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CAPITAL, TECHNOLOGY OR EFFICIENCY?

A Comparative Assessment of Sources of Growth in Industrialized and Developing Countries

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This paper centers on a set of empirical findings about growth. It aims at presenting a comprehensive overview of aggregate and manufacturing growth between 1980 and 1990 in a sample composed of industrialized and developing countries. In this overview, the focus is on quantifying the respective contributions to growth made by capital accumulation and productivity change, as well as on a decomposition of the latter into the elements of technological change and change in technical efficiency. For these results, which were obtained by use of advanced techniques of productivity measurement, the paper also attempts a broad interpretation within the framework of a standard typology of countries.

1. Introduction

The prospects for achieving the major development goals of the international community crucially depend on economic growth. This is true *a fortiori* of the overarching objective of a substantial reduction of absolute poverty worldwide over the coming 15 years. At the same time it also takes care of the concern with relative poverty, at least in its international dimension, as it is manifested in the distribution of income across countries and its development over time. Since economic growth is what matters, it is of the essence to understand the growth process. And such understanding has to build on theoretical as well as on empirical work.

The empirical analysis of economic growth has been attracting contributions from many researchers over a long period and therefore offers a broad field of investigation. However broad, this field has been unified by one common approach, described by Solow (2001) as 'the search for a dynamic model that could explain the evolution of one economy over time'. This approach is so fundamental that it could also be used to study the question of what is behind between-country variation in growth rates – despite the many problems arising from the application of a theoretical model of change over time to the task of explaining differences among countries.

A shift of emphasis is however taking place in the search for what accounts for most of the income and growth differences among countries, from stressing the traditional role of factor accumulation in growth towards paying more attention to that of productivity increase and one of its main sources, technological progress[1]. This shift has also to do with improvements in our capacity to assess empirically the role of several contributions to growth, which previously could not be disentangled. Owing to the nature of these contributions, it is only too obvious that manufacturing industry is playing a special role in the process and consequently in its analysis. In this

[1] Easterly and Levine (2001) make a forceful plea for what they consider to be the overwhelming importance of technology for growth. They document a number of 'stylized facts' about growth which lead them to assume that growth and income differences among countries must have to do much more with total-factor-productivity growth than with factor accumulation.

vein, the present paper discusses some of the main aspects of the empirical analysis of growth of output and productivity and reports the use of some of the recently developed measurement tools in a growth analysis of a sample of industrialized and developing countries[2].

2. Background

Growth in the aggregate output of an economy – when it is viewed in the traditional analytic framework – is best seen as feeding on three broad sources: growth in inputs to production; improvements in the efficiency of allocation of inputs across activities; and technology, which – under the assumptions of the standard growth model – makes its contribution through technological change, leading to increases in overall factor productivity. The focus of the present discussion will mainly be on the last of these three sources of growth, i.e., on productivity growth and its empirical assessment.

2.1 On measuring productivity

Among the various approaches to measuring productivity and its change over time[3], a broad distinction is usually drawn between measures that consider the role of a single factor, supposed to represent all the factors that combine to obtain output increase and those, which assess the combined contribution of several production factors. The most widely used single-factor measure is that of (average) labour productivity, which is expressed as the ratio of output over some measure of labour input. It can be viewed as a rough indicator of how productively labour is used to generate output. While the output-labour ratio is easy to compute, it suffers from shortcomings as a measure of 'productivity', i.e., of the quality or intensity of effort, of the single factor labour. The reason is that it also reflects the impact on the level of

[2] The source of methodological as well as empirical results reported here are two SIN Working Papers, namely, Forstner and Isaksson (2002a and 2002b). In these papers, the technical details of the methods applied, as well as the empirical results at a disaggregate level are presented in a comprehensive manner.

[3] An overview of different approaches to measuring the growth of aggregate as well as of industry-level productivity is provided in OECD (2001).

output of a number of factors other than labour, such as capital, intermediate inputs or even technological change.

The alternative to a single-factor measure like average labour productivity is the measure of so-called total factor productivity (TFP). It can be defined as the ratio of output over an index of all inputs combined. In the context of empirical analyses of growth, it is changes rather than levels of TFP that are of interest. And for measuring such changes methods have been developed that enable the analyst to take into account explicitly and simultaneously several factors of production as well as a multitude of products of which total output is composed. In addition, these methods allow for a decomposition of productivity increase into some of its major components and thus produce empirical evidence on some of the main sources of growth.

Among the components of productivity change, three are of prime interest in the present context. The first one is technological change, which theory would propose as the source of productivity growth in a world where (technological) knowledge is created continuously and made available to all producers. The second component is change in technical efficiency, which reflects the fact that in the real world not all producers are using best-practice methods of production and hence improvements in technical efficiency offer a real possibility for enhancing productivity. Finally, changes in resource allocation and the consequent changes in output composition – reflecting altered allocative efficiency – can be singled out and assessed empirically as a third component in the rise or decline of overall productivity.

In empirical growth analysis, traditionally the focus has been on aggregate growth and hence also on aggregate, i.e., economy-wide productivity change. Accordingly, the development of empirical methods has taken place primarily with a view to analyzing aggregate productivity and some of its sources. However, recently a strong interest in the measurement and the analysis of productivity change also on a disaggregate level has emerged. The main reason behind this interest is the need for a better

understanding of changes in TFP and of the determinants of such changes. Increasingly, analysts hold the view that substantial progress in this area can only be made when developments in productivity change can be studied at the sector, the industry, and occasionally also the firm level.

As is well known, the main constraint to productivity measurement at a disaggregate level is the availability of data, in particular, those relating to factor inputs. For some of the developed countries, in particular, the United States, productivity measurement at a disaggregate level is well advanced due to a broad and detailed information background. There are also a growing number of productivity studies utilizing plant-level data, which are becoming available for an increasing number of selected countries and time periods[4]. In contrast, comparisons of growth performance and productivity change across a wide range and a large number of countries have still to be conducted in aggregate terms due to data limitations.

2.2 The framework for growth analysis

The empirical analysis presented below employs the Malmquist index as a measure of productivity change. Among the advantages of this approach is the fact that only the most basic data on input and output are required. In addition and more importantly, the method allows for estimation not only of productivity change, but also of some of its major components as they were outlined previously. The following paragraphs give an outline of the main elements of the approach, building on its graphical representation in Figures 1 to 4.

The theoretical framework to which most of the analyses and discussions of long-run aggregate growth refer is that of the 'neoclassical' growth model, often simply called the Solow model[5]. It is based on the

[4] Recent examples of empirical analyses also of growth and productivity at firm level are found among working papers published jointly for the Oxford Centre for the Study of African Economies and UNIDO (see, for example Soederbom and Teal, 2001).

[5] A full account of this analytic framework is presented, for example, in Chapter 1 of Barro and Sala-i-Martin (1995), whereas Solow (1994) offers a succinct non-technical statement on the model, putting it in the context of other modeling attempts.

neoclassical production function, which represents – under a number of standard assumptions[6] - the relationship between total output (GDP) per worker and capital per worker as illustrated in Figure 1. The curve in this figure shows the maximum level of output per worker (y) that is achievable for a given level k of capital per worker, and the shape of the curve – i.e., the decrease of its slope – reflects diminishing returns to capital. Thus, it can be said that for a given technology, as represented, e.g., by the curve in Figure 1, y is a function of k[7]. In the case illustrated by the figure, growth of output per worker results from an increase of capital per worker and the rate of growth diminish with an increase of the capital stock relative to the labour force. In other words and as depicted by points P_1 and P_2 in the figure, the way for a country to grow between period 1 (P_1) and period 2 (P_2) is to move to the right along the k-axis and thereby – in the absence of technological progress – make gains along the y-axis at a steadily decreasing rate. Viewed from the input side, this process would be described as capital deepening, which – in an output perspective – is seen to be reflected in an increase in the overall capital intensity of production. Bearing in mind that it is the growth of aggregate output when technology is stable, such growth must be ascribed to the increase of capital per worker throughout the economy as well as to changes in the structure of aggregate output, which are concomitant with the change in the proportion of factors.

Figure 2, by contrast, pictures a situation quite different from that of the previous figure. While the country studied here has not changed its k-level between period 1 and period 2, the general relationship between k and y has changed over time: the production function f has shifted upwards from f_1 to f_2, due to technological progress. As a consequence, output per worker has increased from y_1 to y_2, now not due to any further accumulation of capital per worker, but solely due to technological change.

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[6] A formal statement of the assumptions underlying the neoclassical production function is given in Barro and Sala-i-Martin (1995), p.16.

[7] In formal terms this can be stated as

$$y = f(k)$$

where the first and the second derivatives obey $f' > 0$ and $f'' < 0$, respectively.

Both Figures 1 and 2 reflect the assumption that the country observed here is not allowed any technical inefficiency: It is in a position to produce the maximum level of y achievable for a given level of k – its production point lies on the 'world technology frontier' corresponding to the world's best practice of producing GDP. According to empirical evidence on the k-y relationship, however, this assumption is not met in reality for the majority of countries. Most countries do produce at a point below the technology frontier, i.e., their production is technically inefficient by comparison with world technological standards. Consequently, another way of increasing output per worker becomes a real possibility, namely, that of increasing the technical efficiency of production. Figure 3 again pictures an extreme case of a country that raises output per worker solely by these means, moving – in the absence of technological progress and with a stable capital-per-worker level – from point P_1 to point P_2 along a vertical line of increasing efficiency. Implicit in this illustration of the above relationship is the notion that the relative (vertical) distance of a production point P from its corresponding frontier point P_f yields a measure of technical inefficiency[8].

Each one of the possibilities depicted in the above figures represents a special case where only one of three sources of growth of output per worker has been isolated and the others neutralized. Quite plausibly, a realistic picture of the sources of a country's growth of output per worker is one that combines all three of the elements singled out in Figures 1,2 and 3. Figure 4 shows such a 'real-life' case of a country moving from point P_1 to point P_2 between two time periods. It is readily seen that this move combines all three effects identified previously: Capital deepening resulting in an increase of the k-level from k_1 to k_2 accounts for the contribution of capital accumulation, the shift of the production function from f_1 to f_2 adds the gains from technological progress and the change in the relative distance to the technology frontier

[8] It is obvious that, conversely, one minus this distance provides a measure of efficiency. Depending on the context, one of the two alternative interpretations is chosen.

between production points P_1 and P_2 enters technological efficiency into the picture of growth of output per worker.

The key variable in aggregate growth analysis is output per capita or output per worker, since it is real growth of this variable, which determines improvements in living standards to a large extent[9]. At the same time, aggregate output per worker is the broadest measure possible of the average productivity of the 'factor' labour. Still, a large portion of its growth over time must be ascribed to increases in capital per worker, so that capital accumulation remains to be an important factor in growth, in particular, for the developing countries. In addition and most probably assuming much higher importance than previously, increases in the overall productivity of factors are a strong force behind output growth. Attaching some figures to these general observations, identifying key elements in growth patterns and also drawing comparisons between different groups of developed and developing countries are all objects of the following section.

3. Empirical findings

In order to illustrate the foregoing reflections on growth empirics, an exercise of output, input and productivity measurement was carried out by use of data on 57 countries for the period 1980 to 1990[10]. The source of information on GDP (measured in 1985 international prices), capital stock and labour were the Penn-World Tables 5.6[11], whereas growth of manufacturing output was derived from data of the UNIDO Statistical Database.

[9] There is a fairly long tradition of discontent with the extent of economic expansion as the dominant or even the sole indicator of development. Among the more recent manifestations of this school of thought are the construction of a 'human development index (HDI)', documented, for example, in UNDP (2001) and a discussion about the 'quality of growth', reflected, for example in Thomas (2000). While these approaches to assessing developmental achievements have certainly broadened the view of development and re-emphasized the complexity of the processes involved, they have not, however, undermined the central position of the quantitive increase of income in any attempt at measuring developmental progress.

[10] The countries in the sample are listed and the composition of groups is shown in Tables 3 and 4. Similar empirical exercises, covering different sets of countries, are those reported in Faere et al (1994) and in Krueger et al (2000).

[11] A description of these widely used data and the underlying methodology can be found in Summers and Heston (1991).

For the industrialized countries and for three groups of developing countries, Tables 1 and 2 present results that refer to the model outlined previously: One output (GDP) is produced by use of two inputs, capital and labour[12], where technology exhibits constant returns to scale. While the first table gives growth rates of output and of the two types of input, the second table shows changes in total factor productivity as well as in the contributions to these changes arising from technological change on the one hand and from change in technical efficiency on the other. All the growth rates in the two tables are averages of annual growth over the time period studied here as well as across the members of each one of the country groups[13].

3.1 Growth of aggregate output and manufacturing output

In the developments discussed on the following pages manufacturing industry plays a key role. Accumulation of capital in the industrial sector still is of high relevance to the overall growth of a developing economy. An equally significant component in the growth process is the increase of productivity in manufacturing industry. In particular, the way in which industry goes about raising productivity can in many respects serve as a model for the entire economy with regard to acquiring, adopting and putting to ever better use new technology in the service of growth. At least for these reasons it appears to be useful to start the discussion with an empirical documentation of the relationship between aggregate and manufacturing growth.

Overall, the relationship between growth in total and in manufacturing output documented in Table 1 shows the familiar relationship within the sample of the present survey: For both the industrialized and the developing country subgroups in the sample, total output grew at about the same average rate of over 2.5 percent per annum. However, while the former group showed

[12] In the present model human capital is not taken into account explicitly. For straightforward technical reasons (see Forstner and Isaksson, 2002a), this should not greatly affect, however, the broad qualitative aspects of the results reported and discussed below.
[13] The averages shown here are of the unweighted kind, giving equal weights to all countries.

a clear trend towards a declining share of manufacturing (with less than 2.0 percent output growth in the sector), the numbers for the 27 developing countries in the sample document further industrialization (with over 3.0 percent manufacturing growth per annum). Clearly, the average over the latter group covers a large variation between three subgroups: Three of the East Asian 'Tiger' economies (Hong Kong, Taiwan and Korea[14]) show outstanding growth performance, with annual rates of over seven percent for both total and manufacturing output. By contrast, on average over nine African countries a growth rate of only around one-and-a-half percent is observed for total output, however, with significantly higher growth (2.7 percent) for manufacturing. The remaining 23 developing countries in the sample also show comparatively low growth at roughly the same rates (around 2.5 percent) for total and for manufacturing output.

Country growth rates underlying the averages of Table 1 are shown in Table 3; they paint a picture of considerable variation. Among the industrialized countries growth rates differed widely, spanning a range of between over four percent (Portugal and Japan) and under 2.0 percent (Belgium, Greece and New Zealand) for total output and an even wider spread for manufacturing. And the general impression of a relative decline of manufacturing is confirmed by individual-country results: Out of the 22 industrialized economies only five showed an increase of the share of manufacturing in total output.

As expected, the group of developing countries in the sample is considerably less homogeneous than that of the industrialized countries. Growth rates of 8.8 and 11.2 percent, respectively, for total and manufacturing output of Korea mark one end of the spectrum. At the other end are countries like Argentina (-1.2 percent for total output) or Madagascar (-2.6 percent for manufacturing output), illustrating the background to some of the low average figures shown in Table 1. Furthermore, developing countries display

[14] For ease of reference in the present discussion, brief names are used for the following three countries/areas: Hong Kong for China (Hong Kong SAR), Taiwan for China (Taiwan Province) and Korea for Republic of Korea.

a wide range of the growth relationship between manufacturing and total output: While for Iran or Mauritius manufacturing growth was over three percentage points larger than total-output growth, it was smaller by nearly three percentage points in the case of Hong Kong.

The above figures provide another empirical confirmation of the notion that differences across countries are large, both in respect of total–output growth and of manufacturing growth, and that there is a broad variation across countries in the relationship between manufacturing and total-output growth. This may be taken as a first hint at substantial differences among countries, also with respect to the main elements in the growth process and their respective weights in this process.

3.2 Capital accumulation and output expansion

A key variable in the present analysis is that of the growth of output per worker or average labour productivity. Comparison between the 22 industrialized countries and the 35 developing countries in the sample provides a clear indication of divergence between the two groups over the decade surveyed here. Average annual growth was 1.7 percent for the former group while for the latter it was virtually zero. Of course, the 35 developing countries included in the sample are not representative of the developing world at large. Nevertheless, they cover a wide range of economies, from the star-performing East Asian 'Tigers' to 'other developing countries', including nine African economies. Accordingly, the group average hides large differences in growth performance among subgroups and even larger ones among countries themselves. This is reflected in the subgroup averages shown in Table 1 with evidence of strong convergence towards the developed world of the three 'Tiger' countries, dramatic divergence of the nine African economies and a widening income gap between the industrialized countries and the 23 developing countries of widely varying size and economic strength.

Already among the industrialized countries the range of growth rates is surprisingly large. It extends from a minimum of close to zero percent (New Zealand) to a maximum of nearly four percent (Portugal) while countries like Canada, Denmark, Norway and the United States gather around the mean in an interval between 1.5 and 2.0 percent. The three East Asian Tigers show a homogeneous growth performance with annual rates of output-per-worker growth roughly between five and seven percent. In the sample group of African countries by far the best growth experience is that of Mauritius (3.3 percent), whereas Cote d'Ivoire, Madagascar, Nigeria and Zambia show rates of strong decline. Finally - and in line with expectations - the highest degree of heterogeneity is observed for the sample of 'Other developing countries'. Here the best performers by far are Thailand (4.5 percent) and India (3.4 percent), followed by Sri Lanka (2.6 percent) and Turkey (2.5 percent). By contrast, Peru (-3.0 percent), Venezuela (-2.5 percent), Panama (-2.3 percent) and Argentina (-2.2 percent) are far below the average growth rate for the group as a whole.

When output per worker is viewed as the crudest and widest-ranging measure of average labour productivity throughout the whole economy, its close relationship with capital per worker is obvious. Table 1 allows for a rough assessment of this relationship, again on the basis of group averages. Comparison between the industrialized and the developing country members of the sample presents some surprises. First, on average over the members of each country group, the growth of aggregate capital was quite similar between the two groups. Second, growth of capital per worker was considerably higher in the (already capital-rich) group of industrialized countries than in that of developing countries. Third, it also exceeded the growth of output per worker by one full percentage point in the former group, whereas in the latter group the excess of capital growth over output growth was smaller. Thus, in no way could further capital accumulation be seen as inessential to industrialized-country growth, while the role that it

played in the developing countries sampled here was at least not a consistently strong one.

An exception, clearly set apart from the experience of other countries, also with respect to the importance of the expansion of the stock of capital per worker, is again provided by two of the three 'Tiger' economies of East Asia. Both Korea and Taiwan show unrivalled growth rates of capital of around 8.0 percent per annum, resulting in growth of capital per worker of over 6.0 percent. On the other hand, Hong Kong achieved its record output growth with a growth rate of capital per worker of only 1.3 percent – an empirical fact, which poses interesting questions about alternative explanations of vigorous output expansion.

For the nine African countries surveyed here, on average, the rate of growth of the labour force significantly exceeded that of capital accumulation, leading to a decline of capital per worker by one-and-a-half percent annually. In some cases, like Kenya, Nigeria, Zambia or Zimbabwe, the annual decrease of capital per worker was even faster at rates of between –3.0 and –5.6 percent. In light of these developments, the decline in output observed for the group as a whole comes as no surprise, given the significance that capital accumulation still appears to have as a source of economy-wide output growth.

3.3 Changes in productivity

Examples of growth patterns like that of Hong Kong prompt the observer to look beyond the capital-accumulation growth relationship also empirically and make attempts at analyzing the role of overall productivity as a major source of output expansion. The results summarized in Table 2 represent such an attempt, not only at measurement of changes in total factor productivity (TFP), but also at assessment of the contributions of technological change and of change in technical efficiency. Like in the case of

Table 1, only averages over time and across country groups are reported here[15].

The discussion of productivity estimates best starts from a broad comparison between the industrialized and the developing countries in the sample. With regard to change in total factor productivity, the dividing line between these two groups is reflected in the difference between group averages. While productivity of the 22 industrialized countries in the sample increased at an average annual rate of one percent over the period studied here, it decreased by nearly one-half percent for the 35 developing countries included in the sample. Thus, while on average over the former group more than one-half of output-per-worker growth arose from productivity increases, on average over the latter group, productivity decline substantially contributed to virtual stagnation of output-per-worker.

Looking into what is behind the averages for each one of the groups produces a fairly differentiated picture. The three 'Tiger' economies in the sample on average recorded annual productivity growth of 3.6 percent, accounting for over three-fifths of their growth in output per worker. In sharp contrast to this outstanding performance is that of the nine African economies in the sample for which an average productivity decline of 1.3 percent per annum was observed. Between these two limiting cases of developing-country performance in productivity change is the average for the 23 'Other developing countries': Their total factor productivity dropped by 0.6 per cent annually, leading to a decline, too, of output per worker.

Regarding the variation of growth experience among individual countries, the group of industrialized countries shows an astonishingly wide range of TFP growth rates. Far above the average of 1.0 percent were the rates of leaders in TFP growth, like Luxembourg (2.9 percent) and Finland (2.3 percent) – countries for which productivity increase was the most important source of growth by far. At the other end of the industrialized-country

[15] The figures for individual countries are presented in full detail in Table 4 and in the underlying working papers.

spectrum – at least over the decade studied here – were countries with nearly negligible TFP growth rates, like Austria, Italy, the Netherlands and New Zealand. Growth rates close to the group average were found for, among others, France, Japan, Sweden, Switzerland, the United Kingdom and the United States, supporting the view that the group average reported in Table 2 is truly representative of a good number of leading industrialized countries. Also – and typical for this country group – for five out of the aforementioned six countries, TFP growth accounted for well over one-half of the growth in output per worker.

Naturally, the variation of TFP growth rates turns out to be considerably larger within the group of developing countries in the sample. On the one end of the spectrum are the two 'Tiger' economies Hong Kong and Korea whose TFP-growth rates (4.8 and 3.5 percent, respectively) are the highest throughout the whole sample and also represent high shares of the respective growth rates of output per worker. From among the 'Other developing countries' only Thailand (3.0 percent) and India (2.9 percent) come close to these rates of productivity increase, both economies also with high relative contributions to overall growth from TFP growth. On the other hand, the low end of the developing-country spectrum is marked by cases of steep productivity decline, like Nigeria (-3.7 percent), the Dominican Republic or Peru (both around –3.0 percent annually).

The decomposition of the growth of output per worker presented in Table 2 confirms and also refines what has been said in the previous section about the role of capital accumulation. In short, the figures show that a positive contribution to the change in labour productivity arose from capital deepening, consistently for all country groups with the exception only of African countries. In the case of the latter country group, a good portion of the observed decline in labour productivity was due to 'capital shallowing', whereas in the Asian 'Tiger' economies the positive contribution of capital accumulation accounted for a substantial share of their formidable increase in output per worker. Finally, the absolute amounts of the contribution to

growth of capital deepening tell an interesting story about the distinction in growth performance between the 22 industrialized countries and the group of 23 'other developing countries' in the sample. Already with respect to capital deepening – the 'conventional' source of growth – the former group enjoyed a clear advantage (0.7 percent) over the latter group (0.2 percent). And the difference in favour of industrialized countries increases considerably – as was documented earlier on in this section – when productivity change comes into play.

The method applied to derive the estimates of TFP change reported here has an added advantage in that it allows for an empirical decomposition of productivity change into the two broadly defined components outlined in Section 2: the contribution made by (world-wide) technological change and that accounted for by (country-specific) change in technical efficiency. Moreover, a slight modification of the estimation method also provides an estimate of one version of change in allocative efficiency. The remaining subsections of this section discuss the results of these extensions of productivity measurement, again in the perspective of the groups of industrialized and developing countries.

3.4 Technological change

Maybe the most striking difference between the groups of industrialized and developing countries emerges from a comparison in terms of what technological change[16] can contribute to productivity growth. According to the figures shown in Table 2, on average over the 22 industrialized countries the whole of the one-percent annual growth of total factor productivity stems from technological change. This result is of course not counterintuitive, but its clarity is surprising, nevertheless, even if some variation among countries within the group is acknowledged. With reference to the discussion in Section

[16] The method applied here to measure the contribution of technological change ensures that anomalies and meaningless concepts like 'technological regress', usually encountered in similar efforts, are ruled out and that only technological progress is taken into account. Details are discussed in Forstner and Isaksson (2002b).

Two, the finding can be given an interpretation also in terms of Figure 4. The industrialized country that would be seen as being representative of average growth performance in the group can be imagined to start at a high level of capital per worker and at a production point close to the world-technology frontier (f_1) in the initial period. In the terminal period capital per worker will have increased further while technical efficiency – measured by the relative distance of a production point to the frontier – might be thought to have remained unchanged between the two periods. And yet, productivity will have increased between the two periods, due to the shifting-upwards of the technology frontier from the position f_1 to that of f_2 – in short, through technological progress – which has 'pulled up' the country's production point.

In contrast, on average over the developing countries in the sample the gains from technological progress, i.e., from the worldwide advancement of technology, were too small (0.3 percent per annum) to avert a decline in total factor productivity. They were also significantly smaller in absolute terms than those made by the industrialized countries, as is witnessed by a 1:3 ratio of the respective growth rates. Hence, for the typical developing country relatively little can be gained from technological change as it occurs around the globe. This situation can be visualized with reference to the framework outlined in Section 2 and with the help of Figure 4. A country that were representative of the average performance of developing countries – due to its factor endowments (k) and the composition of its total output – would find itself below a section of the production function where gains from shifts of the world-technology frontier are only modest. It would take an enormous increase of the stock of capital per worker and dramatic concomitant changes in the structure of output to move such a country to an area where the contribution of technological change to productivity growth could be expected to be significantly higher.

From comparisons among the three subgroups of developing countries dealt with here, a number of additional features of the role of technological

change emerge. First, for each one of the three groups the average rate of technological change becoming effective for productivity increase is about the same, i.e., 0.2 to 0.3 percent annually. Even the three 'Tiger' economies included in the sample had not yet moved on to (technologically) more promising areas of capital endowment and output structure by the time of the 1980s. As a consequence, the role played by technological progress in productivity change was rather limited in all three cases. In that of the 'Tigers' it accounted for less than 10 percent of an otherwise formidable TFP increase. For African countries its force was much too weak to counteract a significant productivity decline. And for 'Other developing countries' it was too little to offset adverse factors responsible for a reduction on average of TFP levels.

A few cases of individual-country experience (reported in Table 4) can serve to reveal the wide range of performance hidden by the average figures of Table 2. Somewhat unexpectedly, there is a fairly wide range of technological-change rates within the group of industrialized countries. The highest rates (between 1.5 and 1.8 percent annually) within the whole sample were attained by (in declining order) Luxembourg, Switzerland, Finland, Norway, Australia, Belgium, Sweden and France. By contrast, for Greece, Iceland, Ireland, Italy, Japan, Portugal, Spain and the United Kingdom the rate of technological change over the period studied here was at a level of between 0.2 and 0.5 percent per annum. For the United States a value of 1.0 percent - the group average - was estimated, indicating that it is not necessarily the technological leader who, in terms of productivity gains, benefits most from technological progress.

Among the developing countries in the sample, the highest productivity gains from technological change were recorded for Hong Kong (0.5 percent). Still, this value would be near the low end of the range of industrialized-country rates. It also accounts only for around 10.0 percent of the economy's TFP growth. For two of the African countries in the sample, Malawi and Sierra Leone, the rate of the contribution to productivity change by technological change was zero, while for Paraguay and, quite astonishingly,

for Korea it was virtually zero. Thus, individual country results confirm and illustrate the impression gained from the averages of technological-change rates discussed previously.

3.5 Change in technical and allocative efficiency

The discussion of the role of changes in technical efficiency for productivity change is bound largely to produce a mirror image of what has been observed about technological change, due to the two contributions being complements. Therefore, this subsection can be rather brief in presenting the main observations on the subject and commenting on them.

On average over all the industrialized countries in the sample, no gains in technical efficiency were recorded, whereas the negative rate of TFP growth estimated on average across the developing countries was entirely due to technical efficiency losses. For the group of African countries such losses amounted to 1.5 percent per annum while for 'Other developing countries' they were close to 1.0 percent annually. By contrast, the group of 'Tiger' economies achieved nearly 90 percent of its high productivity growth (3.6 percent) through technical efficiency improvements.

Again, examples of individual countries produce a rather diverse picture. Among the industrialized countries, the relatively largest technical-efficiency gains were made by Ireland (1.4 percent), Luxembourg and Portugal (both 1.1 percent). Both Ireland and Portugal are atypical cases in the sense that they built their fairly high TFP growth mainly on improvements in technical efficiency. Luxembourg, on the other hand, managed to produce even higher productivity growth by feeding in a balanced fashion on both technological change and a rise in technical efficiency, with the latter accounting for nearly 40 percent of that growth. In contrast, nearly one-half of the developed countries in the sample experienced a decline in technical efficiency. Here the most pronounced examples are provided by Iceland (-1.5 percent) and New Zealand (-1.1 percent) – both countries that showed negative or virtually zero rates of TFP growth. But also for some other

countries like Australia, Austria, the Netherlands or Switzerland technical efficiency decreased by between 0.5 and 1.0 percent with the result of substantially reducing the gains from technological change and hence productivity growth.

Turning to the groups of developing countries, some cases of technical-efficiency improvement were truly impressive, with Hong Kong (4.2 percent), Korea (3.4 percent), India and Thailand (both 2.6 percent) providing the leading examples. In all four cases efficiency improvements accounted for over 85 percent of the growth of productivity and in size were not even approximately reached by any of the developed economies. Also among the group of African countries the technical-efficiency gains of Mauritius (1.6 percent) and of Malawi (1.1 percent) were remarkable and helped to secure TFP growth rates of between one and two percent annually.

In summary, of the ten developing countries with an increase in productivity of at least one percent per annum, all but one also recorded technical-efficiency gains of more than one percent per annum. Thus, the general impression about the nature of productivity growth in developing countries is confirmed also by observations of individual-country performance: Whichever gains developing countries make in aggregate productivity, these have to come overwhelmingly from improvements of technical efficiency.

Finally, an assessment can be made of what a certain type of changes in allocative efficiency contributes to productivity change[17]. The changes considered here are those due to a reallocation of resources between the manufacturing sector on the one hand and the aggregate of other sectors of the economy on the other. From the figures presented in Table 2 it emerges quite clearly that a change in resource allocation between manufacturing and non-manufacturing sectors has only a small impact on productivity growth, at least when group averages are considered. Both for the industrialized country

[17] The extension of the method of productivity measurement which allows the assessment of an allocative-efficiency component is introduced in Forstner and Isaksson (2002a).

and the developing country groups in the sample, on average no allocation effect on TFP growth could be observed. However, there are differences among the three groups of developing countries: The 'Tiger' economies group has lost over one-half percent of TFP growth due to allocative efficiency change while African economies have gained about one-half percent from such change. 'Other developing economies' on average remained neutral in respect of allocative-efficiency changes.

Again, individual-country experience presents a much more diverse performance also with respect to the impact of allocative efficiency changes. In the group of industrialized countries Canada, Switzerland and the United Kingdom all gained at least one-half percent in TFP due to such intersectoral change, whereas Austria, Portugal and Spain lost at least a portion of TFP of that size. Among the developing countries, the Philippines' gains of 1.5 percent per annum were outstanding while losses of over two percent, recorded for Colombia and for Korea were remarkable too.

4. Summary and conclusion

On the basis of the empirical results discussed in the previous section at least four general observations can be stated: First, the range of differing growth experience among countries is large. Unsurprisingly, it is larger for manufacturing growth than for growth of total output. Somewhat unexpectedly, there is broad variation in growth performance not only among the developing countries, but also among the industrialized economies. In a comparison between manufacturing and aggregate growth, the familiar distinction obtains: Even on the crudest group average, the developing countries show a rising share of manufacturing in total output and industrialized countries a declining one.

Second, there is divergence in the levels of output per worker (labour productivity) between the two country groups, as well as between subgroups of the developing countries. Contrary to some of the bolder assertions about the sources of growth, capital accumulation is revealed as still playing a

pivotal role. This is the case, in particular, for the industrialized countries, whereas the developing countries examined here present a diverse picture in this respect too. While a handful of countries within the latter group can count on a reasonably strong capital-deepening component being effective in their growth, growth in the group as a whole clearly suffers from insufficient rates of capital accumulation.

Third, a slightly modified form of the title of the study by Easterly and Levine (2001) seems to be the best characterization of growth patterns: 'It's *not only* factor accumulation'. Changes in total factor productivity – in the present context briefly termed productivity – are decisive for output growth on average across both country groups. Where output per worker increases vigorously, productivity gains usually account for a high portion of such increase. In contrast, more often than not a visible drop of output per worker is rooted in an even more pronounced productivity decline. This seems to hold for the averages taken within country groups on the one hand and – more conspicuously – for the results on individual countries.

Fourth, there is a clear distinction between the industrialized and the developing economies with regard to the sources of productivity growth. On average over the former group, all productivity increase comes from technological change, i.e., from innovation in those industries in which industrialized economies are relatively specialized. By contrast, for the developing countries the direct impact of technological change on productivity growth appears to be minor. On average, these countries for their productivity gains depend mostly on improvements in technical efficiency, i.e., on learning or catching-up with best practices that are typical for their levels of capital per worker and their output composition.

A synoptic view of the above general observations would suggest the following somewhat simplified story on growth and its main sources: Both capital deepening and productivity increase matter crucially for growth at the aggregate level. Capital deepening is important at all observed stages of development; in particular, it has not ceased to be the basis of satisfactory

growth performance of the developing countries. However, it is productivity increase, which accounts for most of the difference between good and bad growth performers. Regarding the nature of such increase, the world is divided: While industrialized countries enjoy large benefits from technological progress, developing countries have to achieve all their productivity gains by raising technical efficiency. This process has several aspects to it. They are usually and conveniently subsumed under the label of 'learning', interpreted as a broad concept, which embraces issues like access to, as well as adoption and adaptation of new technology.

The circle of impacts on growth performance is closed through a secondary effect of capital accumulation: Since it is only at higher levels of capital per worker that technological progress can play its productivity-enhancing role, capital deepening, among other things, is essential for making this source of growth ever more effective. That factor accumulation should play an important part also in this respect seems to be a consequence of the nature of technological change at large: Innovation capabilities are heavily concentrated in the industrialized countries and the changes they produce therefore show a labour-saving and skill-favouring bias. As long as this is the case, increases in the capital intensity of overall production remain a necessary condition for countries to benefit from world technological progress to an increasing extent.

A final general remark is owed here to the role that manufacturing industry can be expected to play in the growth process as analyzed previously. Taking into account the main characteristics of the sector, it may not be too bold a hypothesis to say that the characterization of growth and productivity change given above for economy-wide aggregates is likely to hold in much the same form for the manufacturing sector, too. More than that, some features would most likely be considerably more salient when manufacturing industry were the object of analysis. However, to provide empirical support for this hypothesis is a task for further research at a sufficiently disaggregate level.

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Table 1 Average annual growth of output and factors, by country group, 1980- 1990
(percent)

Country group	Output		Factors		GDP per worker	Capital per worker
	GDP	MVA	Labour	Capital		
Industrialized countries (22)	2.6	1.9	0.9	3.6	1.7	2.7
Developing countries (35)	2.7	3.1	2.8	3.4	-0.1	0.6
East Asian 'Tigers' (3)	7.6	7.3	1.9	6.4	5.7	4.5
African countries (9)	1.5	2.7	3.3	1.8	-1.8	-1.5
Other countries (23)	2.3	2.5	2.7	2.9	-0.4	0.2

Note: The growth rates for each country group shown here are unweighted arithmetic group averages of the country growth rates presented in Table 3. The number of countries in each group is given in parentheses, while the composition of country groups can be seen in Table 3.

Table 2 Average annual change of productivity and its components, by country group, 1980- 1990 (percent)

Country group	Labour productivity	Capital deepening	Total factor productivity	Technology	Technical efficiency	Allocative efficiency
Industrialized countries (22)	1.7	0.7	1.0	1.0	0.0	-0.1
Developing countries (35)	-0.2	0.2	-0.4	0.3	-0.7	-0.1
East Asian 'Tigers' (3)	5.8	2.2	3.6	0.3	3.3	-0.6
African countries (9)	-1.8	-0.5	-1.3	0.2	-1.5	0.5
Other countries (23)	-0.4	0.2	-0.6	0.3	-0.9	0.0

Note: The rates of change for each country group shown here are unweighted arithmetic group averages of the country-specific rates of change given in Table 4. The above table presents – in columns two to five - a nested decomposition of the change in labour productivity at two levels: Labour-productivity change (column one) is first decomposed into a capital-deepening component (column two) and a total-factor-productivity (TFP) component (column three). Change in total factor productivity in turn is decomposed into contributions from technological change (column four) and from change in technical efficiency (column five). Furthermore, in column six an independent estimate of the contribution to TFP change arising from change in allocative efficiency is given. All technical details of the above decomposition – which is inspired by Faere *et* al (1994) and Maudos *et al* (2000) – can be found in Forstner and Isaksson (2002a and b). The number of countries in each country group is given in parentheses while the composition of country groups can be seen in Table 4.

Table 3 Average annual growth of output and factors, by country, 1980- 1990, (percent)

Industrialized countries

Country	Output		Factors		GDP per worker	Capital per worker
	GDP	MVA	Labour	Capital		
Australia	3.0	1.1	1.9	3.9	1.1	2.0
Austria	2.1	2.4	0.8	4.1	1.3	3.0
Belgium	1.8	2.6	0.5	2.1	1.3	1.6
Canada	2.9	2.3	1.1	5.0	1.8	3.9
Denmark	2.1	1.7	0.6	2.2	1.5	1.6
Finland	3.0	3.0	0.7	3.8	2.3	3.1
France	2.1	0.8	0.9	2.9	1.2	2.0
Greece	1.8	0.4	0.5	2.2	1.3	1.7
Iceland	2.6	-0.1	1.5	6.5	1.1	5.0
Ireland	3.4	4.2	0.7	2.8	2.7	2.1
Italy	2.1	1.7	0.7	2.9	1.4	2.2
Japan	4.1	4.9	0.8	5.8	3.3	5.0
Luxembourg	3.7	2.8	0.8	4.4	2.9	3.6
Netherlands	2.0	2.1	1.3	2.4	0.7	1.1
New Zealand	1.8	0.7	1.5	3.1	0.3	1.6
Norway	2.4	-0.3	0.9	2.4	1.5	1.5
Portugal	4.1	3.8	0.3	4.1	3.8	3.8
Spain	3.0	2.0	0.9	4.3	2.1	3.4
Sweden	2.0	2.0	0.7	3.8	1.3	3.1
Switzerland	2.1	1.3	1.0	3.5	1.1	2.5
United Kingdom	2.8	1.2	0.5	3.0	2.3	2.5
United States	2.6	1.9	1.1	3.4	1.5	2.3

East Asian 'Tigers'

Country	Output		Factors		GDP per worker	Capital per worker
	GDP	MVA	Labour	Capital		
Hong Kong	6.6	3.8	1.7	3.0	4.9	1.3
Korea	8.8	11.2	1.9	8.0	6.9	6.1
Taiwan	7.5	7.0	2.0	8.3	5.5	6.3

(continued)

Table 3 (continued)

African countries

Country	Output		Factors		GDP per worker	Capital per worker
	GDP	MVA	Labour	Capital		
Cote d'Ivoire	-0.1	0.8	2.8	2.3	-2.9	-0.5
Kenya	3.7	4.2	5.2	2.2	-1.5	-3.0
Madagascar	-0.8	-2.6	2.1	1.5	-2.9	-0.6
Malawi	2.8	4.6	2.6	0.9	0.2	-1.7
Mauritius	4.9	8.5	1.6	5.4	3.3	3.8
Nigeria	-0.7	0.0	4.8	1.4	-5.5	-3.4
Sierra Leone	0.0	3.0	1.7	4.0	-1.7	2.3
Zambia	0.1	3.4	3.4	-2.2	-3.3	-5.6
Zimbabwe	3.2	2.8	5.2	0.4	-2.0	-4.8

Other developing countries

Country	Output		Factors		GDP per worker	Capital per worker
	GDP	MVA	Labour	Capital		
Argentina	-1.2	-2.1	1.0	0.6	-2.2	-0.4
Bolivia	0.7	-0.2	2.5	-0.5	-1.8	-3.0
Chile	2.8	2.6	2.5	5.6	0.3	3.1
Colombia	3.1	2.6	2.5	3.2	0.6	0.7
Dominican Republic	1.4	1.3	3.2	5.4	-1.8	2.2
Ecuador	1.0	-0.6	2.8	4.1	-1.8	1.3
Guatemala	1.0	0.0	2.9	1.7	-1.9	-1.2
Honduras	2.4	2.9	3.9	0.8	-1.5	-3.1
India	5.7	7.3	2.3	4.8	3.4	2.5
Iran	3.4	7.4	3.9	7.9	-0.5	4.0
Israel	3.5	3.7	2.3	2.2	1.2	-0.1
Jamaica	2.8	3.2	2.3	-0.6	-0.5	-2.9
Mexico	1.6	1.9	2.6	1.7	-1.0	-0.9
Morocco	3.6	4.0	3.4	0.5	0.2	-2.9
Panama	0.5	-0.2	2.8	2.2	-2.3	-0.6
Paraguay	1.3	0.4	3.1	4.0	-1.8	0.9
Peru	-0.5	-1.2	2.5	2.3	-3.0	-0.2
Philippines	1.8	1.0	2.6	2.6	-0.8	0.0
Sri Lanka	3.9	4.4	1.3	3.4	2.6	2.1
Syria	2.0	0.5	3.2	4.3	-1.2	1.1
Thailand	6.8	8.6	2.3	6.1	4.5	3.8
Turkey	4.9	6.8	2.4	3.9	2.5	1.5
Venezuela	0.7	1.9	3.2	1.4	-2.5	-1.8

Note: The average growth rates shown here are based on geometric means of annual increases over the whole period. The grouping of countries deviates from conventional practice in that Israel is included in the developing countries sample.

Table 4 Average annual change of productivity and its components, by country, 1980- 1990
(percent)

Industrialized countries

Country	Labour productivity	Capital deepening	Total factor productivity	Technology	Technical efficiency	Allocative efficiency
Australia	1.1	0.1	1.0	1.6	-0.6	0.3
Austria	1.3	1.1	0.2	0.9	-0.7	-0.6
Belgium	1.3	0.0	1.3	1.6	-0.3	-0.4
Canada	1.8	0.0	1.8	1.6	0.2	0.5
Denmark	1.5	0.7	0.8	0.7	0.1	0.0
Finland	2.3	0.0	2.3	1.7	0.6	0.4
France	1.2	0.0	1.2	1.5	-0.3	0.2
Greece	1.3	0.8	0.5	0.3	0.2	0.2
Iceland	1.1	2.3	-1.2	0.2	-1.4	-0.1
Ireland	2.7	1.0	1.7	0.3	1.4	-0.8
Italy	1.4	1.3	0.1	0.4	-0.3	-0.3
Japan	3.3	2.2	1.1	0.5	0.6	-1.7
Luxembourg	2.9	0.0	2.9	1.8	1.1	0.3
Netherlands	0.7	0.6	0.1	0.7	-0.6	0.1
New Zealand	0.3	0.2	0.1	1.2	-1.1	0.0
Norway	1.5	0.0	1.5	1.7	-0.2	0.0
Portugal	3.8	2.3	1.5	0.4	1.1	-0.5
Spain	2.1	1.8	0.3	0.3	0.0	-0.6
Sweden	1.3	0.0	1.3	1.6	-0.3	0.0
Switzerland	1.1	0.0	1.1	1.8	-0.7	0.6
U.K.	2.3	1.1	1.2	0.3	0.9	0.5
United States	1.5	0.5	1.0	1.0	0.0	0.0

East Asian 'Tigers'

Country	Labour productivity	Capital deepening	Total factor productivity	Technology	Technical efficiency	Allocative efficiency
Hong Kong	4.9	0.1	4.8	0.5	4.3	0.5
Korea	6.9	3.4	3.5	0.1	3.4	-2.2
Taiwan	5.5	3.1	2.4	0.3	2.1	-0.3

(continued)

Table 4 (continued)

African countries

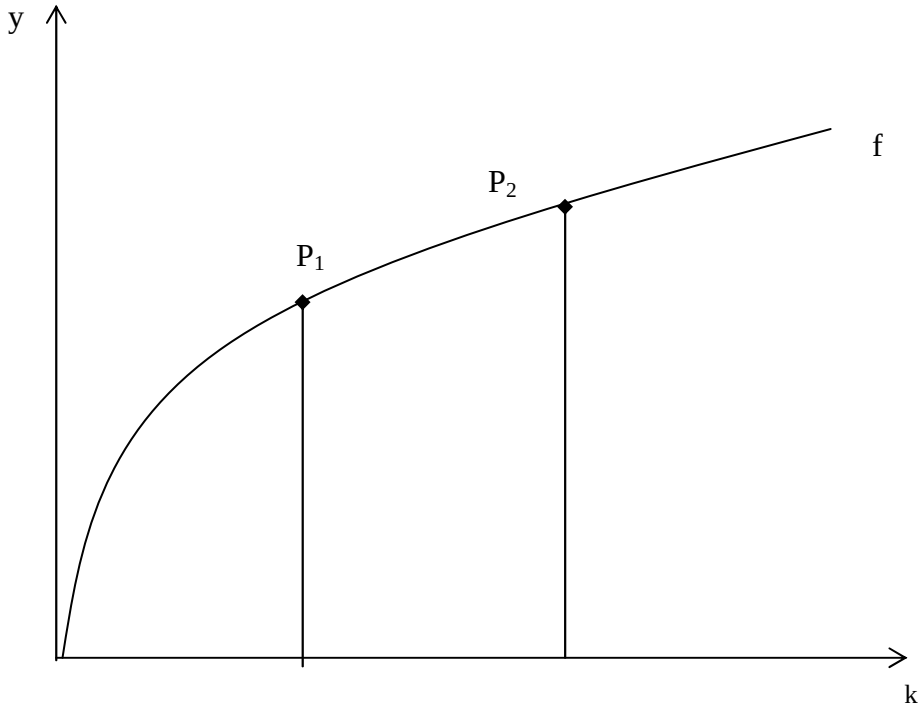
Country	Labour productivity	Capital deepening	Total factor productivity	Technology	Technical efficiency	Allocative efficiency
Cote d'Ivoire	-2.9	-0.1	-2.8	0.2	-3.0	0.7
Kenya	-1.5	-0.5	-1.0	0.2	-1.2	0.1
Madagascar	-2.9	-0.2	-2.7	0.2	-2.9	-
Malawi	0.0	-1.1	1.1	0.0	1.1	-
Mauritius	3.3	1.4	1.9	0.3	1.6	0.6
Nigeria	-5.5	-1.8	-3.7	0.2	-3.9	1.0
Sierra Leone	-1.7	1.0	-2.7	0.0	-2.7	-
Zambia	-3.3	-1.4	-1.9	0.2	-2.1	-
Zimbabwe	-2.0	-2.2	0.2	0.3	-0.1	-0.1

Other developing countries

Country	Labour productivity	Capital deepening	Total factor productivity	Technology	Technical efficiency	Allocative efficiency
Argentina	-2.2	-0.3	-1.9	0.4	-2.3	-0.8
Bolivia	-1.8	-1.6	-0.2	0.3	-0.5	-0.1
Chile	0.3	1.8	-1.5	0.4	-1.9	-1.2
Colombia	0.6	0.5	0.1	0.4	-0.3	-2.3
Dominican Rep.	-1.8	1.1	-2.9	0.3	-3.2	-0.6
Ecuador	-1.8	0.5	-2.3	0.3	-2.6	-0.6
Guatemala	-1.9	-0.4	-1.5	0.3	-1.8	0.5
Honduras	-1.5	-1.4	-0.1	0.3	-0.4	0.9
India	3.4	0.5	2.9	0.2	2.7	0.1
Iran	-0.5	2.1	-2.6	0.4	-3.0	1.0
Israel	1.2	0.0	1.2	0.3	0.9	-0.2
Jamaica	-0.5	-1.2	0.7	0.3	0.4	-0.9
Mexico	-1.0	-0.4	-0.6	0.4	-1.0	-0.1
Morocco	0.2	-0.9	1.1	0.2	0.9	0.3
Panama	-2.3	-0.3	-2.0	0.3	-2.3	0.8
Paraguay	-1.8	0.2	-2.0	0.1	-2.1	0.0
Peru	-3.0	-0.1	-2.9	0.4	-3.3	-1.1
Philippines	-0.8	0.0	-0.8	0.3	-1.1	1.5
Sri Lanka	2.6	1.3	1.3	0.4	0.9	0.9
Syria	-1.2	0.5	-1.7	0.3	-2.0	2.2
Thailand	4.5	1.5	3.0	0.3	2.7	-1.7
Turkey	2.5	0.8	1.7	0.4	1.3	-0.3
Venezuela	-2.5	-0.8	-1.7	0.3	-2.0	-1.9

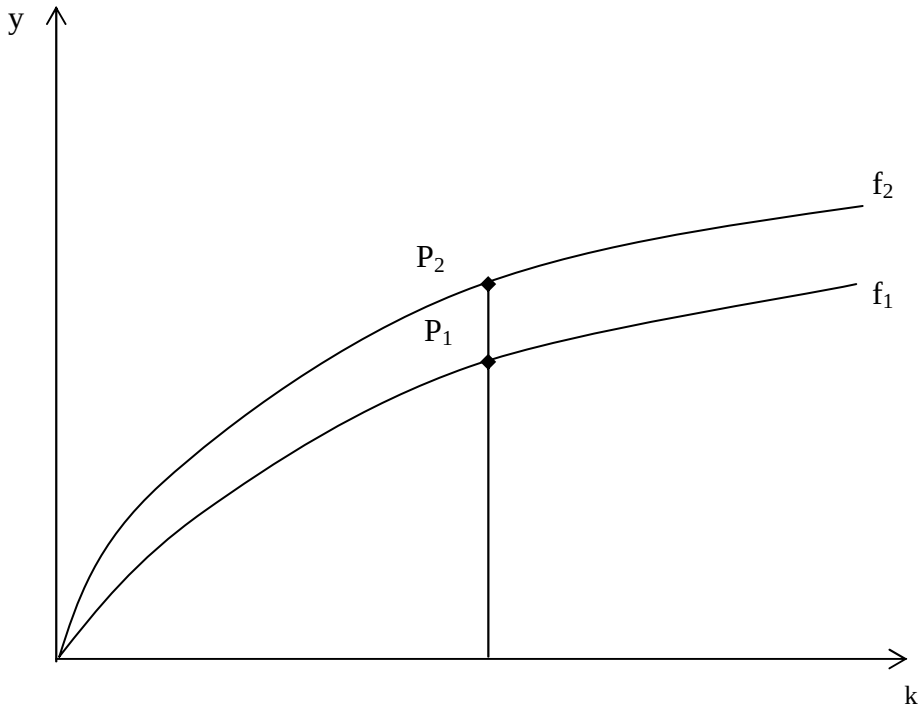
Note: The notes of Tables 2 and 3 apply analogously. A dash indicates missing information.

Figure 1 The neoclassical production function



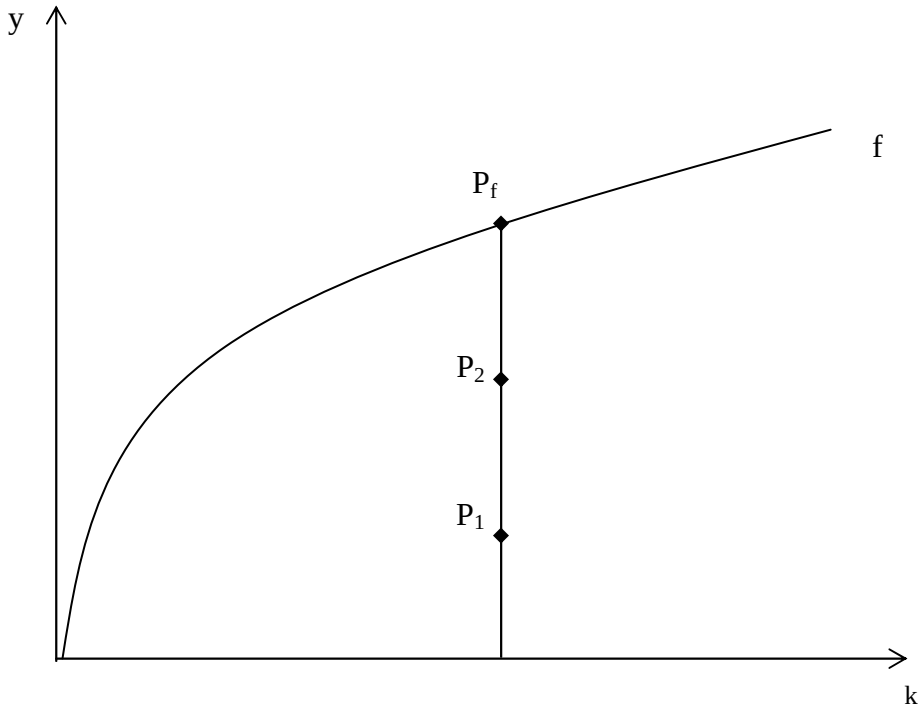
Note: Based on the assumptions of constant returns to scale and diminishing returns to capital, the curve f shows the relationship between capital per worker (k) and output per worker (y).

Figure 2 Technological progress



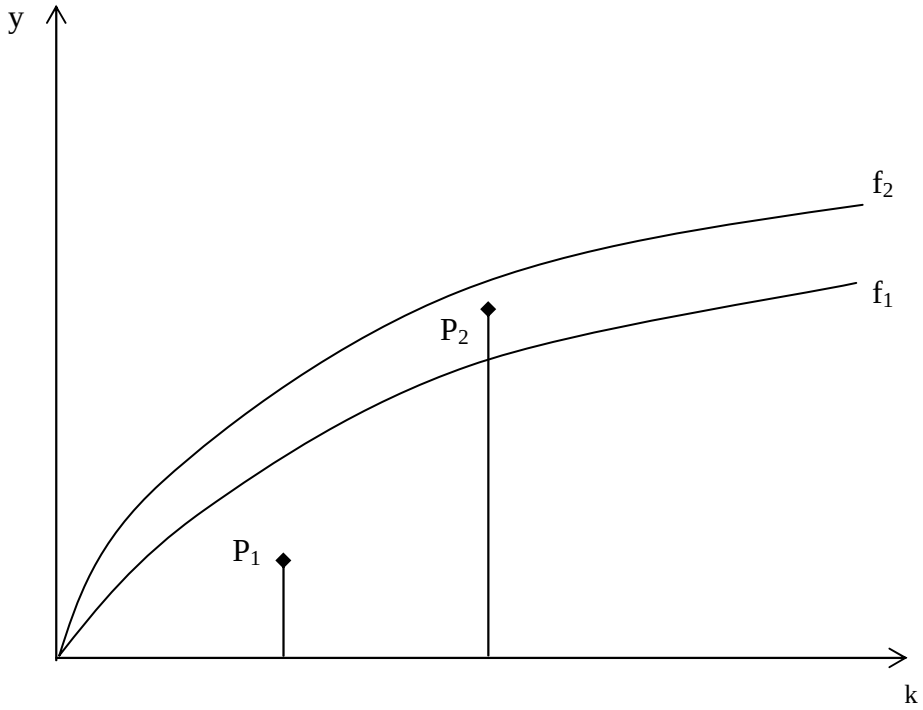
Note: Using the concepts behind Figure 1, this figure depicts technological progress as the shift between production functions f_1 and f_2.

Figure 3 Technical-efficiency change



Note: The designations of the previous figures apply also to Figure 3.

Figure 4 Change in total factor productivity



Note: The designations of the previous figures apply also to Figure 4.