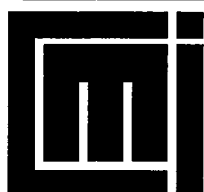


Economic development and industrial structure - an overview

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Summary:

This essay offers a selective review of central issues related to economic growth. The interrelationship between technological progress, capital accumulation, specialisation and industrial structure is emphasised. It is concluded that, first, there is little evidence that industrial structure plays an independent role for growth. Second, economists have been more successful in explaining the consequences of technological progress than the determinants of technological progress. However, even the consequences are not well understood, and there is still a long way to go before general and well-documented policy implications can be drawn

Sammendrag:

Dette notatet gir en selektiv oversikt over teorier og empiri omkring økonomisk vekst, med vekt på samspillet mellom teknologisk utvikling, investeringer og økt grad av spesialisering. Vi finner at det er lite som tyder på at industristrukture spiller en selvstendig rolle som vekstfaktor. Videre finner vi at økonomisk teori så langt er bedre til å forklare konsekvensene av teknologisk utvikling enn hva som driver den teknologiske utviklingen. Men selv konsekvensene er ikke særlig godt forstått og det er derfor langt igjen før vekstteori kan bidra med velfunderte anvendelser innenfor praktisk økonomisk politikk.

Indexing terms:

Economic growth
Industrial structure
Structural adjustment

Stikkord:

Økonomisk vekst
Industri
Strukturendringer

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1. Introduction

According to Maddison (1995), world income per capita was low and stagnant before the industrial revolution, after which economic growth gained momentum.¹ However, in this long-term perspective, growth has been uneven. Africa was the poorest and least industrialized region in 1820 and still is. Furthermore, the income gap has widened from less than 3:1 towards Western Europe in 1820 to more than 16:1 towards the United States in 1992. Convergence of income levels is observed in the period since 1950, but mainly within regions and among the richer countries.² This essay discusses the determinants of growth with a focus on the interrelationship between economic growth and industrial structure.

Economic growth and economic development will be used interchangeably. Strictly speaking, economic growth only relates to the long-run expansion of income, but studies of long-run growth always find that growth is associated with substantial changes in the structure of production, consumption and standard of living, although the degree and reach of the changes may vary from country to country. Indeed, if a distinction is to be made between growth and development, growth is concerned with the process of income expansion and its determinants in general, while development is occupied with why growth rates and income levels differ. Economic growth is a

¹ All the data presented in this section is taken from Maddison (1995).

² There is an ongoing debate on the convergence issue. Absolute convergence, meaning that the spread of absolute levels of income per capita is narrowing, is rejected by most economists, while a number of studies have found conditional convergence during the period since 1950. Conditional convergence means that when controlling for discrepancies in exogenous factors not taken into account in the growth model, the initially poorest countries grow faster than the richer countries. See Levine and Renelt (1992) for an overview, and Caselli et. al. (1996) and Barro and Sala-i-Martin (1997) for recent contributions. Conditional convergence does, however, not explain how the discrepancies emerged in the first place. Since the forces which created the discrepancies do not disappear at an arbitrary point in time chosen as the base year for econometric analysis, the conditional convergence literature is not very illuminating, in my view.

complex process involving at least four interrelated elements, or building blocks. Different models emphasize different aspects, but no model can ignore the impact of technological progress. It lays the foundation for profitable investment in human and physical capital and it facilitates interspatial specialization. Hence, investment in human and physical capital and specialization constitute the three other building blocks in growth theory, and these elements in turn drive technological progress.

Industrial structure plays a role for growth because sectors may differ regarding the rate at which new, improved vintages of capital are introduced, the rate of process innovation, the level of skills required in order to operate the best-practice production process effectively, the capital intensity of production and the intermediate components intensity. This notwithstanding, there is little empirical support for the idea that sectoral allocation or re-allocation of factors of production plays an independent role for economic growth (Nelson 1964, Dowrick 1989, Maddison 1995). Rather, sectoral reallocation of labor is seen as a consequence of changes in the composition of demand and uneven technological progress among sectors as the economy grows. The interrelationship between technological development, investment, specialization and industrial structure in the growth process is further discussed below. Section 2 discusses the role of investment in physical and human capital. Division of labor as an engine of growth is dealt with in section 3, while theories emphasizing the role of history are briefly discussed in section 4. Section 5 offers some thoughts about the role of natural resources in the growth process, while section 6 concludes.

2. Capital accumulation

The neoclassical growth model is mainly concerned with the accumulation of capital. It was developed by Solow (1956) and Swan (1956) and assumes diminishing return to capital, which is aggregated into one homogeneous production factor. Thus, as the stock of capital per worker increases, the return to new investments decline and capital deepening grinds to a halt in the long run in the absence of technological progress. However, technological progress, which is unexplained, creates new, profitable investment opportunities and the trajectory just described repeats itself.

Technological progress is perhaps most visible in the development of new goods, including new machinery and equipment. Thus, early attempts at explaining technological progress within the neoclassical framework featured technology embodied in successive vintages of capital goods (Arrow 1962, Solow 1962). Arrow (1962) in particular has inspired a large body of research focusing on the interrelationship between human and physical capital accumulation and technology. His story is therefore dealt with in some detail: Workers in the capital goods producing sector learn through experience such that their ability to build more sophisticated machines increases with experience. The quality improvement of machines manifest itself through a capacity to produce a given quantity of output at lower cost. However, investors expect wages to increase over time. A particular vintage may therefore become economically obsolete before it is physically worn out. As a consequence, new capital goods are produced and employed when the technological distance to the previous vintage is sufficient to yield non-negative profits over the expected economic or physical life-span of the capital good.

Usually it takes more than effortless learning by doing to develop new technology. Extensions of Arrow (1962) thus add a human capital intensive research and development (R&D) activity to the model. When new products and processes are improvements of existing ones, the latter may be rendered obsolete. Models with this property include quality ladders, product cycles and models of creative destruction. When new products or processes are complementary or unrelated to existing ones, we have models of expanding product variety, which will be discussed in section 3.

In quality ladder and creative destruction models, the relationship between technological progress and growth is not always a positive one because the social cost of driving existing firms out of business may outweigh the benefit of introducing the new technology.³ Models of creative destruction differ from quality ladder models in assuming that the successful innovation improves all industrial products in the economy and therefore apply to major technological break-throughs (Aghion and Howitt 1992), while the quality ladder models relate to less fundamental improvements in technology on a sectoral level (Grossman and Helpman 1991a). The pace of innovation differs among industries. Consequently, industrial structure matters for growth. Note finally that these models presupposes that investors in new technology enjoy temporary monopoly rents from their innovation, as opposed to Arrow's costless innovations and competitive economy.

Closely related to the models of quality ladders are the so-called product cycle models (Vernon 1966, Krugman 1979, Dollar 1986, Grossman and Helpman 1991a). They

³ These models usually assume that new technology is introduced by new firms.

extended the quality ladder approach to an international setting and added incremental process innovation, or learning by doing, after a new product is introduced. Thus, while technological progress takes place in discrete leaps in the quality ladder and creative destruction models, it is a smooth process in the product cycle models. In addition, the product cycle models address the diffusion of technology in a development perspective. It is assumed that the North has a comparative advantage for innovation while it has a cost disadvantage in production compared to the South. As the product cycle unfolds, the production process becomes standardized, the technology gets embodied in machinery and equipment, and the scope for further learning declines sharply. At some stage, depending on the cost differential between North and South and the South's ability to imitate, the comparative advantage shifts to the South. The North's ability to introduce and monopolize new goods sustains the North-South wage gap, but capital will flow to the South and in the long run reduce the income gap (Dollar 1986). Both the development and diffusion of technology is strongly related to human capital. Thus, a critical mass of people with a high level of human capital seems to be necessary for the development of technology, while widespread basic knowledge is necessary for developing a capacity to imitate or utilize new technology.

2.1 The special role of human capital

Two major approaches to modeling human capital are found in the literature.⁴ The first sees human capital as a separate factor of production. It is accumulated through foregone consumption, and produced in the same way as physical capital, although the

⁴ The first approach can be seen as a special case of the second.

production technology may be different. This approach can be subdivided into two types of models, in turn. The first is mainly concerned with human capital as such, and once accumulated it enters the aggregate production function in the same way as physical capital (Uzawa 1965, Mankiw et. al. 1992). The other subgroup is mainly concerned with endogenizing technological progress and considers human capital as a crucial input in the R&D sector (Grossman and Helpman 1991b ch 5).

The second approach makes a distinction between human capital and knowledge. Human capital is embodied in a particular person, and can be traded in competitive markets. Knowledge, in contrast, is independent on any physical asset and is non-rival and partly non-excludable. This means that once established, knowledge can be used by anyone without wearing it out, and it is difficult to exclude producers who want to use it from doing so. As a result, there are increasing returns in the aggregate production function. The extent to which knowledge is embodied in tangible assets and the extent to which it is excludable are the major dimensions along which models of human capital can be classified. Seen in this light, the neoclassical models of Solow (1956), Swan (1956) and Arrow (1962) consider knowledge to be a public good, not compensated for by its users, and provided exogenously in the former two papers and as a side effect of investment in the latter.

Barro and Sala-i-Martin (1995 ch 5) showed that sustained, endogenous growth can be obtained even if human capital is an “ordinary” factor of production with no externalities related to its use or accumulation. This result is due to complementarity between human and physical capital such that if both classes of capital are

accumulated at the same rate in steady state, diminishing returns do not set in. However, as pointed out by Lucas (1988) and Romer (1986; 1990), it is reasonable to assume that there are limits to how much knowledge can be embodied in the human being, if not for other reasons, at least because of the limited duration of a human life span.⁵ Disembodied knowledge, on the other hand, may be accumulated without bound, while human beings can specialize and understand different pieces of it. Disembodied knowledge is central to the endogenous growth theory, pioneered by Romer (1986). This theory aims at capturing the history of non-diminishing rates of growth over time as presented in Maddison (1995) without resorting to exogenous explanatory variables.⁶

When knowledge contributes to the production of marketable output and is at least partly excludable through a legal system of protecting intellectual property rights or otherwise, economic agents will invest in knowledge. Furthermore, since knowledge is only partially excludable, there are positive externalities related to such investments. Models typically include an R&D sector which uses human capital intensively in the production of blueprints or designs for new goods or processes. Once invented, the designs or blueprints can in principle be used by any producer who wants to, but the legal system grants at least a temporary property right to the innovator. A competitor can nevertheless study the patent documents, the product or

⁵ Lucas (1988; 1993) argues that while it is reasonable to assume decreasing returns to formal schooling, on the job training is less likely to exhibit diminishing returns, particularly if new goods are allowed for.

⁶ Nonetheless, as pointed out by (Barro and Sala-i-Martin 1995) a sufficient condition for sustained growth is that the return to capital is bounded from below. Therefore, exogenous technological progress is not a necessary condition for growth even in the neoclassical model. Critics point out that the difference between Arrow and Romer's stories boils down to whether the marginal product of capital, broadly defined, is decreasing or not, which is an empirical question not easily resolved.

the process and learn something that could be useful if she wants to develop a more or less similar design. Thus, productivity in the R&D sector may be an increasing function of the stock of knowledge already accumulated. (Romer 1990). However, as pointed out by Maddison (1995) and Rosenberg (1994), the adoption of technology developed by others is by no means a costless trade. Thus, economy-wide increasing returns to knowledge is likely to be at best moderate. An R&D sector as described above is a building block in models of creative destruction, product cycle models and models of expanding variety of inputs as discussed in section 3.

A final point on human capital and development worth mentioning is the idea that human capital is less internationally mobile than physical capital. If this is true, and if in addition human and physical capital are complementary to each other, this creates a binding constraint on international capital flows and permanent income inequality (Lucas 1990; 1993, Barro et.al 1995).

2.2 Industrial structure and capital accumulation

Structural transformation in the process of economic growth has been a central issue in development economics from its infancy. Early work includes Lewis (1954) who discussed the transformation from an economy dominated by subsistence agriculture to an industrialized economy. The engine of growth and transformation in this model is capital accumulation in the industrial, urban sector. Lewis assumed that a pool of surplus labor existed in the agrarian economy which could be employed at wages below their marginal product in the industrial sector, creating profits which in turn were invested in the modern sector. Lewis predicted that this process would continue

until the entire stock of surplus labor was absorbed in the modern sector. However, unless the marginal product in agriculture is negative, which is unlikely, the transfer of labor from agriculture to industry could only take place if there was a simultaneous improvement in the productivity of agriculture. Otherwise those who left for the city could not be fed by those who staid behind. A substantial improvement in productivity in the primary sectors is indeed what happened during the industrial revolution and after, to the extent that by the 1990s the capital-labor ratio in the United States was six times higher in agriculture than in manufacturing (Johnson 1997).

Johansen (1960) showed that when technological progress is asymmetric among sectors, sectors which experience a fast rate of technological change tend to grow faster (more slowly) than GDP if the sector faces (in)elastic demand. Income elasticity of demand is often assumed to be smaller the more the good or service in question is considered a necessity, which is why the primary sectors are found to face inelastic demand. In other words, technological progress in sectors producing necessities improves welfare by releasing resources to the production of more income elastic goods and services. However, if a country is specialized in producing necessities, deteriorating terms of trade may well follow. This was a concern to the so-called structuralists in the 1960s (UN 1964) who advocated an import substitution policy in order to generate industrialization rather than facing economic decline due to unfavorable developments in terms of trade. However, there is no convincing evidence of a long-run secular deterioration in terms of trade for the primary sector

(Cuddington 1992), while the cost of infant industry protection turned out to be substantial.

Industrial structure is strongly related to comparative advantage and international division of labor, as in the product cycle models. If a country is specialized in an industry of slow productivity growth and trades with a country specialized in a rapid productivity growth industry, the productivity gap widens if there are no technological spillovers across sectors and international boundaries, and persists if there are. Thus the industrial structure and trade pattern are locked in (Krugman 1987, Lucas 1988). The OECD classifies manufacturing industries according to technology level, measured as R&D intensity, and find substantial differences among industries. This does, however, not necessarily lead to differences in productivity growth since the returns to R&D are sometimes more related to (temporary) monopoly rents than to productivity gains.

2.3 Empirical evidence on the role of capital accumulation

During the first century of industrialization in the Western world, the capital stock grew faster than output (Maddison 1995), and capital productivity declined as a consequence. Abramovitz (1993) explains this development by a strong capital-using bias in technological progress. In particular, the new industrial technologies required a wide range of inputs from transport and communication services, energy and producer services in order to operate effectively. Therefore, large-scale investment in infrastructure and a higher degree of urbanization, which is also capital-intensive, was a prerequisite for industrialization. Infrastructure provided commonly shared inputs

and were probably not fully utilized for decades. The same trend of diminishing returns to investment was observed during the period after the first oil price shock in 1973. David (1991) argues that this time investment was related to new information technology of which the fruits are yet to be reaped.

There was a sharp increase in the average number of years of education of the labor force in all industrialized countries during the period 1913 to present, but the growth rate slowed down in the European OECD countries after 1950. This development coincided first by a decline in the share of capital in GDP, followed by stabilization (Maddison 1995). Empirical evidence thus suggests that technological development was biased towards physical capital during an early stage of industrialization and that technological progress has become more neutral over time.

The neoclassical growth model laid the foundation for an extensive body of empirical research known as growth accounting. Solow (1957) estimated the contribution from labor, capital and a residual which was referred to as total factor productivity (TFP) for the US economy, and a number of similar studies followed. As pointed out by Abramovitz (1993), this literature as well as growth regressions discussed below, should be taken as first proxies to quantifying the determinants of growth because they do not take into account the interrelationship between the variables included in the model. Furthermore, measuring inputs and outputs correctly is prone with difficulties and may lead to questionable conclusions. Bearing in mind these qualifications, the data suggest that physical capital accumulation accounted for

between one and two thirds of actual growth in the post war period.⁷ The importance of capital accumulation seems to be larger in the poorer countries while TFP accounts for about half of observed growth in the richer countries and about a third in middle-income countries.⁸ Given that capital is relatively scarce in the poorer countries, the results support the predictions of the Solow model. However, Jorgenson and Griliches (1967) and later Young (1995) argue that if both inputs and outputs are correctly measured, TFP plays a more modest role for growth than the growth accounting estimates suggest. This debate is probably mostly semantic, though, and boils down to whether quality improvements, particularly of capital inputs, should be counted as contributions from factor inputs or from TFP in the growth accounting studies.

A different approach to empirical estimates of the determinants of growth is regressions on panel data. Within this framework, De Long and Summers (1991; 1993) emphasized the role of mechanization for economic growth and estimated the interrelationship between growth and investment in machinery and equipment. They found that such investment is the single most important factor explaining growth in GDP per worker in a sample of 61 countries, and that the social return to such investment is higher than the private return. Their findings support both the idea that technology is largely embodied in machinery and equipment and the idea that such investment may generate positive externalities. Moreover, they find that this relationship is weaker in the richer Western European countries than in the developing

⁷ The papers use quality-adjusted labor and thus takes improvements in education into account, but not learning by doing.

⁸ The results are summarized in Barro and Sala-i-Martin (1995).

world, while investment in infrastructure contribute more to growth in poor countries than in rich countries. This latter finding seems to bode well with the suggestion that a critical mass of infrastructure is necessary for growth to take off (Baumol 1986, Abramovitz 1993). However, there may well be even a one to one relationship between investment in machinery and equipment without the causal inference made by De Long and Summers if machinery and equipment investment is more internationally mobile than investment in other forms of capital, which is very likely.

Mankiw et. al. (1992) show that the Solow model augmented by human capital as a separate factor of production is consistent with the data. Further, they show that human capital accumulation, measured as the share of working age population in secondary education, is more important than physical capital in explaining the variety of income levels in the world. This result is even stronger when only the OECD countries are considered. It should finally be noted that regression analysis generally ascribe a more important role to human capital than does growth accounting. A possible explanation is that growth accounting only takes into account the rate of change of school attainment, which levels off as economies mature, while regression analyses take into account both stock and flow variables related to human capital and in addition incorporates proxies for the quality of human capital. Thus, parts of the increasing importance of TFP with income found in growth accounting studies may be due to an increase in human capital not captured by increases in school attainment.

Growth regressions typically find that the investment ratio (e.g. total non-residential investment as a share of total GDP) is one of the most important determinants of

growth, measured by the size of the regression coefficient, given that it is significant. (Barro and Sala-i-Martin 1995). However, some studies have casted doubt on this conclusion. Using instrumental variables in order to capture a possible endogeneity of the investment ratio, Blomström et. al. (1993) and Barro and Sala-i-Martin (1995) find that the contribution of the investment ratio is positive, but insignificant for growth.⁹ They interpret this result as an indication that the causation runs from growth to investment, not the other way around. This finding, together with positive and significant coefficients on a number of indicators of human capital accumulation, could also be interpreted as a support for Lucas' (1993) view that the main engine of growth is accumulation of human capital, while physical capital is essential but plays a subsidiary role.¹⁰

Looking at sectoral developments, Syrquin (1986) finds that labor productivity and the capital/labor ratio are typically lowest in agriculture at low income levels. However, as the income level rises, the productivity gap between agriculture and manufacturing first increases up to a middle-income level and then starts to narrow as a result of a faster growth rate in the capital/labor ratio in agriculture than in any other sector. During the industrialization process, reallocation of resources is typically found to account for about 20-30 percent of observed growth (Chenery et. al. 1986). Finally, the product cycle theory seems to find some support in empirical studies. Thus, Beelen and Verspagen (1994) find that productivity levels in "high-tech" industries exhibit a divergent pattern among countries, while "low-tech" sectors converge.

⁹ Mankiw et.al. (1992) draw the same conclusion for the OECD countries in a simple OLS regression.

¹⁰ Indicators of human capital accumulation are government expenditure on education, educational attainment, and life expectancy. The only indicator of human capital which is negatively related to economic growth is female educational attainment.

From this section it can be concluded that the virtuous circle of capital accumulation and technological progress is one of the most important determinant of economic growth. In the early stages of industrialization, physical capital accumulation seems to have been the most important, although there was probably not a causal effect from investment to growth. Rather it seems like technological development, largely embodied in physical capital, drove both investment and growth. For newly industrialized countries, the technology was obtained from abroad, once the absorptive capacity was in place. However, as the economy reaches a high capital/labor ratio, total factor productivity seems to play a more important role, while the accumulation of productive assets is increasingly shifted towards intangible capital. This development is seen in the economy as a whole, but it is also seen within the industrial sectors (Dowrick 1989), although sectors undergo this transformation at a different pace and at different periods in time. Therefore, structural changes are hardly an independent source of growth and development.

3. Productivity growth through specialization

The advantages of extensive division of labor was emphasized already by Adam Smith, but have only recently gained center stage in research on economic growth and development. Again technological progress, particularly in transport and communication, plays the facilitating role: As transport and communication technology improved over time, the scope for division of labor was gradually extended from the household to the world economy. Thus, one dimension of

economic growth is the development from household production for own consumption, via large-scale factories broadly self-sufficient with inputs except raw materials, to more specialized units buying inputs such as components, cleaning services, maintenance and book-keeping, from other specialized firms. Moreover, as transport costs decline even further, these inputs can be traded farther afield and need not involve further increases in the degree of urbanization or agglomeration. In a sense, therefore, the nature of division of labor has changed more than the composition of output during the process of industrialization.

Models of economic growth through increased specialization have the property that productivity in the production of final goods increases with the number of intermediate inputs available. Technical progress in these models manifest itself in the rate of introduction of new intermediate products. If there are fixed costs involved in the development of new inputs, which is usually assumed, the number is limited by the extent of the market. Therefore, demand plays an important role for economic development in this context. First, a critical level of demand is needed for production to shift from the household to the market (Goodfriend and McDermott 1995), and second an even higher level of demand is necessary to trigger the process of industrialization (Murphy et. al. 1989, Goodfriend and McDermott 1995). The more productive the “primitive” sector is, the higher the level of demand necessary to trigger industrialization (Chenery et. al. 1986, Goodfriend and McDermott 1995).

If intermediate inputs are not internationally tradable or traded at large costs, models of expanding input variety predict that large countries grow faster than small countries

and rich countries grow faster than poor countries. Furthermore, poor countries may find themselves in a poverty trap because a small market yields a shallow division of labor and thereby low productivity which manifest itself as low returns to capital and labor. Hence, in models of expanding product variety, the marginal return to capital is not higher in capital-poor developing countries than in capital-rich industrialized countries as predicted in the neoclassical growth model discussed in section 2. Ways out of the poverty trap are coordinated investment. This is assumed to work because industries provide markets for each other such that a "big push" would trigger the industrialization process (Murphy et. al. 1989). Alternatively, integration of markets would raise the level of demand facing each producer and thus reduce the disadvantage of being small or poor (Rivera-Batiz and Romer 1991, Ciccone and Matsuyama 1996).

3.1 Empirical research on the division of labor and industrial structure

Structural changes related to industrialization is characterized by a sharp increase in the ratio of intermediate demand to total output in all sectors of the economy, but manufacturing is by far the most intermediate input intensive sector. Kubo et. al. (1986) found that about half of the observed structural change was accounted for by changes in input-output coefficients while the rest was explained by changes in output composition in a selection of countries undergoing the transition towards industrialization. Further, they found that countries that grow faster tend to have more rapid increases in intermediate input demand. However, empirical studies lend little support to the hypothesis that a small market per se should lead to shallow division of labor and a poverty trap. Thus, Kubo et. al (1986) find that small, open economies

such as Norway, Israel, Taiwan and South Korea have a similar level of intermediate demand relative to total domestic demand as larger countries, and that imported intermediates account for a much higher share of total intermediate demand in these countries, indicating that intermediate inputs are traded at reasonable cost in a liberal trade regime. Finally, there is no evidence that large countries grow faster than small countries.

4. Path dependent models of growth

Path dependent theories of growth focus on technological progress and its interrelations with capital accumulation, specialization and demand factors, emphasizing that this development takes place in a world with a high degree of uncertainty and incomplete information. The theory is more concerned with the content of knowledge than the stock of knowledge. Thus, scientific knowledge is distinguished from technology which in turn can not be applied directly off the shelf in productive activities. Thus, there may be substantial costs involved in acquiring information about technology and putting it into use.

Since disembodied knowledge is costly to acquire, there is no reason to assume that firms know the technological options available to them. Therefore, the technology actually chosen is somewhat stochastic. But once a technology is chosen, subsequent technological progress is dependent on this choice. This is because improving the existing technology is less costly for producers, and because products and processes are complementary in consumption (Rosenberg 1994). Path dependent theories of

growth aim at capturing the full complexity of the growth process, and has hitherto been constrained by insufficient analysis tools. In particular, in order to formalize the ideas, complex dynamic systems usually not found in economists' tool-kit are required. Therefore the field has been left in the domain of economic history and an emerging and highly experimental field inspired by methods developed in the natural sciences.¹¹

5. The role of natural resources

Natural resources are essential inputs in the production of final goods and services, both directly and indirectly. Thus, manufacturing industries essentially process raw materials in a succession of operations, while both machinery and workers run on energy provided by nature. Technological development has saved both labor and natural resources such that the amount of resources per unit of output has steadily declined. Indeed, Romer (1990) defines technological progress as "improvement in the instructions for mixing raw materials" (p. S72). Natural resources are, however, not merely harvested. The extraction or cultivation, basic processing and marketing of such resources involve labor, capital and intermediate goods and services. Indeed, in the pre-industrial state, it occupied most of the productive resources available. Therefore, the role of natural resources in growth and development has at least two dimensions. They first provide a source of income for people employed or investing in the primary sector, and second constitute an essential input in the production of manufactured goods. The quality and cost of raw materials are therefore strongly

¹¹ Recent work include Arthur (1994) and Krugman (1996)

related to the productivity and cost of manufacturing and other productive activities. Suffice it to mention the impact of the oil price shocks of the 1970s and 1980s.

Looking at the role of natural resources as an input, David and Wright (1992) argue that abundance of natural resources, together with rapid population growth laid the foundation for industrialization in the US. First, abundant high-quality land induced the relative price of food to be comparably low. Consequently, the demand for industrial output accounted for a higher share of total demand than in Europe. Second, the production technology was resource-intensive, largely as a result of resource abundance, and transport costs of natural resources were relatively high at the time, providing a comparative advantage in resource-intensive manufacturing industries. Furthermore, it has been argued that the erosion of this comparative advantage as the world economy became less natural resource-intensive and transport costs of bulky raw materials declined, accounts for the decline in American leadership since the 1970s (Maddison 1995). In this regard it is also worth mentioning that a large proportion of the aggregate productivity growth slowdown in the US since the early 1970s is attributed to a sharp fall in mining productivity (Maddison 1995). These findings notwithstanding, natural resources are by and large absent from both theoretical and empirical studies of economic growth. Exceptions are Bruno and Sachs (1985) and Nordås (1997a) who show that a trend change in the real cost of raw materials induces productivity changes in the production of final goods in the opposite direction of the price trend. Nordås (1997a) suggests that this has contributed significantly to the spectacular growth performance of South Korea and Taiwan.

Natural resources as a source of income feature somewhat more prominently in the development literature and in the so-called Dutch disease literature. Empirical findings suggest that natural resources are a curse rather than a blessing as a negative correlation is found between natural resource abundance and economic growth (Sachs and Warner 1995). Several reasons for this correlation have been put forward. The Dutch disease literature suggests that a demand driven change in relative prices renders the most dynamic, exporting sectors uncompetitive (Corden and Neary 1982, Van Wijnbergen 1984, Krugman 1987). Others suggest that since the resource rent largely falls on the government, the government sector typically becomes "too big" and interventionist. Finally, slower growth in natural resource rich countries over the past few decades is seen as a result of technological features of the natural resource extracting and basic processing industries and recent developments in the world economy:

First, while transport costs and a relatively resource intensive production technology made location of industries close to natural resource deposits an advantage during the emergence of the US as the leading economy of the world, a service intensive production structure with much attention to consumer preferences makes location close to the large consumer markets an advantage today. This is reinforced by a substantial decline in transport costs for raw materials, and significant trade barriers in the service sectors. Second, the resource extracting and basic processing industries are typically large-scale, capital-intensive and the technology is to a large extent embodied in expensive, slowly depreciating capital equipment. Finally, these sectors have not hitherto been very extensive users of intermediate inputs. These

characteristics amount to a relatively static sector subject to economies of scale at any point in time, but limited scope for dynamics such as learning by doing, rapid technological progress or growth through an expanding variety of inputs. At any point in time, allocating a relatively large share of the economy's factors of production to the resource sector yields the highest rate of return on labor and capital, but this does not generate the technological spillovers (Nordås 1996) or pecuniary externalities (Nordås 1997b) that are thought to be so important for economic growth.

Nevertheless, countries which have exploited their comparative advantage in the natural resource sector while leading an open trade regime, have performed much better than natural resource-rich countries which have attempted at premature import-substituting industrialization (Chenery et. al. 1986). Examples of successful resource-rich countries are Malaysia, Thailand and Norway. These countries have invested in human capital and infrastructure rather than protecting manufacturing industries, and have experienced late industrialization, but in more technologically sophisticated and skill-intensive industries, some of which has strong linkages to the natural resource sector.

Natural resources are essential inputs in the production of final goods. Therefore, the supply of low-cost natural resources is important for growth. However, some of the essential resources are exhaustible, such that conservation is important for long-run growth. As shown in Nordås (1997b) a compromise between these two considerations is a sustained increase in the real cost of raw materials which is more than compensated by an expanding variety of inputs in the production of final goods.

Given that both the resource sector and final goods producing sectors use intermediate goods and services, the latter more intensively than the former, a reduction in trade barriers in such inputs, particularly producer services, would induce such a development.

6. Concluding remarks

The long-run data show divergence rather than convergence of income levels in the world economy. The theory of economic growth has hitherto not been able to explain this historical fact. Thus, we know that a high level of investment in physical and human capital is strongly related to growth, but this does not imply that countries are poor because of lack of capital. Further, we know that growth is strongly associated with a high and increasing extent of specialization. But again this does not imply that countries are poor because of shallow division of labor. Mancur Olson (1996) went through the list of possible explanations for diverging income levels and arrived at the conclusion that differences in national institutions are the key explanatory variable. He arrived at this conclusion by eliminating all other possibilities, but he did not scrutinize the institutional issue in the same way as the eliminated explanations, so we can probably not safely conclude that countries are poor because they have weak institutions.

What seems to lie behind growth is technological progress. This is a somewhat loosely defined concept which affects and is affected by capital accumulation, division of labor and institutions. Technological progress is thus a dynamic and complex

process largely outside the realm of economics, and therefore difficult to capture in relatively simple economic models. Consequently, growth theory has been better at explaining the consequences of technological progress than its determinants. Models emphasizing the dynamics of division of labor and the emerging field of path-dependent technological progress seem to be promising areas where growth theory can finally start to say something interesting about growth.¹² However, there is still the danger that research on economic growth will contribute to the things we know that ain't so.

¹² A phrase borrowed from Romer (1986)

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