40951
5	1950.0	7.9662	2.1106	5.8555	16.2100	.37078
6	1960.0	4.3739	.28587	4.0880	17.6308	.52773
7	1973.0	2.0517	.13011	1.9215	14.5933	.67697
JAPAN						
8	1890.0	2.5055	1.0384	1.4671	11.4261	.20397
9	1913.0	3.6986	.81711	2.8815	14.5688	.18334
10	1929.0	3.5948	1.0733	2.5215	13.6000	.21792
11	1950.0	8.8279	2.2717	6.5562	20.0800	.17227
12	1960.0	9.6061	1.2635	8.3426	26.6385	.26132
13	1973.0	3.9275	.96038	2.9672	23.9333	.55810
FRANCE						
14	1870.0	1.2814	.20657	1.0748	9.6900	.55537
15	1890.0	1.6585	.19633	1.4622	10.4315	.53391
16	1913.0	1.8650	.24163	1.6234	11.2312	.48071
17	1929.0	-.39467	-.79670	.40202	12.1444	.47068
18	1950.0	4.5667	.023370	4.5433	13.7600	.41507
19	1960.0	5.4083	.74160	4.6667	17.0385	.52742
20	1973.0	2.3247	.13573	2.1890	14.9467	.72510
NETHERLANDS						
21	1913.0	3.6475	1.6407	2.0068	14.8890	.68950
22	1929.0	.32759	.52545	-.19786	13.9778	.71385
23	1950.0	4.6110	1.1739	3.4371	18.2300	.54323
24	1960.0	4.8323	.82213	4.0102	19.8308	.61829
25	1973.0	1.9910	1.1153	.87570	14.6800	.78341
AUSTRALIA						
26	1870.0	4.4953	4.6480	-.15265	12.7800	1.3144
27	1890.0	2.5610	.95069	1.6103	10.7217	.99140
28	1913.0	1.2919	1.2092	.082769	12.6125	.92050
29	1929.0	2.0571	1.0711	.98598	10.7780	.70619
30	1938.0	3.4814	2.4337	1.0477	10.4083	.77017
31	1950.0	4.0439	1.6274	2.4165	19.5600	.65929
32	1960.0	5.2100	2.8425	2.3675	20.4615	.67960
33	1973.0	3.1255	1.8080	1.3175	18.9000	.69716
UNITED KINGDOM						
34	1870.0	2.0480	.92330	1.1247	6.6850	1.0517
35	1890.0	1.7631	1.0012	.76185	7.0261	1.0194
36	1913.0	.70519	.12341	.58178	5.3125	.78185
37	1929.0	1.8953	1.0584	.83693	5.9556	.64953
38	1938.0	1.6262	.61222	1.0140	5.5667	.69912
39	1950.0	2.8657	.78632	2.0793	11.3000	.59741
40	1960.0	3.1595	.26594	2.8936	14.2462	.59714
41	1973.0	1.9497	.40612	1.5436	14.0000	.65961
CANADA						
42	1870.0	3.0619	1.7724	1.2895	11.1900	.64243
43	1890.0	4.9520	2.2690	2.6830	15.2652	.64180
44	1913.0	2.7977	1.7207	1.0769	13.6437	.75124
45	1929.0	-.035769	.61057	-.64634	10.3889	.67324
46	1938.0	5.7797	1.5485	4.2313	10.7333	.63489
47	1950.0	4.5812	1.9206	2.6606	17.5200	.78507
48	1960.0	5.4467	2.9184	2.5283	17.7769	.82783
49	1973.0	3.6018	2.2193	1.3824	16.0467	.86605

UNITED STATES

50	1870.0	3.9836	2.6776	1.3060	9.7950	1.0000
51	1890.0	3.8979	1.9372	1.9607	10.9565	1.0000
52	1913.0	3.1007	1.3241	1.7766	11.3187	1.0000
53	1929.0	-.70822	-.71534	.0071223	9.8444	1.0000
54	1938.0	5.0766	2.6741	2.4025	10.0417	1.0000
55	1950.0	3.2527	1.1611	2.0916	12.5700	1.0000
56	1960.0	3.9517	1.8121	2.1396	13.0231	1.0000
57	1973.0	2.6713	1.9499	.72140	13.2800	1.0000

III Participation rates (Part) and annual hours worked per person (Hours)[26]

	Year 1	Year 2	Part in year 1	Part in year 2	Hours in year 1	Hours in year 2
GERMANY						
1	1870.0	1890.0	26.1528	24.4573	2.9410	2.7650
2	1890.0	1913.0	24.4573	25.8339	2.7650	2.5840
3	1913.0	1929.0	25.8339	29.4058	2.5840	2.2840
4	1929.0	1938.0	29.4058	30.9286	2.2840	2.3160
5	1950.0	1960.0	42.3424	47.0478	2.3160	2.0810
6	1960.0	1973.0	47.0478	43.6717	2.0810	1.8040
7	1973.0	1989.0	43.6717	44.5798	1.8040	1.6070
JAPAN						
8	1890.0	1913.0	50.6650	49.8355	2.7700	2.5880
9	1913.0	1929.0	49.8355	46.3791	2.5880	2.3640
10	1929.0	1938.0	46.3791	44.9227	2.3640	2.3910
11	1950.0	1960.0	43.0434	47.8983	2.1660	2.3180
12	1960.0	1973.0	47.8983	48.3987	2.3180	2.0930
13	1973.0	1989.0	48.3987	49.7742	2.0930	1.9980
FRANCE						
14	1870.0	1890.0	46.3059	48.3325	2.9450	2.7700
15	1890.0	1913.0	48.3325	48.7956	2.7700	2.5880
16	1913.0	1929.0	48.7956	48.9207	2.5880	2.2970
17	1929.0	1938.0	48.9207	44.7307	2.2970	1.8480
18	1950.0	1960.0	47.0002	43.1420	1.9260	1.9190
19	1960.0	1973.0	43.1420	41.6286	1.9190	1.7710
20	1973.0	1989.0	41.6286	39.4801	1.7710	1.5430
NETHERLANDS						
21	1913.0	1929.0	37.8001	38.8461	2.6050	2.2600
22	1929.0	1938.0	38.8461	36.4882	2.2600	2.2440
23	1950.0	1960.0	40.7356	40.3099	2.2080	2.0510
24	1960.0	1973.0	40.3099	38.3213	2.0510	1.7510
25	1973.0	1989.0	38.3213	41.4169	1.7510	1.3870
AUSTRALIA						
26	1870.0	1890.0	38.8889	50.3058	2.9450	2.7700
27	1890.0	1913.0	50.3058	40.3028	2.7700	2.5880
28	1913.0	1929.0	40.3028	36.8199	2.5880	2.1390
29	1929.0	1938.0	36.8199	37.5435	2.1390	2.1100
30	1938.0	1950.0	37.5435	42.3016	2.1100	1.8380
31	1950.0	1960.0	42.3016	39.5620	1.8380	1.7670
32	1960.0	1973.0	39.5620	43.3321	1.7670	1.7080
33	1973.0	1989.0	43.3321	46.3078	1.7080	1.6310
UNITED KINGDOM						
34	1870.0	1890.0	39.1329	39.3864	2.9840	2.8070
35	1890.0	1913.0	39.3864	40.6712	2.8070	2.6240
36	1913.0	1929.0	40.6712	41.4609	2.6240	2.2860
37	1929.0	1938.0	41.4609	43.8329	2.2860	2.2670
38	1938.0	1950.0	43.8329	44.4771	2.2670	1.9580
39	1950.0	1960.0	44.4771	46.2547	1.9580	1.9130
40	1960.0	1973.0	46.2547	44.6113	1.9130	1.6880
41	1973.0	1989.0	44.6113	46.7468	1.6880	1.5520
CANADA						
42	1870.0	1890.0	34.7707	37.5339	2.9640	2.7890
43	1890.0	1913.0	37.5339	39.3832	2.7890	2.6050
44	1913.0	1929.0	39.3832	39.4265	2.6050	2.3990
45	1929.0	1938.0	39.4265	37.4754	2.3990	2.2400
46	1938.0	1950.0	37.4754	36.6164	2.2400	1.9670
47	1950.0	1960.0	36.6164	33.9717	1.9670	1.8770
48	1960.0	1973.0	33.9717	40.0643	1.8770	1.7880
49	1973.0	1989.0	40.0643	47.8665	1.7880	1.6730

UNITED STATES

50	1870.0	1890.0	36.8876	39.5997	2.9640	2.7890
51	1890.0	1913.0	39.5997	39.9282	2.7890	2.6050
52	1913.0	1929.0	39.9282	39.3488	2.6050	2.3420
53	1929.0	1938.0	39.3488	34.5598	2.3420	2.0620
54	1938.0	1950.0	34.5598	40.4877	2.0620	1.8670
55	1950.0	1960.0	40.4877	38.2989	1.8670	1.7950
56	1960.0	1973.0	38.2989	41.2399	1.7950	1.7170
57	1973.0	1989.0	41.2399	47.8461	1.7170	1.6040

NOTES

1. We are grateful to Angus Maddison for providing us with a data diskette on time series of investment ratios. We should also like to thank Sjak Smulders and the participants of the CEPR Workshop "Interpreting Economic Growth" in Berlin (June 1993) for useful comments on an earlier version of the paper.
2. To illustrate his point, Scott (1989) mentions replacements for a fleet of taxis which are included in gross investment, because they are lumpy, whereas they should be included in maintenance.
3. As shown in Diederen (1993), the Kamien-Schwartz model can easily be adapted to a model of endogenous growth similar in spirit to the model of Scott.
4. Scott (1989) accounts for catch up in a somewhat different manner by premultiplying the catch-up variable in equation (4) by σ. This result comes from the specification of the growth equation as an investment programme contour that shifts along a radius under the impact of different factors (dummies, catch up, etc.).
5. Sub-periods should be of approximately equal length to allow for a uniform impact of catching up across the sample.
6. From Maddison (1991): Table A.2, *Gross Domestic Product in 1985 US Relative Prices (adjusted to exclude impact of boundary changes)*, Table C.8, *Total Employment, 1870-1989* and Table C.9, *Annual Hours Worked per Person, 1870-1989*. From Maddison (1992): *Gross Non-Residential Fixed Investment as % of GDP, 1870-1988.* The missing figures for France (1870-1938) were derived by scaling the time series for Gross Fixed Investment as % of GDP. The missing figures for Germany (1870-1924) were obtained by adjusting the series of Hoffman (1965) to that of Maddison. The investment ratio for the Netherlands (1913-1929) is the average of 1921-1929. The investment ratios of the sample are the annual averages of 1871-1890, 1891-1913, 1914-1929, 1930-1938, 1939-1950, 1951-1960, 1961-1973 and 1974-1988.
7. Alternatively, trend growth rates of employment and output could be estimated by, for instance, piecewice linear trend regression. Complete time series for employment are lacking, however, so that we have to rely on comparing peak levels.
8. The data of the core sample are presented in the Appendix.
9. There are only three out of 57 cases with negative output growth: France, Canada and the US in the 1930s. See Appendix.
10. The bottom of the table shows the F-statistics of the Lagrange multiplier test of residual serial correlation, the Ramsey RESET test using the square of the fitted values as additional explanatory variable and a test on heteroscedasticity based on the regression of squared residuals on squared fitted values.
11. White's heteroscedasticity-consistent t-statistics (not reported here) deviate only slightly from the t-statistics in the tables.

12. This holds for equation (1) in Table 2. For equation (1A) in Table 3, the coefficient of the investment ratio is significant at the 0.01 probability level.
13. Potential additional variables are human capital accumulation and the share of exports in GDP. The impact of human capital could not be tested because adequate proxi variables are not easy available before WW II. The share of exports in GDP proved to be statistically highly insignificant and of the wrong sign. In this connection it should be recalled that the growth equation (3) is concave in σ and g_P. However, both investment ratio squared and labour input growth squared are not significant.
14. To check for a simultaneous equation bias equation (2) in Table 2 is reestimated by applying 2SLS. This results in: $g = 0.24 + 0.15\sigma + 0.83g_P - 2.17Pncu_{1950} - 3.08Pncu_{1960} + 0.21\sigma D_{38\text{-}50} - 0.06\sigma D_{aus}, R^2 = 0.87$. As the differences with OLS estimation in Table 2 are very minor no further use is made of instrumental variables.
15. Gross Non-Residential Fixed Investment comes from adding the time series on Public Works and Machinery Equipment in current prices. This is related to GDP at market prices from the same paper. The average investment ratios are 8.4 (1890-1913), 10.7 (1913-1929), 11.3 (1929-1938), 14.2 (1950-1960), 15.3 (1960-1973) and 16.0 (1973-1989).
16. Source: OECD (1970), (1990) and (1992).
17. This hypothesis was suggested by N. Crafts in discussing an earlier version of the paper.
18. For each sub-period the (initial) Secondary Enrollment Rate is the ratio of the number of pupils in secondary schools and population in age group 15-19 calculated from Mitchell (1982, 1992, 1993). For Canada *SEC* is approximated by the US enrollment rates.
19. This is reduced to 82% in case of $g\text{-}g_P$ as independent variable. Other empirical growth studies (Barro, 1991; Mankiw, Romer and Weil, 1992) explain $g\text{-}g_P$ instead of g. This reduces the t-value for g_P (t=1.89) on the RHS of equation (2). In case of equation (2A) the coefficient of g_P then becomes insignificant (t=0.50). This result (population growth is not robust), which is stressed by Levine and Renelt (1992), actually depends on measuring labour input growth in persons and choosing labour productivity as the variable that has to be explained.
20. Robustness of the results here refers to the tests reported in section 3.
21. If the Australian economy is included without a dummy, the constant term in the regression equation and its t- value become higher as should be the case when observations relating to a lower growth curve are combined with observations relating to the normal pattern.
22. Notice that for Italy also pre-war data have been added to the core sample.
23. The dummy is one in each postwar subperiod (multiplied by σ) for Denmark, Norway, Sweden and Finland and zero for the other countries. As explained in note 18, the introduction of dummies for underperforming countries reduces also the constant term.
24. Scott defends this by pointing at heteroscedasticity in the unweighted regression. Testing for heteroscedasticity of our results does not reveal serious problems of this kind (see section 3).

25. Applying Scott's procedure to our data (1870-1973) results in:

$$g = \underset{(0.33)}{0.175} + \underset{(3.62)}{0.166\sigma} + \underset{(7.89)}{0.817g_\ell} - \underset{(-4.98)}{0.106\sigma\ell ncu_{50}} - \underset{(-4.66)}{0.119\sigma\ell ncu_{60}} + \underset{(4.50)}{0.20\sigma D_{38\text{-}50}} - \underset{(-2.88)}{0.07\sigma D_{Aus}}$$

$$\overline{R}^2 = 0.86 \qquad N = 49$$

All coefficients are significant except the constant term. As appears from this equation, the influence of catching up on growth is reduced substantially. It is about 20% of the impact in our equation (1).

26. Part / Total Employment (persons)/Total Population.