Convergence or Divergence – The Impact of Technology.

by Jan Fagerberg,*

Norwegian Institute of International Affairs (NUPI),

P.O.B. 8159 DEP, 0033 Oslo, Norway

Abstract

This paper presents an overview and assessment of the theoretical and empirical work on catch-up and growth, with particular emphasis on the impact of technology, and the consequences for developing countries. The point of departure is the neoclassical theory of economic growth, as laid out by Solow and other in the 1950s, and the applied work that followed ("growth accounting"). Then the contributions from economic historians and more heterodox economists, such as Schumpeter, Kaldor and others, are discussed, followed by an account of the most recent theoretical developments in this area ("new growth theory"). Finally an assessment is made of the lessons from the recent surge in empirical (econometric) work in this area.

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Introduction

To what extent may technologically and economically less advanced countries be expected to catch up with the most advanced ones (and, hence, display faster growth)? This has been one of the central issues in theoretical and applied work on growth for a long time. It was introduced by economic historians (Gerschenkrohn 1962), who pointed to the potential advantages accruing to backward countries from imitating the technologically and economically more advanced ones. Empirical work on post war growth in the OECD area seemed to confirm these expectations. However, recent research has thrown doubts on whether these experiences are valid for other time periods and countries, in particular the developing ones.

The empirical support found in earlier studies for catching up or convergence was comforting news for the established neoclassical theory of growth (Solow 1956, 1957), which - on certain assumptions - predicts this outcome. In this theory technology was assumed to be a public good, freely available for everyone without charge, and technological progress was assumed to be exogenous. Similarly, the contradictory findings of the more recent literature have been used by critics of the established theory, in particular the adherents of the so-called "new growth theories", where technological progress is assumed to depend on economic activities (i.e., endogenous). This debate has also led to increased interest in the works of non-orthodox economists, particularly those of Schumpeter and Kaldor, and to a rapidly increasing empirical literature on differences in growth across countries with varying levels of development.

This paper presents an overview and assessment of the theoretical and empirical work on catch-up and growth, with particular emphasis on the impact of technology, and the consequences for developing countries. The point of departure is the neoclassical theory of economic growth, as laid out by Solow and other in the 1950s, and the applied work that followed ("growth accounting"). Then the contributions from economic historians and more heterodox economists, such as Schumpeter, Kaldor and others, are discussed, followed by an account of the most recent theoretical developments in this area ("new growth theory"). Finally an assessment is made of the lessons from the recent surge in empirical (econometric) work in this area.

Traditional Growth Theory

It was neoclassical economists that brought technological progress to the forefront as an explanatory factor of economic growth, although this was not their original intention. The model suggested by Solow (1956) was based on standard neoclassical assumptions, such as perfect competition (and information), maximizing behaviour, no externalities, positive and decreasing marginal productivities, production function homogeneous of degree one etc. On the assumptions of a given rate of population growth and a given savings rate[1], the model was shown to yield a long-run equilibrium

[1] This was Solow's assumption. Alternatively, one may assume inter-temporal utility maximization, in which case the discount factor for future versus present consumption must be exogenously determined. This is of no importance here.

with gross domestic product and the capital stock growing at the exogenously determined rate of population growth. Hence, on these assumptions there can be no growth in GDP per capita in the long run.[2]

It was at this point that technological progress came into play. To allow for long-run growth in GDP per capita, Solow added an exogenous term, labelled "technological progress", which among else was assumed to reflect advances in basic science. In this perspective, technology is a "free" good, i.e., something that is accessible for everybody free of charge. Although Solow did not discuss the implications of this for a multi-country world, it was taken for granted in the applied work that followed that this means that the contribution of technological progress to economic growth must be the same all over the world. Hence, in the long run, GDP per capita should be expected to grow at the same rate in all countries.

However, since initial conditions generally differ, countries may grow at different rates in the process towards long-run equilibrium (so-called "transitional dynamics"). A case can be made, then, for poor countries growing faster than the richer ones: countries where capital is scarce compared to labour (i.e., where the capital labour ratio is low) should be expected to have a higher rate of profit on capital, a higher rate of capital accumulation and, hence, higher per capita growth. To the extent

[2] This result follows from the standard neoclassical assumption of decreasing returns. Technically, this result could be avoided if a functional form that imposes a lower, positive limit for the marginal productivity of capital is chosen (Solow 1956, Pitchford 1960). However, this possibility did not attract much attention, probably because an economic justification was hard to find.

that capital is internationally mobile, this tendency should be much strengthened. Thus, the gaps in income levels between rich and poor countries should be expected to narrow (catch-up) and ultimately disappear. This conclusion holds as long as savings rates, or more generally the factors affecting savings, are identical across countries.[3] If not, countries will approach different steady states, but (per capita) growth rates will still converge.

It was pointed out by several authors that Solow's model overlooks that new technology is usually embodied in new capital goods. If this assumption is introduced in neoclassical growth models (so-called vintage models, Johansen 1959; Solow 1960 and Nelson 1964, among others), the importance of capital accumulation in the process towards long-run equilibrium is increased. But as long as the other assumptions of the Solow model are left unchanged, the conclusion that in the absence of technological progress there will be no productivity growth in the long run, remains the same. A more radical departure from the Solow assumptions may be found in Kaldor and Mirrlees (1962) and Arrow (1962). They present vintage models of economic growth where technological progress is endogenized as "learning by doing" in the capital-goods industry. This class of models may in principle allow for long-run growth (see the section on "New Growth Theory"). However, as pointed out by Arrow, this perspective, as well as that of Solow, fails to take into account the part of technological progress that comes through

[3] Strictly speaking, full convergence also requires that the rate of growth of the labour force is the same across countries.

R&D investments in private firms. Attempts to introduce this by presenting models with a separate technology-producing sector were made by Uzawa (1965), Phelps (1966), Shell (1967) and others. However, by the early 1970s, growth theory had gone out of fashion and with it the idea of endogenous technological progress. As a consequence, these models had little, if any, impact on the empirical work that accompanied the theoretical discussions of the 1960s.

Growth Accounting

From the late 1950s onwards empirical research on factors affecting long-run growth grew steadily. Much in the same way as the post war work on national accounts decomposed GDP into its constituent parts, the empirical research on growth attempted to decompose growth of GDP (so-called "growth accounting", for surveys see Nadiri 1970; Maddison 1987). Although some of this work actually preceded the formal models, Solow's growth theory gave a natural theoretical framework for these exercises.

The Solow model predicts that apart from exogenous technological progress, GDP growth (y) will be a weighted sum of the growth in physical capital (k) and the growth of the labour force (n), with the shares of capital and labour in national income (s_K and s_L) as weights:

(1) $y = s_K k + s_L n$

If the functional distribution of income, the growth of the capital stock and the growth of the labour force are known, equation (1) could be used to calculate the contribution of capital and labour to economic growth. What was left when these contributions were deducted, the residual, would then be assumed to reflect exogenous technological progress and other unidentified sources. When this model was applied to empirical data for the US, several studies showed that growth of capital and labour explained only a small part of actual growth (Abramowitz 1956; Solow 1957; Kendrick 1961; Denison 1962). The residual turned out to be surprisingly large. Two avenues were followed for "squeezing down the residual" as Nelson (1981) puts it. One was to embody, as much as possible, technological progress into the factors themselves by adjusting for shifts in quality, composition etc (Denison 1962; Jorgensen and Griliches 1967).[4] Another, later dominant, approach in this literature, was to add other possible explanatory variables (Denison 1962, 1967).

Empirical analyses of differences in growth across countries based on this latter methodology have been undertaken by Denison (1967), Denison and Chung (1976), Kendrick (1981) and Maddison (1987). The additional factors taken into account range from differences in the scope for "catch-up" to differences in the degree of governmental regulation and crime. These studies show that it is possible to "explain" a larger part of the actual differences in growth across countries by introducing additional explanatory

[4] Jorgensen and Griliches initially argued that the residual could be eliminated altogether, but later retreated from that position. See Denison (1969) and Jorgensen and Griliches (1972).

variables.[5] However, it has been pointed out that the theoretical basis for the whole exercise is questionable, since it is not taken into account that many of these variables are in fact interdependent (Nelson 1964, 1973, 1981). This holds not only for the additional factors introduced by Denison and others, but also for the relation between technological progress and factor growth.[6] It follows that it may be difficult to discuss questions related to causality within this framework.

An example may illustrate this point. In the 1950s, Western Europe grew much more rapidly than the USA. Many would probably expect diffusion of technology from the USA to Western Europe (imitation) to have played an important role in this process (see the next section). However, Denison (1967) argues that this was not the case. Instead he points to other factors, among them structural changes and exploitation of economies of scale; to a large extent these are said to be related to the rapid growth of European consumer durables industries during this period. The obvious counter-argument would be: Where did the technological and social conditions for the rapidly growing consumer durables

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[5] However, much of the variation in the data continues to be unexplained. Maddison (1987) presents a growth-accounting study based on Denison's methodology for six OECD countries between 1913 and 1984. Fourteen different explanatory variables were taken into account. Still, the part of actual growth that can be explained in this way does not on average exceed 75 %. For some countries in some periods it is not more than 50-60%.

[6] Several authors have suggested that technological progress and accumulation of physical and/or human capital interact, so that the contribution of each factor is not easily defined. For example, technological progress may take the form of "learning from using" the existing machinery and equipment, as suggested by Arrow, Kaldor and others, or technological progress may be "biased" towards physical or human capital (in contrast to what is normally assumed in growth theory) as suggested by, for instance, Abramovitz and David (1973). I discuss this in somewhat more detail in Fagerberg (1994).

industries first develop, if not in the USA? How to decide which argument to trust? The problem is that there are several interacting variables, and without a theory that takes this properly into account, any statement on causality will to some extent be arbitrary.

"Catch-Up"

The "catch-up" or "imitation" argument is not identical to the neoclassical case of "transitional dynamics", although the two arguments may yield identical growth predictions. The "catch-up" argument, developed by Gerschenkrohn (1962), Gomulka (1971), Abramowitz (1979, 1986, 1994a,b), Maddison (1979, 1982, 1991) and others, puts its emphasis on differences in the scope for imitation. Countries behind the world innovation frontier, it is argued, can grow faster by copying technologies already developed in technologically more advanced economies. In the neoclassical case of "transitional dynamics", on the other hand, the main vehicle for growth differences is differences in profitability and, hence, capital accumulation, not technological differences. However, both perspectives imply that economic growth should be expected to be negatively correlated with the level of GDP per capita. The interpretation of this indicator differs, though. In the "catch-up" literature, GDP per capita is assumed to reflect the degree of technological sophistication of the country, in the neoclassical story it is a proxy for the capital-labour ratio.

Much of the "catch-up" literature is descriptive, with a strong emphasis on historical analysis. In addition to economic factors, especially investments in physical and human capital, this literature emphasizes the importance of social and institutional factors for the outcome of the "catch-up" process. Thus, catch up is by no means automatic: " a country's potential for rapid growth is not strong when it is backward without qualification, but rather when it is technologically backward but socially advanced" (Abramovitz 1986, p. 388). Abramovitz, following Ohkawa and Rosovsky (1973), has used the concept "social capability" to cover some of the latter. In a recent paper he defines this concept as follows:

> "... it is a rubric that covers contries' levels of general education and technical competence, the commercial, industrial and financial institutions that bear on their abilities to finance and operate modern, large-scale business, and the political and social characteristics that influence the risks, the incentives and the personal rewards of economic activity including those rewards in social esteem that go beyond money and wealth." (Abramovitz 1994b, p.25)

He also points out that since technologies are shaped by the environment in which they develop, a country that differs much from the technological leader in factor supply, market size etc. may sometimes find it difficult to absorb leader country technology (so-called lack of "technological congruence", see Abramovitz 1994a,b). For instance, the failure of most industrialized countries to catch up with the US prior to the Second World War has been explained in this way (Abramovitz 1994a, b; Nelson and

Wright 1992).[7]

Thus, although this is not always made explicit, authors in this tradition view technology quite differently from the followers of Solow. For instance, to the extent that innovation is taken in to consideration, it is seen as highly dependent on interaction between firms and their environments. This puts a context-specific stamp on technology and may hamper diffusion to other settings (cf. for instance Abramovitz's analysis of "technological congruence"). Some extend this perspective to include the national level, e.g., "national systems of innovation" (Lundvall 1992; Nelson 1993). A consequence of this perspective, i.e., the interdependence between technology and other factors, is - as already emphasized - that technological catch up is far from easy. It requires a host of supporting economic and institutional factors to succeed.

Still, when it comes to statistical tests, most "catch-up" studies include one independent variable only: GDP per capita (as a proxy for the scope for "catch-up"). Several studies of this type, including Singer and Reynolds (1975), Abramovitz (1979, 1986), Maddison (1979, 1982, 1991) and Baumol (1986), have shown that a large part of the actual difference in growth rates between the OECD countries in the post war period can be statistically explained by differences in the scope for "catch-up". This result

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[7] US technology, these authors argue, were capital-, resource- and scale-intensive. To make sense economically, these technologies required a large, homogenous market. The European countries (and even more so, Japan) had less natural resources, much smaller markets, demand was less homogenous etc. These problems were enforced by the low growth and increasing protectionism of the interwar period. However, after the Second Word War, these constraints were relaxed, and this resulted - according to these authors - in a very rapid catch-up process.

has been criticized by De Long (1988) as an example of a "ex post selection bias": while long-run convergence can be established for the richest countries today (the OECD countries), it does not hold for the richest countries of the previous century. Similarly, several studies, including Baumol et al. (1989), Skonhoft (1989) and Barro (1991), have shown that a simple "catch-up" model has little explanatory power for the performance of the poorest countries of the world.

Thus, the "catch-up" debate has a very clear conclusion: a simple "catch-up" model with one independent variable is not sufficient to explain differences in growth. This would probably not surprise the group of economic historians who initiated much of this work, their emphasis on other economic, social and institutional factors taken into account. The idea of technology as a "free good" has probably never been very appealing for someone well acquainted with modern economic history.

However, the basic question remains: Which additional variables to choose? This is not an innocent question, at least not if the common practice of including a large number of variables in an ad hoc (and to some extent arbitrary) manner is to be avoided. The following discusses some theoretical and empirical contributions that may be helpful in answering this question.

Schumpeterian Perspectives

The Schumpeterian approach is deeply influenced by classical economic thinking. Indeed, as Schumpeter himself recognized, the model of growth based on technological competition (innovation and diffusion of technology) was initially formulated by Marx. Basically, what this model suggests is that both innovation and "catch-up" (imitation) are conducive to growth. However, while it may be possible to "catch up" by mainly imitating activities, it is not possible to surpass the technological leaders without passing them in innovative activity as well. Thus, in principle at least, the Schumpeterian framework allows for both divergence and convergence.

Even though the Marx-Schumpeter model is a model of the firm, it is tempting to apply the model at a more aggregated level, i.e., as a model for the growth of countries. The first attempt to do so was made by Pavitt and Soete (1982), but the empirical results presented there were ambiguous. Fagerberg (1987, 1988a, 1991) has presented a simple model where growth depends on (1) the growth of knowledge, whether diffused to the country from abroad or created within the country itself, and (2) efforts to exploit the available knowledge, wherever created. The tested model included three variables: the scope for exploitation of foreign-produced knowledge (proxied by GDP per capita), growth in national innovative activity (proxied by growth in patents) and efforts (proxied by investments). All three variables contributed significantly to the explanation of the observed differences in growth in a sample of developed and newly industrializing countries. It was concluded that "to catch up with the developed countries, ... semi-industrialized countries cannot rely only on a combination of technology imports and investments, but have to increase their national technological activities as well" (Fagerberg 1988a, p. 451).

Verspagen (1991) has introduced some of these ideas into a non-linear framework, and tested the resulting model on a sample of more than one hundred countries, including many developing ones. Basically what this model suggests is that countries characterized by a large technological gap and a low "social capability" (education level) run the risk of being caught in a low-growth trap. In addition to the technological gap and the education level, the tested equation also included equipment investments and the level of innovative activity (measured by patents). It was shown that this non-linear model has a higher explanatory power than simple linear relationships of the type considered by either Pavitt and Soete or Fagerberg. However, this result was not confirmed by Amable (1993), who applied the same type of model to a somewhat smaller sample.

Amable (1993) presents a (linear) catch-up model where several of the conditioning factors are endogenized. Catch up is conditioned by equipment investment, the level of education and the share of governmental expenditure in GDP. Investment is endogenous and depends on growth (the accelerator), the level of innovative activity (as measured by patents) and the share of governmental expenditure in GDP. Innovative activity is also made endogenous in the model (assumed to depend on the level of education). This model may allow for both converging and diverging growth paths. The results, based on data for 59 countries between 1960 and 1985, suggest that only a minority of the countries (around one-fifth) will catch up completely. Most countries will converge towards a level well below the most advanced countries, while some will be caught in a low-growth trap.

The Kaldorian Heritage[8]

Arguing along "Keynesian" or "Post-Keynesian" lines several authors have presented models and analyses where structural differences across countries may lead to long-run differences in growth rates. The origins of this work can be traced back to Harrod's and Hicks's early attempts to develop a Keynesian understanding of open-economy macroeconomics, in which the growth of a country was seen as constrained by the demand for its exports. However, the main contributor and source of inspiration in this area has been Kaldor.

In the 1950s Kaldor developed models of economic growth in which technological progress was assumed to be endogenous (the technological progress function, see Kaldor 1957, 1961 and Kaldor and Mirrlees 1962). The basic idea was that investment and learning were interrelated, so that technological progress could be modelled as a function of capital accumulation per worker. These models contained only one production sector and structural aspects were therefore not taken into consideration. In his applied work, however, he was at pains to stress that the prospects for technological progress were not equal across sectors or industries. Generally these prospects were assumed to be more favourable in manufacturing than elsewhere (Kaldor 1966, 1967), giving manufacturing the role as an "engine of growth" in the economy.

[8] This section draws on Fagerberg et al. (1994).

Following Verdoorn (1949), Kaldor saw productivity growth in manufacturing as related to growth of manufacturing output, e.g., the higher the rate of growth of manufacturing output, the higher the rate of learning, and hence the rate of productivity growth. He also noted the interaction between the growth of manufacturing and demand: since income elasticities of demand vary across production sectors, rising national income will (in a closed economy) go hand in hand with structural changes in the composition of output, a theme later elaborated by Pasinetti (1981). However, export markets may allow a country to change – and grow – at a faster rate than the domestic markets would have allowed. Thus, for Kaldor growth of manufacturing exports was one of the chief ways to increase manufacturing output and, hence, learning, technological progress and the competitiveness of a country (Kaldor 1978, 1981).

Kaldor often stressed the interactive character of the factors taking part in the growth process, leading to "cumulative causation" or "virtuous" and "vicious" patterns of development.[9] In a paper from 1970, devoted to the issue of why growth rates of countries – and regions – differ, Kaldor sketched an approach which combined the Keynesian assumption of growth as constrained by export demand with his own emphasis on endogenous technological progress. This approach was later formalized by Dixon and Thirlwall (1975). In this model the impact of growth in export demand on economic growth through the multiplier is magnified by the Kaldor-Verdoorn relationship: the increase in demand induced by export growth affects productivity positively, this leads to improvements in the

[9] This idea is often attributed to Myrdal (1957).

price competitiveness for exports (assuming wages constant), and, hence, further increases in the rates of growth in exports and GDP. The most likely outcome (according to Dixon and Thirlwall) would be one of countries growing at different rates – reflecting differences in structural characteristics – implying divergence rather than convergence in productivity levels.

Thirlwall (1979) introduced a constraint on the external account into this framework (balanced trade), arguing that export-led growth models may otherwise overestimate growth. On the additional assumption that relative prices are relatively sticky, so that their impact can be ignored (eliminating the feedback from endogenous technological progress), Thirlwall showed that the growth rate of a country's GDP relative to the rest of the world depends on the relation between the demand elasticities for its exports and imports, i.e., on structural aspects of the economy. This means that a country that produces goods which are in high demand both at home and abroad will grow faster. Thirlwall (1979) showed that with the exception of Japan this simple model "explained" postwar growth remarkably well. But these results, although highly suggestive, have been subject to some controversy (for an overview see McCombie 1986).

A pertinent question is what the estimates (of income elasticities of demand) that Thirlwall used really reflect. The concept "income elasticity of demand" makes sense for products, but it is intuitively more difficult to see how it can be applied to the total exports or imports of a country. It may simply be, as Thirlwall himself points out, that these estimates reflect the impact of so-called "non-price" factors on competitiveness. Kaldor (1981, p. 603) suggested that these elasticities should be seen as shorthand for "the innovative ability and adaptive capacity" of the producers in the different countries. Following this Fagerberg (1988b) presented a balance-of-payments constrained growth model where exports and imports were determined by the differences across countries in the potential for catch-up, indigenous technological efforts, investments and other factors. This model presented a possible explanation of the finding of Kaldor (1978) that the market shares for exports for countries seem to move in line with relative costs (and not the other way around).[10]

The Kaldorian perspective on "why growth rates differ" rests on three assumptions: (a) endogenous technological progress (in the form of learning by doing), (b) differences in the prospects for technological progress across industries and sectors and (c) differences in income-elasticities of demand across products and markets. A fully adequate formalisation of this perspective would require a multi-sector approach. Some attempts in that directions have been made (Cimoli 1988; Dosi et al. 1990; Cimoli and Soete 1992; Verspagen 1993). As for Dixon-Thirlwall type models the growth paths generated by these multi-sector models are highly dependent on structural features. In an international context, this may be consistent with lasting differences in growth rates (lock-in effects). Similar results have been reached by Lucas (1988, 1993),

[10] McCombie and Thirlwall (1994) argue that the predictive power of this model depends on the inclusion of Japan, i.e., that while the model may explain the (large) difference in performance between Japan and other industrialized countries, it has little to say about the (much smaller) differences among the latter.

albeit via a more neoclassical route. The Lucas model combines assumptions (a) and (b) above with the assumption of differences in comparative advantages across countries. In this model, endogenous technological progress reinforces existing comparative advantages. Thus, a country that happens to be specialized in a high-learning activity, will stay so and, as a consequence, grow permanently faster than other countries. An implication of this is that it may make sense for a government to intervene in the economy in order to change its pattern of specialization (towards high-learning activities).

New Growth Theory

The view that the handling of technology in the traditional neoclassical theory of economic growth is problematic, has gained support in recent years. Indeed, for this very reason, neoclassical growth theory is now rapidly changing. Basically, there are two different perspectives on the relation between technology and growth in the "new neoclassical" camp.[11] Following Arrow's (1962) analysis of "learning by doing", Romer (1986), Lucas (1988) and others have developed models in which growth in new knowledge is analysed as a by-product (externality) of other economic activities (investments in physical and human capital). A similar perspective, although distinctly non-neoclassical in character, has been

[11] We do not attempt to review these theories here, just emphasize some main points that appear to be important in the present context. For overviews/ reviews of this literature the reader may consult Helpman (1992), Renelt (1991), Shaw (1992), Siebert (1991), van der Ploeg and Tang (1992) or Verspagen (1992).

presented by Scott (1989). This type of model suggests an explanation of why "catch-up" does not take place in many cases. In Solow's model, the rate of profit (and, hence, the rate of growth) is a decreasing function of the capital-labour ratio. However, if there are positive external effects of physical and/or human capital, these may outweigh the negative effects on profitability and, hence, growth of an increasing capital-labour ratio. Thus, due to the positive external effects of capital, rich countries may stay rich, while poor countries continue to be poor.

Another, although related, approach may be found in Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992) and others. In these models, innovation (the introduction of new goods or production methods) occurs because firms are capable of preventing a situation in which the new knowledge diffuses so quickly that they can not cover their initial outlays. There is, in other words, imperfect competition. However, in addition to the private, proprietary competent, innovation also has a public component ("technological spill-overs") that facilitates subsequent innovation projects. This prevents the returns to investments in innovation activity to decline. Thus, it is the dual public-private character of the innovation process that allows growth to go on in these models. A typical result is that the rate of growth is proportional to the amount of resources devoted to innovation. If a country allocates very little of its resources to innovation, for instance because the country is very poor, the result may be no (or low) growth.

The implications of new growth theory for differences in growth and welfare across countries that trade with each other, are discussed in detail by Grossman and Helpman (1991). They place the ideas outlined above in a traditional neoclassical general equilibrium setting. As is common in this literature, the population of each country is assumed to be represented by one "representative" consumer that maximizes utility over an infinite horizon. The subjective discount rate is assumed to be the same in all countries. If technological spill-overs (i.e., diffusion) are international rather than national in character, and a "perfect" international capital market prevails, consumers in all countries tend to be equally well off in terms of welfare, although there may be differences in the growth of output. However, when these assumptions are relaxed, the possibilities for diverging patterns increase. In these cases "lock-in" situations may occur, in which case a country with a comparative advantage in traditional industries may be permanently worse off compared to a country with a comparative advantage in R&D. According to these models a small domestic market may also be a considerable disadvantage for a country under such circumstances.

The Recent Surge of Empirical Work

In recent years many new empirical studies on growth differences have appeared. To a large extent this is a reflection of the "catch-up" debate and the development of the "new growth theory", but it is also a result of easier access to data (Summers and Heston 1991) and, probably, the introduction of econometric programs for the PC. In general, the research in this area may be characterized as highly explorative. However, although the theoretical perspectives of the authors of these studies may differ, the empirical models are rather similar. The variables taken into account in these studies may be divided into three groups:

(i) GDP per capita, as a proxy for the scope for "catch-up";

(ii) Variables reflecting attempts to affect the "gap", such as investment, education and resources devoted to - or output from - innovation activities;

(iii) Other variables of a "structural" or political nature assumed to affect growth (such as the degree of openness to trade, country size, share of public sector in GDP, population growth etc.).

The samples in these studies vary from rather small ones, including the OECD countries only, or - alternatively - a selection of less developed countries, to very large samples including both developed and developing countries. In general, the quality of the data is worse for poorer countries. For many poor countries the data are pure estimates. This implies that the results from tests including such estimated (low quality) data may be biased. However, it has been shown (Blomström et al. 1992; Levine and Renelt 1992) that the inclusion of such low-quality data does not significantly influence the results.

The following appears to be some of the most important conclusions that can be drawn from the empirical literature in this area:

(1) General support is found for models where the scope for "catch-up" is combined with some other variable(s) reflecting the

"efforts" to close the gap. The fact that convergence in income levels appears to have slowed down after 1973 (Abramowitz 1986), does not necessarily invalidate this result (Dowrick and Nguyen 1989).

(2) The two "efforts" variables most commonly used are investments and education. The positive impact of the investments variable is generally supported.[12] The main disagreement - on which no conclusive evidence exists - has been to what extent investment should be regarded as exogenous, as suggested by Solow, or endogenous as advocated by some new growth theorists. Education variables work fine for the less developed countries, or large samples containing both developed and less developed countries, but not for samples where all non-OECD countries are excluded. Probably, education variables - such as literacy rates or the percentage of population enroled in schools - are much too "rough" to reflect differences in "social capability" and/or innovative efforts between developed countries. There are only a few studies that include innovation variables (R&D, patents, scientists and engineers etc.). In small, high-income samples innovation variables have been shown to contribute positively to the explanation of differences in growth across countries. This also applies when NIC countries are included. A recent study (Lichtenberg 1992) includes data for more than fifty countries. This study suggests a strong

[12] De Long and Summers (1991) report that the impact of investments in equipment is far greater than investments in structures. Their results also indicate that the social returns to equipment investments exceed the private returns by a sizeable amount. However, these results are not confirmed by Wolff (1994), who attributes the De Long-Summers findings to a neglect of capital-embodied catching up. Most other studies also conclude that the social and private returns to investments in physical capital are about the same.

positive impact of R&D - especially when privately funded - on levels and growth of productivity.

(3) The evidence on the impact of variables other than those related to technology gaps and "efforts" is rather mixed. Levine and Renelt (1992), in a sensitivity analysis of the impact of policy-related variables, found that none of them were "robustly" correlated with growth. A "non-robust" relationship means that the impact of the variable was found to be sensitive to the inclusion of (some) other variables. This does not necessarily imply that the variable under test is unimportant for growth. For instance, the finding may be explained by the fact that variables are closely correlated, as economic variables often are (see below).

(4) The results indicate there is a good deal of interaction between variables that take part in the growth process. For instance, when both investments and education are included, the impact of each variable, especially education, is reduced. This is not necessarily surprising, since these two variables tend to be correlated (Barro 1991). Thus, generally speaking, countries do not invest in either education or physical capital, they invest in both. A similar finding holds for "openness", which in contrast to common belief was not found to be "robustly" correlated growth.[13] There was, however, a robust correlation between investment and "openness",

[13] This is also confirmed by a number of other studies (see Fagerberg 1994, Table 2). An exception is the study by Edwards (1992). Following Leamer (1988), Edwards defines openness as the difference between the actual and predicted level of trade (using a prediction model based on neoclassical trade theory). Since this definition differs from those used elsewhere, the reported results are not directly comparable. However, Levine and Renelt (1992), using the same definition of openness as Edwards, found that openness (so defined) is not robustly correlated with growth, while - as for other measures of openness - a robust correlation with investment seems to exist.

i.e., countries that trade much, compared to their size (GDP), invest more than others.

These are some of the "stylized facts" that emerge from the empirical literature. There is some support here for a Schumpeterian approach to the "catch-up" process. But many of the findings can also be interpreted as consistent with other theories in this area, including, for instance, an extended neoclassical growth model, incorporating human capital (Mankiw et al. 1992). Thus, it is difficult to use the results from these studies to discriminate among the different theories in this field. Indeed, many of the tested models in the empirical literature look very much like reduced-form equations. Since different systems may share identical reduced forms, it is not surprising that it is difficult to discriminate between the conflicting views. Probably, the estimation of a single-equation model - with GDP per capita and other variables included - is an activity to which there are now sharply diminishing returns.

Concluding Remarks

As demonstrated in this paper, a convergence between orthodox and non-orthodox views on the importance of technology for economic growth has to some extent taken place. Increasingly, innovation and diffusion of technology are now acknowledged as the major factors in growth processes, not only by Schumpeterians and other heterodox economists, but by many neoclassicals as well. However, important differences remain between the competing views, both with respect to how technology, firms and other agents are conceived and what the policy implications are. But, as this paper shows, the recent empirical work in this area is not able to discriminate between the competing views, and thus is of little help when it comes to policy advice. Still, when the many individual studies are put together, one message comes through quite clearly: The potential for "catch-up" (imitation) is there, but is only realized by countries that have a sufficiently strong "social capability", e.g., those that manage to mobilize the necessary resources (investments, education, R&D etc.). Thus, real world "catch-up" is far from the easy, smooth process envisaged by traditional neoclassical growth theory.

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