Accumulation, Productivity and Technology: Measurement and Analysis of Long Term Economic Growth

By Bart van Ark
Groningen Growth and Development Centre
University of Groningen, The Netherlands

Abstract
This paper provides a brief overview of the "state of the art" on research on the sources of long term economic growth. It is argued that, despite the enormous progress in development of the theory and empirics on long term economic growth, we are still not able to unambiguously distinguish between the determinants of growth. The distinction between accumulation, productivity and technology is a useful device to structure the debate, as the former two tend to emphasize the importance of investment and increased efficiency in use of resources, whereas the latter puts the contribution of invention and innovation change into the spotlight. However, the most powerful explanations of economic growth are those which combine these various aspects of growth with an explicit focus on historical, institutional and political factors in the growth process. To strengthen empirical research, the paper recommends greater attention for reconstruction of historical national accounts, the development of a broad range of technology indicators

1. Introduction

During the past two centuries the world economy has experienced unprecedented growth. Between 1820 and 1997, World Gross Domestic Product in constant prices has increased at about 2.2 % per year on average, which is between six and seven times the world growth rate during the preceding period, 1500 to 1820 (Maddison, 1995). However, the fortunes of growth have been distributed unequally over time as well over space. Almost everywhere in the world, growth rates have accelerated since 1870 and once again since 1950. Since the mid 1970s growth of the world economy has slowed down, even though the overall growth rate is still considerably higher than before 1950. Whereas the growth acceleration between 1870 and 1973 has been pretty much world wide, people have benefited from it to different degrees given the large differences in population growth rates. Hence in terms of income per head of the population, Northwest Europe, North America and Japan have shown much faster growth than the rest of the world between

1820 and 1992. Today's developing world has also known phases of rapid growth, but at different times and different places. For example, GDP per capita in Latin America improved relatively rapidly during the first half of the twentieth century, whereas Southern Europe and East and Southeast Asia have experienced high growth rates relative to the rest of the world since 1950.

A main issue for historical research in economic growth is to understand what explains this diversity in long run economic growth. What has caused the acceleration of growth since 1870, the extraordinary rapid growth between 1950 and 1973, and the slowdown since 1973? Why has the population in Europe, Japan and North America benefited most strongly from the "golden era" between 1950 to 1973? Why have all regions except East Asia faced a substantial slowdown in growth since 1973? To what extent has the acceleration of output growth arisen from putting more resources into the production process (accumulation), from a more efficient use of those resources (productivity), or from better technology? Do we have the theoretical and empirical understanding to unambiguously distinguish between these sources of growth? And how important is the broader historical, institutional and political context in which the sources of growth are analyzed?

This paper gives a brief overview of the "state of the art" of research on the sources of economic growth. Section 2 reviews the various theoretical and conceptual approaches which have been employed to disentangle the sources of growth.[1] Section 3 discusses the major empirical sources required for the study of long-run economic growth, and in particular reviews the reconstruction of historical national accounts.[2] Section 4 reports results from recent work on assessing the sources of growth of advanced economies.[3] Section 5 concludes with recommendations for the future research agenda in this field.

2. Analytical Approaches to Economic Growth

To disentangle the sources of economic growth one requires an analytical framework to assess the contribution of various factors to growth. This involves the formulation of theories, models and hypotheses on the role of accumulation, productivity and technology. Over the past decades this has been mainly the domain of economists and economic historians, but as yet there is no consensus on what emphasis should be given to the key factors behind growth and how these are linked.

Accumulation concentrates on the role of investment and the effect of investment on the stock of physical, human and natural resources. It is strongly represented by Post-Keynesian growth theories, which started with Harrod (1939) and Domar (1946), but became more advanced with Kaldor (1957) and more recently Scott (1989). The traditional neoclassical approach also starts from the accumulist perspective by relying on a production function framework (Solow, 1956, Swan, 1956).

However, in the empirical work on sources of growth, referred to as "growth accounting", the contribution of productivity became visible. Tinbergen (1942), Abramovitz (1956) and Solow (1957) defined output as a function of labour and capital, weighted at their respective factor shares in value added. Then they identified a "residual" which accounts for the difference in the growth of output and the contribution of the inputs. This residual has been named "total factor productivity" (or the "Solow residual") and has often, in particular by economists, been equated with technical progress. According to these early growth accounting studies, total factor productivity growth contributed very substantially to economic growth. For example, Solow (1957) reported that 52 per cent of US output growth between 1909 and 1949 was due to TFP growth. Kendrick (1961, 1976) has contributed to the growth accounting tradition by augmenting factor inputs with the quality of labour (distinguished by levels of education, and age- and sex- composition) and capital (distinguished by vintage effects).

In the growth literature of the 1960s a discussion emerged on the extent to which technical progress was, at least partly, embodied in the factor inputs (Solow, 1960). Salter (1960) clearly argues the case that capital accumulation is the main vehicle of technical progress, and he introduced the vintage approach to capital accumulation. However, Salter argues that a clear distinction between technical progress and economies needs to made and that the latter contributed significantly more to growth than the former. Jorgenson made a clear distinction between investment and productivity.[4] He applied a rigorous criterion, namely that investments concern commitment of current resources in the expectation of future returns, which implies that the returns can be internalized by the investor. In contrast, productivity relates to incomes that are generated external to the economic activities undertaken by the investor. Hence productivity is associated with spillovers and externalities that cannot be appropriated. The effects of substitution between labour and capital or between different types of capital is therefore part of the investment process, leaving less room for productivity growth as a contributing factor to growth than in the more aggregate growth accounting approaches.

Another strand in the growth accounting tradition focussed in more detail on the opening up of the "black box", i.e. the residual, that remains after allowing for the contribution of the quantity and quality of labour, capital and land to growth. The work by Denison (1962, 1967, 1974, 1979) has been of fundamental importance in understanding the role of economies of scale, allocation of resources, advances in knowledge, and the effects of irregularities in demand. Maddison (1972, 1982, 1991, 1996) has continued to expand international comparisons of growth accounting by quantifying the contributions of augmented inputs, foreign trade effects, catch-up effects, structural effects and economies of scale to output growth. Maddison identified these factors as typical "proximate" sources of growth as they contribute directly to changes in output growth. However, Maddison also emphasized the importance of "ultimate" sources of growth which are related to the political-institutional environment, and he stressed the importance of historical events. Hence this growth accounting strand can be linked to the historical approaches to economic growth, which will be discussed later. [5]

Traditional growth accounting measures assume that a fixed combination of inputs increases proportionally with output (i.e. it assumes constant returns), so that the residual output growth can be allocated to a more efficient use of inputs. The recent "new growth" literature has argued that the possibility of increasing returns needs to be reflected in the underlying production function. Increasing returns may either arise from physical capital (Romer, 1986, 1987), from human capital (Lucas, 1988) or from the creation of new ideas and knowledge (Romer, 1990, 1994). Many of these ideas were not really new as these were identified and measured by the earlier generations of growth theorists and growth accountants.[6] The novelty, however, lies in the attempts to model and test these ideas on the basis of econometric specifications and by giving a greater role to the firm which creates new knowledge in an environment of imperfect competition.

The testing of new growth models requires cross-section regression analysis as the coefficients on the variables cannot be assumed beforehand as in the case of the constant return models.[7] Empirical studies of increasing returns on physical capital have rejected the hypothesis (Barro and Sala-i-Martin, 1992, Mankiw, Romer and Weil, 1992). In the case of human capital, Mankiw, Romer and Weil (1992) has argued that a constant-returns Solow-model augmented with human capital included as a separate input greatly strengthens the explanatory power of the model. The most convincing approach to increasing returns comes from models on ideas and knowledge. In these models the spillover from returns on R&D, or from inventions and innovations, are seen as the main engine of growth. Recently this approach has been refined by Aghion and Howitt (1998).

It should be emphasized that the “new growth” approaches have opened up new avenues to model the role of technological change in economic growth, as the Schumpeterian concept of “creative destruction” at firm level is an essential part of knowledge models. However, the historical and empirical evidence for these models still needs to be further developed.[8] Crafts (1997) emphasizes that much of the research by economic historians on technological change and by other researchers on technology economics has largely gone unnoticed by growth economists.

A number of alternative approaches to growth puts technological change more explicitly in the spotlight. These approaches see investment in human and physical capital as a necessary but insufficient factor to achieve growth. They emphasize that countries require enterpreneurship, innovation and learning before they can employ new technologies to achieve growth. The technology approaches to growth are of a more hybrid nature than the accumulation and productivity approaches, but most studies have strong "Schumpeterian" characteristics as they give an explicit role to firms, to organizational change, management, marketing and finance and to the discontinuous nature of technological change (e.g. Schumpeter, 1943). Firstly, a range of studies recognized that the assumptions of rational optimization and perfect foresight, which are characteristic of the neoclassical approach, are not adequate in explaining the process of technological change. The evolutionary approach to economic growth therefore analyzes strategies to optimize profit (not maximize) profits under assumptions of bounded rationality. These theories much emphasis on the uncertainties of the search process and the importance of "routines" in these searches (Nelson and Winter, 1982). A major problem of the these microeconomic evolutionary models is that they cannot be solved analytically, but require computer simulation. A calibration of the Nelson and Winter-model of the time series on US sources of growth from 1909-1949 suggest results which are broadly in line with Solow's growth accounting results for 1957.[9]

A second group of studies in the Schumpeterian tradition has a more historical flavour to it. It focuses on the importance of historical factors which determine the role of institutions in the process of technological change. For example, Von Tunzelmann (1995) analyzes how the organization of science and technology, together with organization of finance, production, etc., form a "National System of Production", which differs over time and across space. A particularly important aspect of the historical approach are the concepts of "path-dependency" and "technological lock ins". These explain the economic supremacy of certain nations and regions at different points in time. For example, the advance of the United States as the world economic leader in terms of labour productivity at the end of the 19th century, is strongly related to a greater reliance on mass production strategies in combination with a rapid increase in capital intensity due to shortages of skilled labour and large economies of scale (Broadberry, 1997). Similarly the rapid growth of the East Asian economies since the 1960s can be related to a combination of large opportunities for catch-up in combination with rapid investment in human and physical capital, the opening up of economies for foreign trade and foreign direct investment, and effective government policies accompanying this process of accumulation, productivity and technological progress (World Bank, 1993). The main message of the historical studies therefore is the greater emphasis on the role of historical, institutional and political factors influencing the growth process.

3. National Accounts and the Analysis of Long Term Economic Growth

To test the theories, models and hypotheses on the sources of economic growth, one requires detailed empirical information on output and inputs, including the quantities and quality of land, labour, physical capital and human capital, and technology inputs. National accounts are a good starting point to obtain such information, as they provide a comprehensive accounting framework for output, expenditure and income. It constitutes an important improvement over the alternative of having to use scattered primary statistics, such as population and production censuses, during pre-national accounts era. Although the concept of national accounting goes back to the works of Sir William Petty and Gregory King in the late seventeenth century, the construction of national accounts according to internationally agreed accounting standards dates back no more than half a century.

The past few decades have been characterised by a great deal of activity in constructing and reconstructing of historical national accounts for many countries. Some national statistical offices have undertaken (part of) the backward reconstruction of the national accounts for the post World War-II period, but for the pre-World War II period the major contributions in this area have come from individual academic scholars in many countries.

The first generation of historical national accounts which emerged during the early post-1945 period concerned only a small number of advanced countries, including Canada, Denmark, France, Germany, Italy, Norway, Sweden, the UK and the USA. Later more industrialized countries got their historical national accounts, such as Japan, Finland and Spain. Belgium and the Netherlands are also well underway in completing historical national accounts in their first generation, and major studies for China and India are being undertaken. The national accounts of some countries, including Canada, Denmark, the UK, Sweden and the USA even went into their second, third of even fourth generations. But there is still a large group of countries outside the core of the industrialized world for which information is scattered and which lack comprehensive long-term national accounts.[10]

The international comparability of historical national accounts still leaves much to be desired for. Unlike present-day national accounts, at the time of the origin of the earlier accounts, there was no commonly accepted framework such as the post-war System of National Accounts (SNA). This has created substantial problems in the reconstruction efforts, though most scholars have adhered (more or less strictly) to the post-war SNA conventions. Some scholars have done a great deal to place historical national accounts into an international comparative perspective. For the post-1950 period, the Penn World Tables are an extensively used source on national accounts and related information for some 130 countries, whereas for a longer time span back to 1820 the work of Angus Maddison features most prominently.[11]

Even though historical national accounts greatly differ in quality, detail and sophistication, a number of general remarks can be made about the main issues of concern for international comparison of long run economic growth:

1) *Weighting procedures.* One of the main purposes of national accounts is to provide an accurate picture of the changes in real GDP and its components over time. Such changes in volume terms need necessarily be related to a benchmark year with a given basket of goods and services. The weights for the benchmark year are assumed representative for the volume index or the price index (which was used to deflate the output value in current prices) over any length of time. As it has mostly not been possible for historical national accountants to obtain information on weights for all years, one usually had to rely on a few or, in the worst case, only one benchmark year. The most appropriate approach is the use of regular shifts in benchmark years every five or ten years, and some coordination among various countries would highly increase comparability.[12]
2) *The estimation of intermediate inputs, capital and labour*. An important ingredient of any empirical study of economic growth, is the estimation of intermediate inputs and factor inputs. With the exception of manufacturing, there is very little comprehensive evidence on intermediate inputs in the production process before the era of input-

output tables. Historical sources on capital stock and capital services are only available for a very limited number of advanced countries.[13] Historical labour statistics are more widely available, but the consistency with the national accounts is still weak in many cases. Finally, the estimation of technology indicators is still insufficiently developed (Griliches, 1994).

3) The treatment of services. Much of the work on historical national accounts has focused primarily on the commodity sectors of the economy. The measurement of real output in services is not as sophisticated even though the procedures are not much different from what they mostly still are today. Historical national accounts often assume no productivity change in services and rely largely on changes in the wage bill in services. On the whole real output growth in services is likely to be understated in most accounts, because the "no productivity growth"-assumption seems quite unrealistic even for non-market services. In some cases, in particular for goods-related services, quantity indicators were used or it has been assumed that real output growth in these services moved parallel to commodity production. Another problem associated with services concerns the boundaries of the economic activity domain. For example, as household production is kept outside the boundaries of the national accounts, the growth of output in current prices in the long run is partly affected by the shift of many activities from households to the monetised sector of the economy.

4. Major Empirical Evidence and Controversies

What have we learned on the sources of economic growth over the past century? It goes beyond the scope of this paper to provide a complete overview. However, some evidence from the most recent work might illustrate the present “state of the art” and the major controversies.

Table 1 presents growth accounting estimates for six advanced economies from Maddison (1991, 1996). Maddison’s estimates are very well documented, and, for example, his procedures to obtain capital stock using a perpetual inventory method by accumulating investment and discarding assets according to standardised assumptions on asset lives, are fully transparent and can be reconstructed.[14] Maddison's estimates suggest that more than two thirds of real GDP growth since 1913 can be explained, with the notable exceptions of France and the UK from 1913-1950.

The Maddison-estimates span a relatively long period which makes his work unique.[15] For the period since World War II there are two important extensions in growth accounting. The first concerns the greater detail on input structures, which is most clearly represented in the work of Jorgenson and associates. Table 2 compares the contribution of "productivity" to GDP growth according to Maddison's and Jorgenson's estimates. Even though the periodisation of the two studies is somewhat different, it emerges that, with the exception of Japan (1950-73) and US (1973-1995), Jorgenson assigns a larger part of growth to investment than Maddison. This in particular due to the greater share of substitution between different types of labour and capital in Jorgenson's investment concept.

The second extension in growth accounting concerns the disaggregation of the estimates to sectors of the economy. Table 3 presents sectoral growth accounts for France, Germany, the Netherlands and the USA for 1973-1995 updated from Van Ark (1996). The estimates assign a large role to the rise in capital intensity in explaining labour productivity growth for France, Germany and the Netherlands relative to the United States. However, despite the greater capital intensity, TFP growth in these European countries was also faster than in the United States, in particular in manufacturing. Even in services capital intensity growth was faster in Europe than in the USA, but with the exception of Germany, European TFP growth in services was not faster than in the USA. If TFP is assumed to proxy efficiency and innovation, the conclusion might be that the rapid capital accumulation process in European manufacturing has also led to greater efficiency and more technological change during the past two decades. However, in services both Europe and the USA suffer from low efficiency and a lack of technological progress.

As discussed in section 2, approaches to economic growth which model increasing returns to scale require testing on the basis of cross-section regression analysis or data panel techniques. Table 4 represents results of a regression analysis, derived from

Van Ark and Crafts (1996) using the formulation of Levine and Renelt (1992), to identify the factors contribution to “average” European growth of GDP per capita. The underlying equation finds a positive relation with investment and education variables and a negative relationship with the share of government consumption in GDP and with initial income per capita. The latter effect represents a catch-up effect, and can be compared with one of Maddison’s four additional explanatory variables (see Table 1). Maddison (1996) defined the catch-up effect as 20% of the productivity growth bonus of each country over the USA. On average, for the four European countries in his growth accounts (France, Germany, Netherlands and UK), Maddison finds a slowdown of –0.13 %-point in the catch-up effect after 1973 relative to the 1950-73 period. This is considerably less than the –1.06 %-point according to the Levine and Renelt specification. Indeed both Maddison’s and Jorgenson’s results ascribe a much bigger part of the growth slowdown since 1973 to the actual decline in productivity rather than to the exhaustion of the catch-up effect per se. However, the regression results must be regarded at best as illustrative on the sources of growth because this accounting method can be quite sensitive to the specification of the variables and the countries included in the regression. For example, as Table 4 shows the regression results considerably understate the acceleration of growth during the 1950-73 period compared to the 1929-1938 period. So far all comparisons have been in terms of growth rates, but for a complete assessment of economic performance one needs to take account of the relative levels of economic performance as well. Measures of GDP per capita expressed in a common currency, like US dollars, or levels of labour productivity relative to the USA are an essential ingredient of studies of convergence and divergence. These measures can be constructed from comparison of income based on purchasing power parities as regularly constructed by the International Comparisons Programme of Eurostat, OECD, the United Nations and the World Bank.

For the study of long run economic growth, comparisons of labour productivity by sector and industry is a useful complementary analytical tool. Measures of relative levels of industry productivity were pioneered in studies by Rostas (1948) and Paige and Bombach (1958). The ICOP (International Comparisons of Output and Productivity) programme at the University of Groningen has developed a large range of contemporary studies for manufacturing and other sectors of the economy, complemented with historical studies of benchmark year estimates for the first part of the century.[16] Recently, Broadberry (1997) assembled the information from historical benchmark studies of manufacturing productivity levels, which were linked with time series of manufacturing productivity growth (Table 5). Strikingly Broadberry's estimates for manufacturing suggest a very different pattern of long term convergence in manufacturing than has been observed for the economy as a whole. Instead of a general process of productivity-catch up in advanced countries to the US level, the manufacturing estimates suggest a pattern of local convergence. For example, productivity levels in the North European countries seem to have fluctuated around a fairly similar level since 1870, but have not caught up much relative to the USA except for the period 1950-1973. Broadberry explains the stability in comparative manufacturing productivity levels from differences in technological regimes, and the strong impact of path-dependency on changes in these regimes.

A major problem of the accounting approaches described above is that they all fail to give a precise estimate of the contribution of technological change to growth. This has led to major controversies in the literature on the contribution of technological progress to growth, of which the discussion on the Solow "productivity paradox" is only the most recent.[17] To measure the effects of technological change on growth, the impact of increases in expenditure on research and development or patents on growth is obtained from regression analysis. Table 6 shows estimates from Verspagen (1996), which establish the %-point contribution of the increase in the stock of patents on labour productivity growth between 1950 and 1988. The estimates suggest that in Europe technological progress contributed between 8 and 13 percent to productivity growth, which is much less than in Japan where the growth contribution accounted for between 15 and 30 percent but more than in the USA where the technology contribution to growth was virtually zero.

This "macro"-work on technological progress is now increasingly complemented with micro-indicators which are obtained from innovation surveys and production censuses and surveys. Micro-based technology indicators, such as those presently constructed in the framework of the Community Innovation Survey, identify a broader range of technological activities than what is measured by either patents or R&D. In combination with recent micro-work on productivity, job flows and innovation from longitudinal data bases from production censuses and surveys, empirical research in these areas may open up new avenues for research on linking productivity and technology.[18]

5. Conclusion and Areas for Further Research

This paper argues that, despite the enormous progress in development of the theory and empirics on economic growth, we are still not able to unambiguously distinguish between the determinants of growth. The distinction between accumulation, productivity and technology is a useful device to structure the debate, as the former two tend to emphasize the importance of investment whereas the latter puts invention and innovation change into the spotlight. However, the most powerful explanations of economic growth are those which combine these aspects of growth, and in particular give a role to historical, institutional and political factors in the growth process.

Apart from the need for more theoretical work on the link between investment, productivity and technological progress, further empirical work on data construction is required as well. Firstly the construction of comprehensive long-term national accounts needs to be refined and extended to other countries. In particular the use of weighting systems, the construction of input-output tables and labour and capital accounts, as well as coordination on techniques to estimate real output in services deserve attention. However, even in the most recent System of National Accounts (1993) there are important gaps in solving these problems. For example, even though SNA 1993 includes an extensive chapter on production accounts, it still lacks the description of an intermediate inputs account in constant prices. A labour account, which provides estimates of labour input in current and constant prices is part of SNA 1993, but has only been implied for a small number of countries. A capital account, for which the idea was implemented by Jorgenson and Griliches (1967), is still entirely lacking.

Secondly, the development of indicators measuring technological change needs to go beyond the measurement of R&D and patents. These measures are increasingly unsatisfactory, in particular since an increasingly large part of the economy consists of services. Micro-surveys on innovation, such as the Community Innovation Survey, and longitudinal data bases underlying the production censuses and surveys are of great help in this respect.

Thirdly, comparisons of relative levels of economic performance are an important ingredient for understanding the link between investment, productivity and technological change. For example, the catch-up potential of a country in combination with its technical and social capabilities to realize this potential determine the possibility to benefit from technology diffusion (Abramovitz, 1991). Comparisons of relative level of performance, require the use of purchasing power parities or related measures to convert output to a common currency. Recently, the ICP PPP programme has been criticized in a number of reports for lack of methodological coherency and shortage of funding.[19] If these developments are not reversed, this puts an important aspect in understanding the link between growth and technological process in jeopardy, in particular for low-income countries.

Finally, and perhaps most importantly, the analysis of economic growth requires a broader perspective that does not pay exclusively attention to the "proximate sources" which can be relatively easily quantified and linked to output growth. In addition, a focus on the underlying "ultimate sources" of growth, including the institutional, political and historical environment in which economies function, is needed.

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Table 1 – Percentage Point Contribution of Sources of Growth to Growth of Real GDP, 1913-1992, Based on Growth Accounts of Maddison (1991, 1995 and 1996)

	France			West Germany			Netherlands		
	1913-50	1950-73	1973-92	1913-50	1950-73	1973-92	1913-50	1950-73	1973-92
GDP	*1.15*	5.02	2.26	*1.28*	5.99	2.30	*2.43*	4.74	2.14
Labour Inputs	*-0.53*	0.01	-0.32	*0.17*	0.32 c	-0.27	*0.77*	-0.05	-0.05
Human Capital	*0.36*	0.36	0.69	*0.21*	0.19	0.12	*0.27*	0.43	0.57
Non-residental Capital	*0.36*	1.44	1.30	*0.32*	1.89	1.01	*0.73*	1.37	0.88
Capital Quality (a)	*n.a.*	0.15	-0.04	*n.a.*	0.31	-0.08	*n.a.*	0.13	-0.06
Total Augmented Factor Inputs	*0.20*	1.96	1.63	*0.70*	2.71	0.78	*1.77*	1.88	1.34
Other Explanatory Items (b)	*0.10*	1.34	0.65	*0.11*	1.64	0.70	*0.22*	1.80	0.50
Explained Growth (%)	*26*	66	101	*63*	73	64	*82*	78	86
Unexplained Growth (%)	*74*	34	-1	*37*	27	36	*18*	22	14

	United Kingdom			Japan			United States		
	1913-50	1950-73	1973-92	1913-50	1950-73	1973-92	1913-50	1950-73	1973-92
GDP	*1.19*	2.96	1.59	*2.24*	9.25	3.76	*2.84*	3.91	2.39
Labour Inputs	*-0.32*	-0.11	-0.40	*0.28*	1.89 d	0.32	*0.25*	0.81	0.86
Human Capital	*0.21*	0.13	0.42	*0.62*	0.52	0.46	*0.41*	0.48	0.43
Non-residental Capital	*0.33*	1.55	0.99	*1.25*	2.76	2.04	*0.60*	0.98	0.94
Capital Quality (a)	*n.a.*	0.09	-0.06	*n.a.*	0.30	-0.07	*n.a.*	0.07	-0.04
Total Augmented Factor Inputs	*0.21*	1.66	0.95	*2.15*	5.47	2.75	*1.26*	2.34	2.19
Other Explanatory Items (b)	*0.01*	0.59	0.31	*-0.05*	3.01	0.79	*0.41*	0.33	-0.05
Explained Growth (%)	*19*	76	79	*94*	92	94	*59*	68	90
Unexplained Growth (%)	*81*	24	21	*6*	8	6	*41*	32	10

Note: 1913-50 are printed in italics because the estimates are not strictly comparable with those for 1950-73 and 1973-92. For France, Germany and The Netherlands the capital stock estimates for these three countries are not based on the "standardized perpetual inventory capital stock estimates as described in Maddison (1995a). Moreover there is no capital quality effect and catch-up effect calculated for any of the countries for the period 1913-50.

(a) Includes adjustment for age effect and, in case of Germany and Japan for 1950-73, a capacity reactivation effect

(b) For 1913-50: foreign trade effect, structural effect and economies of scale; for 1950-73 and 1973-92 also incluing a "catch-up effect"

(c) Includes adjustment for labour dishoarding of 0.32 percentage points

(d) Includes adjustment for labour dishoarding of 0.88 percentage points

Source: 1950-73 and 1973-92 derived from Maddison (1996); 1913-50: for France, Germany and the Netherlands derived from Maddison (1991); 1913-50 for Japan, UK and USA from Maddison (1995)

Table 2 – Comparison of Percentage Point Contribution of Investment And Productivity to GDP Growth, Based on Growth Accounts of Maddison (1996) and Jorgenson (1999)

	Maddison 1950-73	Jorgenson 1960-73	Maddison 1973-92	Jorgenson 1973-95
France				
GDP Growth	5.02	5.32	2.26	2.25
- Contribution of Investment	1.96	3.19	1.63	1.41
- Contribution of TFP	3.06	2.13	0.63	0.83
Germany				
GDP Growth	5.99	4.63	2.30	2.37
- Contribution of Investment	2.71	2.11	0.78	1.74
- Contribution of TFP	3.28	2.52	1.52	0.63
United Kingdom				
GDP Growth	2.96	3.30	1.59	1.57
- Contribution of Investment	1.66	1.53	0.95	1.47
- Contribution of TFP	1.30	1.77	0.64	0.10
Japan				
GDP Growth	9.25	9.98	3.76	3.14
- Contribution of Investment	5.47	3.56	2.75	2.68
- Contribution of TFP	3.78	6.42	1.01	0.45
United States				
GDP Growth	3.91	4.16	2.39	2.65
- Contribution of Investment	2.34	2.78	2.19	2.24
- Contribution of TFP	1.57	1.38	0.20	0.41

Note: "Investment" is contribution of augmented factor inputs. "TFP" is total factor productivity and equals growth of GDP minus factor inputs
Source: Maddison (1996) (see also Table 1); Jorgenson and Yip (1999)

Table 3 – Labour productivity, Capital Intensity and Total Factor Productivity by Major Sector of the Economy, 1973-1995

	Whole Economy	Agriculture	Industry		Services		
			Total	of which: Manufacturing	Total	of which: Producer & Distributive Services (a)	Personal & Government Services (b)
France							
GDP/hour	2.7	6.2	3.5	3.5	1.8	2.1	1.5
Capital Stock/hour	4.2	6.3	4.6	4.9	3.8		
Total Factor Productivity	1.5	4.6	1.9	2.0	0.5		
Germany (c)							
GDP/hour	2.7	5.9	2.5	2.8	2.4	3.2	1.8
Capital Stock/hour	3.7	4.9	3.7	3.7	3.1	3.3	2.8
Total Factor Productivity	1.6	4.7	1.9	2.3	1.3	1.6	1.1
The Netherlands							
GDP/hour	1.9	5.3	2.6	3.2	1.4	2.1	0.4
Capital Stock/hour	2.3	5.1	3.0	3.4	1.7		
Total Factor Productivity	1.3	3.5	-0.4	2.3	-0.2		
United States							
GDP/hour	1.0	3.4	1.6	2.4	0.9	1.5	0.2
Capital Stock/hour	0.4	-1.7	1.0	2.0	0.4	2.2	-1.4
Total Factor Productivity	0.6	2.9	1.0	1.7	0.5	0.5	0.6

(a) Retail and Wholesale Trade, Transport and Communication, Finance, Insurance and Business Services
(b) Personal and Community Services and Government Services
(c) Business Services included with Personal and Community services

Note: Capital stock (1973-1989) is derived with perpetural inventory method, using standardized asset life assumptions. For France, Germany and USA updated with trend in official capital stock estimates from 1989 onwards. Total factor productivity on the basis of Cobb-Douglas production function. For France, Germany and USA with constant 1975 shares; for Netherlands with annually changing factor weights.

Source: France, Germany and USA from Van Ark (1996), updated to 1996. Capital stock 1973-1989 from O'Mahony (1996), updated with trend from official capital stock estimates. Netherlands from Van Ark and de Haan (1998)

Table 4 – Regression Estimates of GDP Per Head, 1929-1989 Based on Specification by Levine and Renelt (1992)

	1929-38	1950-73	1973-89
Growth of GDP per head			
Estimated	2.44	3.54	1.83
Actual	2.12	3.84	2.14
Overestimation	0.32	-0.30	-0.31
Regression Results			
Constant	2.01	2.01	2.01
Initial GDP per capita	-2.43	-2.49	-3.55
Investment/GDP Ratio	1.42	2.22	2.06
Secondary school enrolment	0.16	0.68	0.79
Primary school enrolment	1.9	1.99	1.79
Government consumption/GDP	-0.62	-0.87	-1.27
Change in Catch-Up Effect over Previous Period			
According to regression		-0.06	-1.06
According to Maddison (1996) (a)			-0.13

(a) period refers to 1973-92.
Note: Estimates concern unweighted averages of European countries as in Maddison (1991), excluding Belgium and Switzerland. Specification is according to Levine and Renelt (1992), equation (ii), with population growth and irrelevant dummies ignored
Source: Van Ark and Crafts (1996)

Table 5 – Labour Productivity Level in Manufacturing Relative to USA, 1870-1989, Based on Broadberry (1997)

	1870	1913	1929	1938	1950	1973	1989
"Northern Europe"							
Denmark			46	51	33	41	53
Germany	49	56	42	56	37	55	59
Netherlands			41	61	33	62	72
Norway		42	44	49	39	48	48
Sweden		48	38	52	45	60	68
UK	49	47	40	52	38	47	56
"Southern Europe"							
France		37	33	40	32	53	65
Italy		28	24	26	26	45	63
Australia		65	41	53	37	40	46
Canada	43	72	68	76	57	71	69
Japan		11	13	22	8	44	81
USA	100	100	100	100	100	100	100

Note: comparisons relative to the UK converted to comparisons relative to the USA
Source: Broadberry (1997)

Table 6 – Contribution of Technological Progress to Labour Productivity Growth, 1950-1988, Based on Cross-Country Growth Regressions from Verspagen (1996)

	Labour Productivity Growth Rate (1950-88)	%-Point Contribution of Technology Indicator	
		Patents long-time (a)	Patents short-time (b)
France	3.27	0.30	0.51
Germany	3.65	0.26	0.50
Netherlands	2.73	0.24	0.38
Sweden	2.14	0.25	0.38
United Kingdom	2.21	0.06	0.09
Japan	5.76	0.96	1.68
United States	1.64	0.05	0.06

(a) Stock of patents assuming a lifetime of 15 years
(b) Stock of patents assuming a lifetime of 10 years
Source: Verspagen (1996)

Endnotes

1. For a more detailed overview of theories and concepts, see Van Ark and Crafts (1996).
2. For a more extensive review on historical national accounts, Van Ark (1995).
3. For a collection of pioneering and leading papers in the field of empirical research on long run economic growth, see Van Ark, ed. (1997)
4. See Jorgenson (1995) for an overview of papers by himself and his associates on productivity.
5. Harberger (1998) represents yet another approach to growth accounting. He interprets the TFP residual as "real cost reductions" which, when expressed in money terms, can be made additive. Harberger also stresses the importance of the multiplicity of sources from which real cost reductions can arise, and emphasizes the need to look at TFP performance at firm level to understand these sources.
6. Another "new growth theory" approach to analyzing the sources of growth stems from the Post-Keynesian tradition, and is best represented by Scott (1989). Scott rejects the possibility to distinguish between investment and technological change, but also ignores the distinction productivity and investment, the importance of substitution effects between different types of investment, and the influence of other factors than investment on growth.
7. Alternatively, there has been some recent work in growth accounting using panel regressions (Islam, 1995). It has the advantage over cross-section regression that it is less sensitive to the inclusion/exclusion of variables and countries. However, panel regressions require econometric specifications on the basis of specified functional forms.
8. For example, Jones (1995) has challenged knowledge models on the basis of the observation that despite a tripling of the number of scientists and engineers since the 1950s, productivity growth has not accelerated accordingly.
9. Silverberg and Verspagen (1995) describe a number of macroeconomic evolutionary models that can be solved analytically.
10. For a more complete overview on historical national accounts European countries, including references to country sources, see Van Ark (1995). For a world-wide overview, see Maddison (1995)
11. See, for example, Summers and Heston (1988, 1991) and Maddison (1995, 1998)
12. From a historical perspective it is undesirable to shift weights in historical national accounts every year, which is now done in several postwar national accounts (including the Netherlands and France, and recently, also the United States). It seriously hampers the usefulness of comparisons of real growth rates over long periods. See, for example, Krantz (1988).
13. See, for example, Maddison (1995a) for historical estimates of capital stock using the perpetual inventory method for France, Germany, Japan, the Netherlands and the United Kingdom. See O'Mahony (1996) for similar estimates at a sectoral level
14. See, for example, O'Mahony (1996) who applied the standardised method to sectoral estimates of capital stock. See Albers, Groote and de Jong (1996) for a reconstruction of the capital stock estimates for the Netherlands using slightly different investment series.
15. Maddison (1995) includes growth accounting estimates for Japan, the United Kingdom and the United States even going back to 1820.
16. For a review of contemporary ICOP studies, see Van Ark (1993, 1996a). For historical ICOP studies, see Pilat (1994) for Japan/USA in 1937, Fremdling (1991) and Broadberry and Fremdling (1990) for Germany/UK from the first half of the 20th century, De Jong (1999) for Netherlands/Belgium and Netherlands/Germany since 1913, and Horlings and Van Ark (1998) for East European countries relative to West Germany.
17. The Solow "productivity paradox" is best summarized with Solow's own remark that "You can see computers everywhere except in the productivity statistics" (Solow, 1987). Griliches (1994) is a good review of the general problems in linking technological change and economic growth.
18. For a review of studies on micro-technology indicators, see Kleinknecht (1996). For a review of longitudinal studies based on censuses and surveys, see Audretsch (1995) and Davis, Haltiwanger and Schuh (1996).
19. See Castles (1997) and Ryten (1998).