# Total Factor Productivity, the East Asian Miracle, and the World Production Frontier

By

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## I. Introduction

It is well known that increasing the amount of a specific production factor such as capital or labor is not sufficient for sustained economic growth when decreasing marginal returns are working. As a main force fostering economic growth technological progress is considered, which increases the productivity of the factors of production. This was the basic message of the early work in the area of growth accounting by Abramovitz (1956) and Solow (1957). Later research in this field, e.g., by Jorgenson et al. (1987), attributed a large fraction of growth in the United States to the augmentation of capital and labor combined with increasing quality of the production factors. But there still remained a substantial part of total factor productivity growth unexplained: the residual.

Within this context, the focus of macroeconomic productivity analysis has recently shifted to the growth performance in the four East Asian "Tigers" (also called newly industrializing countries) Hong Kong, Singapore, South Korea, and Taiwan having experienced substantially high growth rates in per capita income during the post-war era. Young (1994a), who provides a crude calculation of total factor productivity for 118 countries in the period 1970–1985, finds that the Tigers (with the exception of Hong Kong) are not distinguishable from a large number of developing countries with much slower growth. In a following detailed growth accounting study by Young (1995) and a broad cross-country comparison by Collins and Bosworth (1996), this result is supported further. Applying an econometric approach, Kim and Lau (1994)

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estimate an aggregate translog production function, in which exogenous technological progress is represented by a time trend. During the period 1960–1990, for a group of established industrial countries (Germany, France, Japan, United Kingdom, and the United States), the time trend proves to be statistically significant, whereas in the case of the Tigers this trend is not distinguishable from zero. Thus, one is forced to conclude that the dominating sources of growth in these countries are to be found in pure accumulation of capital and increasing labor input combined with improved education and training.

Paul Krugman (1994) summarizes this evidence in his very provocative article in *Foreign Affairs* and concluded with the provoking hypothesis: "Asian growth [...] seems to be driven by extraordinary growth in inputs like labor and capital rather than by gains in efficiency" (Krugman 1994: 70). The prevalence of decreasing marginal returns prevents high growth rates over a long time period.[1]

Krugman's hypothesis not only has been disputed by the politically responsible authorities in the affected countries but there has also arisen a controversial discussion of this subject in the academic sphere. Even before Krugman's article the World Bank report, which coined the term "East Asian Miracle" presented a growth accounting exercise where the four Tigers realized the highest total factor productivity growth rates over the period 1960–1989 in a sample of 87 countries (World Bank 1993: 56). In this respect, Pack and Page (1994) look at the large positive residuals of the high-performing East Asian economies in standard cross-country growth regressions. They interpret this as an indication of unusual high productivity gains and classify these countries as "productivity driven". Methodology and results of this study have been heavily disputed in the subsequent comment by Young (1994b). A shift in focus and another argument is put forward by Freeman (1995), who highlights the ambitious promotion of high-tech industries in the Tigers. This point of view is also taken up by Nelson and Pack (1999), who additionally criticize the empirical methods applied

[1] The "New Growth Theory" following the pioneering models of Romer (1986) and Lucas (1988) supposes an unboundedly accumulable production factor with nondecreasing marginal returns, which allows for a positive long-run growth rate without using the notion of exogenous technological progress and which results in increasing returns to scale on the aggregate level in the presence of further production factors. Efforts in empirical work so far were not able to find convincing evidence for the existence of nondecreasing marginal returns or increasing returns to scale neither on the basis of cross-section data (see e.g. Backus et al. 1992; Mankiw et al. 1992) nor using time-series data (Jones 1995).

in Young (1994a, 1995) and deny their ability to measure anything like technological progress in principle because growth accounting can be validly applied only to equlibrium states and marginal changes over short periods of time. In their evolutionary view, the crucial device for the assimilation of technological innovations (assimilation theory) is the huge investment effort of the Tigers combined with learning processes, orientation towards the world market and the central role of innovative entrepreneurship. This view contrasts with the accumulation approach put forward by Krugman, Young, and others.

To take up this criticism and to shed some additional light on the controversy in this paper, we employ an alternative method of productivity analysis which has been applied in the past mainly on the micro-level: the nonparametric approach to production frontier determination or data envelopment analysis (DEA) to determine international productivity differences, and the Malmquist productivity index to track the productivity development over time.[2] Doing this, we are able to decompose the productivity change of a country into catching-up and technological progress (or falling behind and technological regress).

As a major result, we find that during the period 1960–1973 the growth of the Tigers was mainly due to pure augmentation of production factors; thus, we achieve a clear confirmation of Krugman's accumulation hypothesis. In the following, more recent period 1973–1990, however, we find a stronger impact of increasing total factor productivity and of efficiency gains as the main driving force. Thus, the positive effects of technology assimilation and learning show up here; for this period the assimilation hypothesis provided by Nelson and Pack (1999) finds support.

Our investigation proceeds as follows: Section II introduces data envelopment analysis and the Malmquist index. It also briefly discusses the advantages of this approach compared to alternative methods. In Section III, we present the results of the empirical analysis of 18 countries from America, Europe, and Asia out of a sample consisting of 87 countries, representing the world economy. These results are further discussed in Section IV. The concluding Section V sums up and gives a perspective for future research effort.

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[2] Only recently this has been done by Färe et al. (1994) in a similar fashion for a comparison of some OECD countries during a shorter time period.

## II. Methodological Considerations

Since the pioneering growth accounting exercise of Solow (1957), changes of total factor productivity on the macroeconomic level are measured by the difference between the growth rate of gross domestic product of a particular country and the factor-share-weighted rates of change of the production factors capital and labor. This difference, the so-called residual, represents the contribution of a shift of the production function to output growth due to Hicks-neutral technological progress (see, e.g., Barro and Sala-i-Martin 1995: 346ff.).

The general focus of traditional growth accounting is: (*i*) to treat each particular country as an isolated unit and by this (*ii*) to achieve only a purely actual-practice point of view. Moreover, this approach is based on several quite restrictive assumptions, which result from the presupposed neoclassical framework. At the heart of growth accounting is a production equilibrium with optimal resource allocation reached by maximizing agents, constant returns to scale, and production factors which receive their marginal products on perfect factor markets with full employment – required to aggregate the production factors by using cost shares from the national accounts. Thus, growth accounting assuming that (technical and allocative) efficiency always prevails does not need to care about any changes in efficiency, and any measured change in productivity is inevitably caused by technological progress (Grosskopf 1993: 172f.).

Frequently, the growth accounting approach has been criticized for the explicit requirement of equilibrium assumptions to hold permanently.[3] This can be circumvented in a panel data analysis by estimating the coefficients of a parametrically specified production function (e.g., translog). By that, an average production function for all observations of the panel is obtained, averaging away any differences among the observations. Here, the rate of technological progress can be estimated by a time trend which, however, only is an average rate for the whole sample. Hence, this method does not allow for an investigation of internationally heterogeneous developments in productivity change or technological progress, which is, in our view, needed to shed light on the Asian miracle. In order to get rid of this averaging-away problem, the estimation of a so-called stochastic frontier production function has been sug-

[3] Additionally, growth accounting results hold only for small changes in inputs and outputs because the aggregation weights used are averages over longer periods of time as has been mentioned by Nelson and Pack (1999).

gested by Aigner et al. (1977) among others. This frontier function envelops the sample observations and for that allows to distinguish between best-practice and below-best-practice performance of the individual observations. Except for the level of efficiency (or technology), the coefficients of the frontier function hold for all observations equally, implying that the same parametrically given production function is applicable to all sample items. Technological progress here is still given by a time trend and therefore is the same for the whole sample.

The preceding two statements for the stochastic frontier approach imply a technology as well as a smooth and continuous path of technological progress common to all sample countries. Both implications are quite restrictive and can be circumvented by employing a nonparametric frontier function, determined by data envelopment analysis (DEA)[4] and then tracking its changes over time using the Malmquist index of total factor productivity change.

DEA calculates such a frontier function by finding those production points (defined as the production of a country with a given combination of factor inputs at a particular point in time) that are undominated in a process of simultaneously comparing every observed production point of the sample to each other. This results in a piecewise linear surface which envelops all observations of a sample and which is taken as a benchmark for the determination of the efficiency of all production points as measured by the distance to the frontier function. This efficiency measure is just identical to a measure of total factor productivity relative to the frontier function and by this allows to distinguish between countries of high and of low total factor productivity. Here, as in the stochastic frontier approach for the aggregation of the input factors no price information is required in that the respective aggregation weights are obtained as a solution of a sequence of linear optimization problems.

In order to determine the distance of a production point from the frontier function, we apply the output-oriented version[5] of the DEA under constant returns to scale, as developed by Charnes et al. (1978). The sample considered contains $n$ observations indexed by $h = 1,\dots, n$. Suppose at every point in time there exists a production technology that

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[4] Useful survey articles of DEA are Ali and Seiford (1993) and Charnes et al. (1994).

[5] Output orientation is the more plausible assumption on the macroeconomic level because it is closer to the objectives of growth policy to achieve a social product as high as possible with a given resource endowment, instead of realizing a given social product objective with a minimized amount of inputs.

transforms $j = 1,\ldots, m$ input factors $x$ in $r = 1,\ldots, s$ outputs $y$. The general linear optimization problem for a production point of a specific country $h$ observed in period $q$ with the frontier function in period $p$ is given as follows:

$$\begin{aligned} &\max_{\phi,\lambda} \phi_h \\ &\text{s.t. } \phi_h y_{rh}^q - \sum_{i=1}^{n} \lambda_i y_{ri}^p \le 0 \quad \forall r = 1,\ldots, s \\ &\sum_{i=1}^{n} \lambda_i x_{ji}^p \le x_{jh}^q \quad \forall j = 1,\ldots, m \\ &\lambda_1,\ldots,\lambda_n \ge 0. \end{aligned} \qquad \Rightarrow D_h^p(x^q, y^q) = \phi_h^{-1} \qquad (1)$$

The maximum proportional augmentation factor $\phi_h$ so obtained represents the percentage change of all outputs measured in period $q$ required to achieve a point on the frontier function in period $p$, based on constant input levels. The distinction between the periods $p$ and $q$ will be required below. For the time being, $p = q$ holds. For $\phi_h = 1$ the observation is best-practice; $\phi_h > 1$ states the percentage level to which the outputs of observation $h$ have to be increased so that this observation becomes best-practice. The $\lambda$-values serve to identify the virtual production point on the frontier function with which the production point of observation $h$ is compared. Since the frontier function consists of the best-practice observations, the point of comparison is a certain linear combination of these observations. $\lambda_i$ for $\lambda_i > 0$ then states whether and to which degree observation $i$ ($i = 1,\ldots, n$) enters in the construction of the point of comparison for observation $h$. Performing these calculations for all $n$ observations we get an account of the productivity differences between the observations and the best-practice technology frontier for period $p = q$.

Comparing the respective frontier functions and efficiency measures of different time periods, the Malmquist index allows to quantify the so determined change in total factor productivity of a specific country and to decompose it into one term measuring efficiency change and another term representing technological progress as the shift of the frontier function. This procedure allows to get a quantitative account of technological dynamics by separating innovation (technological progress) from imitation (efficiency change as catching up or falling behind) within a sample of leading and lagging countries.

For computing the Malmquist index and its decomposition we proceed as follows. The $m$ input factors are now given by the vector $\boldsymbol{x}$ and the $s$ outputs by the vector $\boldsymbol{y}$. The Malmquist index $M$ is then defined as the geometric mean of two productivity indexes as they are proposed by Caves et al. (1982). According to the discussion in Färe et al. (1994) and Grosskopf (1993), the productivity change $M_h^{t+1}$ of country $h$ between two points in time $t$ and $t + 1$ is given by:

$$M_h^{t+1}(\boldsymbol{x}^t,\boldsymbol{y}^t,\boldsymbol{x}^{t+1},\boldsymbol{y}^{t+1})=\left[\frac{D_h^t(\boldsymbol{x}^{t+1},\boldsymbol{y}^{t+1})}{D_h^t(\boldsymbol{x}^t,\boldsymbol{y}^t)}\,\frac{D_h^{t+1}(\boldsymbol{x}^{t+1},\boldsymbol{y}^{t+1})}{D_h^{t+1}(\boldsymbol{x}^t,\boldsymbol{y}^t)}\right]^{1/2}. \tag{2}$$

Here $D_h^p(\boldsymbol{x}^q, \boldsymbol{y}^q)$ is a distance function defined as the reciprocal of the maximum proportional expansion of outputs required to reach the frontier function in period $p$ with constant inputs for an observed production point in period $q$ ($p$, $q = t$, $t + 1$). This distance function is just the reciprocal of the DEA efficiency measure. The within-period distance functions ($p = q$) are bounded in the interval [0,1], with efficient production points characterized by a value of 1 for the distance function. In the case of the between-period distance functions ($p \neq q$), which measure distances of the production points in the period $p$ ($q$) from the frontier function in period $q$ ($p$), values greater than 1 are also possible. The geometric mean in (2) is taken in order to avoid possible biases resulting from an exclusive fixing of the production possibilities in $t$ or $t + 1$ as a benchmark for the evaluation of the productivity change.

With data for $t = 1,\dots, T$ time periods (years in our case) and $h = 1,\dots, n$ observations we are able to insert the distance functions for the four combinations of time periods

$$(p, q) \in \{(t, t), (t + 1, t + 1), (t, t + 1), (t + 1, t)\}$$

into the Malmquist index formula (2) for all periods $t = 1,\dots, T - 1$ and all observations.

The index (2) can be easily transformed to the following expression:

$$M_h^{t+1}(\boldsymbol{x}^t, \boldsymbol{y}^t, \boldsymbol{x}^{t+1}, \boldsymbol{y}^{t+1}) = \underbrace{\frac{D_h^{t+1}(\boldsymbol{x}^{t+1},\boldsymbol{y}^{t+1})}{D_h^t(\boldsymbol{x}^t,\boldsymbol{y}^t)}}_{EF}\underbrace{\left[\frac{D_h^t(\boldsymbol{x}^{t+1},\boldsymbol{y}^{t+1})}{D_h^{t+1}(\boldsymbol{x}^{t+1},\boldsymbol{y}^{t+1})}\,\frac{D_h^t(\boldsymbol{x}^t,\boldsymbol{y}^t)}{D_h^{t+1}(\boldsymbol{x}^t,\boldsymbol{y}^t)}\right]^{1/2}}_{TP}. \tag{3}$$

This decomposition of the productivity change into two components can be related to changes in efficiency ($EF$) and to technological progress ($TP$). Efficiency change is captured by changes of the (relative) distance from the frontier functions in periods $t$ and $t + 1$, respectively. They reflect changes in the degree of exploitation of production possibilities given in $t$ and $t + 1$, respectively, and therefore measure the prevalence of catching-up or falling-behind movements of country $h$.[6]

A measure of technological progress is specified via a geometric mean of the intertemporal shift of the frontier function. It is calculated using the distance of the production points in periods $t$ and $t + 1$ from the production frontier in periods $t + 1$ and $t$, respectively. For identical inputs and outputs in $t$ and $t + 1$, the calculation of the Malmquist index and its two components leads exactly to 1. Improvements (deteriorations) of the components or the whole index are expressed by values greater (smaller) than 1.

Figure 1 illustrates how the Malmquist index works. Depicted is the movement of a production point $A = (x^t, y^t)$ in period $t$ that moves to $B = (x^{t+1}, y^{t+1})$ in period $t + 1$ for the special case of one input and one output. The frontier functions in $t$ and $t + 1$ are given by F$(t)$ and F$(t + 1)$, respectively. We assume that the shift of the frontier function is caused by another, here not depicted, production point.

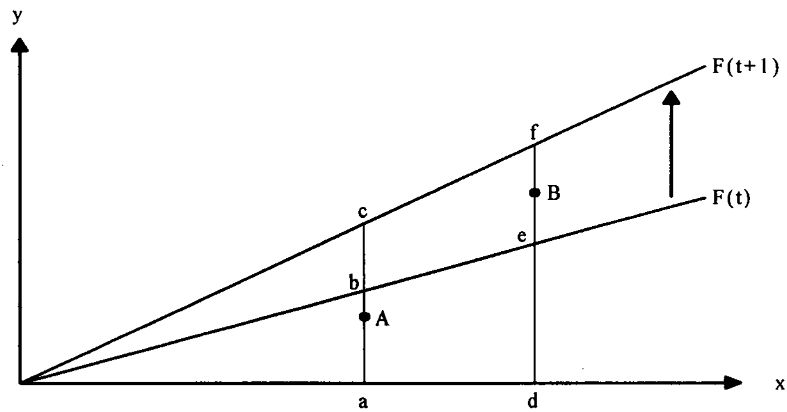
Using the projection points $a$ to $f$, we obtain the four distance functions $D^t(A) = aA/ab$, $D^{t+1}(A) = aA/ac$, $D^t(B) = dB/de$ and $D^{t+1}(B) = dB/df$ and applying formula (3), we achieve

$$M^{t+1}(A, B) = \frac{dB/df}{aA/ab}\left[\frac{dB/de}{dB/df}\,\frac{aA/ab}{aA/ac}\right]^{1/2} = \frac{dB/df}{aA/ab}\left[\frac{df}{de}\,\frac{ac}{ab}\right]^{1/2}.$$

Now, we can easily see that the efficiency term captures the change in the distance from the frontier function in $t$ and $t + 1$ and that the technological progress term gives the geometric mean of the vertical

[6] Efficiency change is obtained from the results of two within-period optimization ($p=q$) problems. Here the consideration of variable returns to scale taking into account the size of the observation (here: output of a country) can be accomplished by imposing the additional constraint $\Sigma_i \lambda_i = 1$ in (1) (see Banker et al. 1984). This allows for the multiplicative decomposition of efficiency change ($EF$) in the change of pure technical efficiency ($TE$) and the change of scale efficiency ($SE$): $EF = TE \cdot SE$. In the case of the between-period distance functions ($p \neq q$) it is, however, possible that the related DEA optimization problem has no solution (see Färe et al. 1995). Therefore, we restrict the measurement of technological progress to the calculation of the shift of the frontier function under constant returns to scale. Since an improvement or deterioration of scale efficiency in the context of whole economies is not easy to interpret, the discussion of the results in the following section concentrates on the change in productivity as well as on its components, efficiency change and technological progress under constant returns to scale. In our analysis the focus is on changes between two points in time, so that this restriction seems not to be too strong (see Grosskopf 1993: 180).

Figure 1 – *Malmquist Index*




shift of the frontier function from F ($t$) to F ($t$ + 1). In the depicted case, we have technological progress ($TP > 1$) and an improvement in efficiency ($EF > 1$).

The described methodological approach of nonparametric frontier analysis and the Malmquist productivity index is well suited to address the critique of Nelson and Pack (1999). It involves no assumptions of general equilibrium theory, requires no fixing of input factor aggregation weights over several decades and is also capable of analyzing discrete changes in inputs and outputs. With respect to the last point Nelson (1973: 464) states: "If periods are short enough there is no real problem introduced here [with growth accounting, the authors]. The real problem is that we are not concerned with growth over a 'year' but rather over a rather lengthy period, say the half century since the end of World War I. [...] It is the finiteness of the total comparison period that causes the difficulty." Since we perform our empirical analysis with yearly data and then aggregate the Malmquist index results to averages over periods of several years, we are in a position to address this difficulty in a more satisfactory way.[7]

[7] Of course, the procedure is in principle also available with a growth accounting approach, but there it is less easily to realize because of the required factor price information. Even then, our nonparametric approach has a lot of further advantages with respect to growth accounting as should have been made clear in the discussion in the text.

## III. Empirical Results

### 1. Data Description

In the following empirical analysis, we apply the combination of DEA and Malmquist index to a macroeconomic production model with $s = 1$ output and $m = 2$ input variables. The sample consists of $T = 31$ years (1960–1990) for $n = 87$ countries.[8] The data are taken from the Penn World Table 5.6 (see Summers and Heston 1991) from which we have excluded countries with missing data for the time period under consideration, former socialist, and primarily oil-producing countries as well as some countries with poor data quality. In what follows, we only report how the 18 countries[9] Germany (DEU), France (FRA), United Kingdom (GBR), Italy (ITA), Japan (JPN), Canada (CAN), USA (USA), Argentina (ARG), Brazil (BRA), Chile (CHL), Colombia (COL), Mexico (MEX), Peru (PER), Venezuela (VEN), Hong Kong (HKG), Singapore (SGP), South Korea (KOR), and Taiwan (OAN) behave within the sample of 87 countries.

As output variable, we take gross domestic product in international prices of the year 1985 (chain index). Labor input is measured by the number of workers according to the labor force concept which is implicitly contained in the data set. From the data on real investment in international prices of the year 1985, we calculate the capital stock for each country applying the perpetual inventory method.[10] We assume a geometric depreciation schedule with a rate of 10 percent per year and estimate the initial capital stock by an infinite geometric series with the average growth rate of investment as in the first 5 years for which data are available.[11] As a consequence, from a typical piece of capital, 35 percent of the starting value are still in use after 10 years. Calculations

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[8] See the Appendix for a list of the included countries. Note that the Malmquist index is calculated for every country and each year between 1960 and 1990.

[9] World Bank country codes in parentheses.

[10] The investment data include both public and private investment expenditures for producer durables (machinery and transport equipment) and for construction (residential, nonresidential, and other construction) (see the Appendix B on diskette to Summers and Heston (1991)).

[11] We prefer this method of estimation of the initial capital stock to the alternative of using a steady-state assumption as done by King and Levine (1994) and to using a Cobb-Douglas production function estimate with common coefficients for all countries which assumes that all countries are operating on the same production function all the time as done in Benhabib and Spiegel (1994). See also the discussion in Nehru and Dhareshwar (1993), who recommend a modification of the approach we use in this paper and show that the capital stock estimates of different authors correlate quite well. We are

Table 1 – *Average Growth Rates (in percent per year)*

| Country group | Gross domestic product 60–90 | 60–73 | 73–90 | Labor force 60–90 | 60–73 | 73–90 | Capital stock 60–90 | 60–73 | 73–90 |
|---|---|---|---|---|---|---|---|---|---|
| G7 | 3.77 | 5.26 | 2.63 | 1.07 | 1.16 | 1.01 | 4.51 | 6.48 | 3.00 |
| LA | 3.64 | 5.37 | 2.31 | 2.55 | 2.50 | 2.59 | 4.16 | 5.24 | 3.34 |
| NIC | 8.34 | 9.30 | 7.61 | 2.71 | 2.89 | 2.57 | 11.07 | 13.32 | 9.36 |

*Note:* Calculated as log differences of data from Summers and Heston (1991).

with alternative depreciation rates of 5 and 15 percent show virtually unaffected country rankings. The Spearman rank correlation coefficients between the respective rankings are all above 0.9 for the 18 countries under consideration. An additional robustness check by the exclusion of further 23 countries with poor data quality or small size from our 87 country sample does not affect our results.

The interpretation of our results concentrates mainly on general patterns and differences in the development of three country groups: established industrial countries (G7), Latin American countries (LA), and East Asian "newly industrializing countries" (NICs). Detailed results and rankings of the individual countries are given in the respective tables.

Before we present our main results, in Table 1, we briefly refer to the growth performance of the three country groups during the entire period of investigation, 1960–1990, as well as during the two subperiods 1960–1973 and 1973–1990.[12]

Looking at the entire period 1960–1990, we find, as expected, an exceptionally high growth rate of output for the NICs followed by G7 and LA countries. Comparing the two subperiods, the average growth rate of gross domestic product declines after 1973, and thereby most markedly in the Latin American countries. With the exception of the labor force in Latin America, similar results are found for the growth rates

well aware of the weakness of our assumption regarding the initial capital stock, especially for countries in which the investment growth rate of the first five years of data availability is untypical for the period before. See Prescott (1998) for a general discussion of capital stock measurement problems.

[12] This choice of subperiods is common in macroeconomic productivity analysis (see, e.g., Collins and Bosworth 1996 and Jorgenson et al. 1987). Like 1960 and 1990, the year 1973 is classified by the NBER as a boom year for the United States, which exerts a major influence on the world business conditions. So we measure productivity change from one business cycle peak to another and are therefore able to mitigate potentially biasing effects from temporal differences in capacity utilization.

of the two main production factors, capital and labor. Especially remarkable is the accumulation of capital in the NICs.[13]

The figures in Table 1 already indicate a correlation between the growth of gross domestic product and the growth of the production factors – a relation which is the focus of the accumulation hypothesis. This point requires further investigation in that we analyze whether this output growth is mainly related to growth of input factors or whether it is a consequence of increasing total factor productivity due to technological progress and/or catching-up. To give an answer, we refer to our Malmquist index calculations. We discuss total factor productivity change, efficiency change and technological progress in turn, starting with productivity change.

## 2. Productivity Change

Table 2 contains the respective period's average rates of productivity change ($M$) for the selected 18 countries calculated by the Malmquist index for different time periods as well as the respective average values of the three country groups. The reported figures are obtained as geometric means over the respective time period, reduced by 1 and multiplied by 100. Thus, positive (negative) values indicate increasing (decreasing) total factor productivity. Looking first at the entire period 1960–1990, we find relatively high productivity improvements in the G7 countries (except GBR), a significantly lower productivity growth in the Latin American countries and even a negative one for the NICs (except Hong Kong).

A closer inspection of the two subperiods reveals interesting differences in the development patterns. First, for the G7 countries we observe a much lower average productivity growth during the second subperiod as compared to the first one. At the same time, the spread between the greatest and the smallest realized productivity changes declines. This suggests a trend towards a convergence of the development within this group of countries. Note that during the first subperiod the United Kingdom, when compared to the other G7 countries, differs substantially in its productivity development.

Second, for Latin America on average we observe an increasing productivity in the period 1960–1973 followed by a decreasing productivity during the period 1973–1990. There, we have to recognize that the

[13] Note that our growth rates for the capital stocks match quite well with those reported in Nehru and Dhareshwar (1993: Table 5).

Table 2 – *Productivity Change (M)*

| | 1960–1990 | Rank | 1960–1973 | Rank | 1973–1990 | Rank |
|---|---|---|---|---|---|---|
| *G7* | | | | | | |
| DEU | 1.5855 | 4 | 2.0310 | 6 | 1.2461 | 2 |
| FRA | 1.2909 | 5 | 1.8312 | 10 | 0.8796 | 5 |
| GBR | 0.3642 | 10 | –0.0425 | 16 | 0.6763 | 7 |
| ITA | 1.6686 | 3 | 2.4241 | 4 | 1.0946 | 4 |
| JPN | 1.7238 | 2 | 2.8604 | 2 | 0.8632 | 6 |
| CAN | 1.0302 | 7 | 2.2168 | 5 | 0.1321 | 12 |
| USA | 1.0591 | 6 | 1.9286 | 8 | 0.3992 | 8 |
| ∅ | 1.2460 | | 1.8928 | | 0.7559 | |
| *LA* | | | | | | |
| ARG | –0.1440 | 16 | 0.5600 | 14 | –0.6791 | 15 |
| BRA | 0.3257 | 11 | 1.7635 | 11 | –0.7601 | 16 |
| CHL | 0.1727 | 12 | 0.6824 | 13 | –0.2154 | 14 |
| COL | 0.9458 | 8 | 1.9931 | 7 | 0.1521 | 10 |
| MEX | 0.8933 | 9 | 1.8956 | 9 | 0.1335 | 11 |
| PER | –0.4189 | 17 | 2.5817 | 3 | –2.6542 | 18 |
| VEN | 0.0435 | 13 | 1.3060 | 12 | –0.9113 | 17 |
| ∅ | 0.2597 | | 1.5403 | | –0.7049 | |
| *NIC* | | | | | | |
| HKG | 1.9887 | 1 | 3.1543 | 1 | 1.1062 | 3 |
| SGP | –0.5836 | 18 | –2.9491 | 18 | 1.2642 | 1 |
| KOR | –0.0005 | 14 | 0.2195 | 15 | –0.1684 | 13 |
| OAN | –0.1421 | 15 | –0.8048 | 17 | 0.3678 | 9 |
| ∅ | 0.3156 | | –0.0950 | | 0.6424 | |

*Note:* Figures are stated as (geometric mean in the related time period – 1) x 100. – ∅ denotes the arithmetic mean of the respective group of countries.

marked positive productivity change in the first subperiod is primarily caused by Brazil, Colombia, Mexico, Peru, and Venezuela. Argentina and Chile, however, show lower productivity growth during the first subperiod as well as productivity declines thereafter. All LA countries but Colombia and Mexico suffered from a productivity decline during the second subperiod.

Third, for the NICs on average we find a modest productivity improvement (higher than for the LA countries) during 1960–1990. This is decomposed into a slightly negative development during 1960–1973 followed by an increase during 1973–1990 comparable to the change of the G7 group. Considering the NICs individually reveals a dramatic productivity decline in the case of Singapore during the first subperiod, which switches sign in the second subperiod. Korea and Taiwan achieved slightly positive or negative productivity changes, respectively. Hong Kong, however, was able to uncouple from the development in the other NICs and realized large positive productivity gains during the entire period. This exceptional performance of Hong Kong within the NICs appears also in Kim and Lau (1994) and Young (1994a, 1995).[14]

Applying in a next step the decomposition of the Malmquist index into efficiency change and technological progress as given by (3), we are able to characterize the observed development patterns in a more detailed way. We start with efficiency change, which informs us about the extent by which a country succeeded in its efforts to move towards the (shifting) world technology frontier (which is determined by the best-performing countries in the sample). Thus, the figures obtained can be interpreted as indicators for catching-up or falling-behind.

### 3. Efficiency Change

Table 3 contains the respective results for efficiency change. The United States is the only country with no efficiency change during the entire period 1960–1990. This is the consequence of the fact that the United States is the only country which continuously is member of the best-practice frontier function. Thus, the United States can only achieve a positive productivity development by shifting the frontier function as a result of technological progress.[15] Consequently, all catch-up or falling-behind movements of the other countries refer to a frontier which, at least in the capital-intensive part, is determined by the technological success of the United States.

Looking now at the results for the period 1960–1990, we observe that most of the countries were able to catch up to the frontier. Most successful were the NICs on average as well as Japan, Brazil, and Colombia. Referring back to Table 1, the ranking of average growth rates of the three country groups matches the efficiency change figures here quite well. Regarding the two subperiods, we observe that the tenden-

[14] The total factor productivity changes from the growth accounting exercise of Young (1995) for the period 1966–1990 are 2.3 for Hong Kong, 0.2 for Singapore, 1.7 for Korea, and 2.1 for Taiwan (all figures in percent per year). Substantially higher figures are discovered by the World Bank (1993: 56).

[15] However, as the referee pointed out, this macroeconomic efficiency result does not hold for all industries included in the study of Harrigan (1999).

Table 3 – *Efficiency Change (EF)*

| | 1960–1990 | Rank | 1960–1973 | Rank | 1973–1990 | Rank |
|---|---|---|---|---|---|---|
| *G7* | | | | | | |
| DEU | 0.2359 | 9 | –0.2220 | 11 | 0.5875 | 12 |
| FRA | 0.1500 | 10 | –0.0597 | 8 | 0.3106 | 13 |
| GBR | –0.0860 | 15 | –1.5318 | 15 | 1.0340 | 11 |
| ITA | 0.8270 | 7 | 0.5482 | 4 | 1.0408 | 10 |
| JPN | 1.1610 | 5 | 1.1785 | 2 | 1.1477 | 9 |
| CAN | 0.1111 | 12 | 0.3373 | 5 | –0.0615 | 17 |
| USA | 0.0000 | 13 | 0.0000 | 7 | 0.0000 | 16 |
| ∅ | 0.3427 | | 0.0358 | | 0.5799 | |
| *LA* | | | | | | |
| ARG | –0.7223 | 17 | –1.8146 | 17 | 0.1212 | 14 |
| BRA | 1.1665 | 4 | 0.1302 | 6 | 1.9663 | 4 |
| CHL | 0.1180 | 11 | –1.7163 | 16 | 1.5439 | 7 |
| COL | 1.6059 | 2 | 0.5514 | 3 | 2.4197 | 3 |
| MEX | 0.3665 | 8 | –0.7812 | 13 | 1.2531 | 8 |
| PER | –0.0739 | 14 | –0.1845 | 9 | 0.0108 | 15 |
| VEN | –0.7662 | 18 | –0.5733 | 12 | –0.9134 | 18 |
| ∅ | 0.2421 | | –0.6269 | | 0.9145 | |
| *NIC* | | | | | | |
| HKG | 2.8924 | 1 | 2.1636 | 1 | 3.4532 | 1 |
| SGP | –0.3219 | 16 | –3.0961 | 18 | 1.8530 | 6 |
| KOR | 1.0104 | 6 | –0.1975 | 10 | 1.9440 | 5 |
| OAN | 1.3068 | 3 | –0.8188 | 14 | 2.9630 | 2 |
| ∅ | 1.2219 | | –0.4872 | | 2.5533 | |

*Note:* See Table 2.

cy of the average G7 country to catch up to the frontier function is stronger in the second than in the first subperiod. In the case of the Latin American and East Asian countries, we observe a similar pattern between the two subperiods – with a falling-behind movement in the first subperiod followed by catching-up in the second. Our results confirm again the exceptional development of Hong Kong within the NICs, where we find a strong catching-up movement during both subperiods.[16]

[16] The additional decomposition of the efficiency term into pure technical efficiency change and change of scale efficiency, which is not reported here, reveals a dominating increase of scale efficiency only in Japan. In contrast to that, we have a predominating improvement of technical efficiency in Colombia, Hong Kong, Korea, and Taiwan.

## 4. Technological Progress

The movements of the best-practice frontier function itself reveal information about technological progress. In interpreting these results, three aspects have to be taken into account. First, the frontier function is only shifted by best-practice countries. Second, as a consequence of the construction of the best-practice frontier function, technological progress in general is local in the sense that only one or a few parts of the frontier with specific input factor combinations are affected by such shifts. According to these local effects, we are able to distinguish technological progress in the range of high capital intensity from technological progress pertaining to the range of high labor intensity. We find the United States continuously responsible for shifts in the capital-intensive range of the frontier, whereas Egypt together with other countries shifts the technology frontier in the labor-intensive technology spectrum, implying either progress or regress.[17] Third, technological progress for each below-best-practice country is computed by assigning to it the progress of that part(s) of the frontier function constructed by the comparison points of the country under consideration.

The results on technological progress in Table 4 exhibit a similar pattern as the figures of productivity change in Table 2. For the period 1960–1990, the NICs are lagging in performance far behind the G7 and LA countries, too. Before 1973, we observe a forward shift of those parts of the frontier function that serve as reference for the NICs and the Latin American countries with much higher rates for the latter. The following subperiod uncovers a backward shifting part of the frontier and thus substantial technological regress for both Latin America and East Asia. Looking at the trend of technological change during this second subperiod, however, shows for the NICs a switch from technological regress to technological progress around the mid of the eighties. For the LAs, we do not find such a switch. The G7 countries on average were able to maintain their leading position with respect to the pace of technological progress although the rate of progress was considerably higher in the first subperiod. Within the G7 countries, technological progress is spurred solely by the United States, while the other countries get assigned part of this progress.

[17] Technological regress is possible here since we are only able to determine the shifts of a best-practice approximation to the true world production frontier. This best-practice frontier function may shift backwards for various reasons even if the world-wide available technological knowledge can, of course, only progress.

Table 4 – *Technological Progress (TP)*

| | 1960–1990 | Rank | 1960–1973 | Rank | 1973–1990 | Rank |
|---|---|---|---|---|---|---|
| *G7* | | | | | | |
| DEU | 1.3464 | 1 | 2.2580 | 5 | 0.6548 | 1 |
| FRA | 1.1392 | 2 | 1.8920 | 7 | 0.5673 | 2 |
| GBR | 0.4506 | 10 | 1.5125 | 13 | –0.3540 | 8 |
| ITA | 0.8347 | 5 | 1.8657 | 10 | 0.0533 | 5 |
| JPN | 0.5564 | 8 | 1.6623 | 11 | –0.2812 | 7 |
| CAN | 0.9180 | 4 | 1.8732 | 9 | 0.1937 | 4 |
| USA | 1.0591 | 3 | 1.9286 | 6 | 0.3992 | 3 |
| ∅ | 0.9006 | | 1.8561 | | 0.1761 | |
| *LA* | | | | | | |
| ARG | 0.5825 | 7 | 2.4185 | 4 | –0.7993 | 10 |
| BRA | –0.8312 | 15 | 1.6312 | 12 | –2.6738 | 18 |
| CHL | 0.0546 | 11 | 2.4407 | 3 | –1.7325 | 12 |
| COL | –0.6497 | 14 | 1.4338 | 14 | –2.2140 | 14 |
| MEX | 0.5248 | 9 | 2.6978 | 2 | –1.1058 | 11 |
| PER | –0.3453 | 13 | 2.7713 | 1 | –2.6647 | 17 |
| VEN | 0.8159 | 6 | 1.8902 | 8 | 0.0021 | 6 |
| ∅ | 0.0217 | | 2.1833 | | –1.5983 | |
| *NIC* | | | | | | |
| HKG | –0.8783 | 16 | 0.9698 | 15 | –2.2687 | 15 |
| SGP | –0.2625 | 12 | 0.1516 | 17 | –0.5781 | 9 |
| KOR | –1.0008 | 17 | 0.4178 | 16 | –2.0721 | 13 |
| OAN | –1.4302 | 18 | 0.0140 | 18 | –2.5206 | 16 |
| ∅ | –0.8930 | | 0.3883 | | –1.8599 | |

*Note:* See Table 2.

## IV. Discussion and Interpretation

To reassess Krugman's (1994) hypothesis and the controversy about the East Asian miracle, let us now have a closer look at our results for the performance of the NICs relative to the performance of the G7 and LA countries. In presenting our arguments, we additionally rely on capital-intensity measures as summarized in Table 5 and relate them to the above-analyzed rates of change of total factor productivity, efficiency change, and technological progress.

For discussing the accumulation and the assimilation hypothesis, we relate our results on productivity change (as given in Tables 2 to 4) to the growth rates of output, capital, and labor (as given in Table 1). Moreover, accounting for the (with respect to factor intensities) local char-

Table 5 – *Period Means of Capital Stock per Worker*

| | 1960–1990 | Rank | 1960–1973 | Rank | 1973–1990 | Rank |
|---|---|---|---|---|---|---|
| *G7* | | | | | | |
| DEU | 49,348 | 2 | 37,854 | 3 | 58,440 | 1 |
| FRA | 46,583 | 4 | 33,319 | 4 | 56,965 | 2 |
| GBR | 28,142 | 8 | 22,032 | 7 | 32,943 | 9 |
| ITA | 44,412 | 5 | 32,775 | 5 | 53,464 | 4 |
| JPN | 29,627 | 7 | 14,837 | 10 | 41,041 | 6 |
| CAN | 46,771 | 3 | 38,660 | 2 | 52,870 | 5 |
| USA | 53,076 | 1 | 48,444 | 1 | 56,724 | 3 |
| ∅ | 42,566 | | 32,560 | | 50,350 | |
| *LA* | | | | | | |
| ARG | 19,260 | 10 | 14,855 | 9 | 22,703 | 10 |
| BRA | 12,019 | 14 | 8,186 | 13 | 14,935 | 15 |
| CHL | 15,716 | 12 | 15,579 | 8 | 15,924 | 14 |
| COL | 9,196 | 18 | 7,588 | 15 | 10,410 | 18 |
| MEX | 16,770 | 11 | 11,929 | 11 | 20,499 | 11 |
| PER | 11,753 | 15 | 10,374 | 12 | 12,789 | 17 |
| VEN | 32,563 | 6 | 30,814 | 6 | 33,940 | 8 |
| ∅ | 16,754 | | 14,190 | | 18,743 | |
| *NIC* | | | | | | |
| HKG | 13,406 | 13 | 7,566 | 16 | 17,793 | 12 |
| SGP | 22,917 | 9 | 7,991 | 14 | 34,311 | 7 |
| KOR | 9,706 | 17 | 3,187 | 18 | 14,562 | 16 |
| OAN | 11,369 | 16 | 4,412 | 17 | 16,600 | 13 |
| ∅ | 14,350 | | 5,789 | | 20,817 | |

*Note:* Given are the means over the respective periods in international dollars of the year 1985. – ∅ denotes the mean in the respective group of countries.

acter of technological change in Table 5, we state the countries' capital intensities (capital stock per worker).

Concerning the NICs, our first observation is that within the first subperiod 1960–1973 these countries show a high investment ratio paired with a slightly negative or nearly absent change of total factor productivity. Consequently, the tremendous growth of GDP is entirely due to the accumulation of capital combined with a considerable growth of the labor force employed. The extreme case in this respect is Singapore where the ratio of investment to gross domestic product has risen from 11 in 1960 to 41 percent in 1971 and afterwards remained constant at about 30 to 40 percent. Japan (here considered as an "early Tiger"), South Korea, Taiwan, and to a lesser degree Hong Kong reveal a similar development. For 1973–1990, we observe a decline in the

NICs' rate of capital accumulation from about 11 to 9.4 percent; moreover, the growth of the labor force declined although only slightly. Their productivity development, contrariwise, shows up rather positive. This is to be interpreted as the consequence of the successful assimilation of technologies (embodied in previous investment) and learning in the NICs. Looking at the individual NICs, however, we find that in this respect they differ quite considerably.

In order to get a better understanding of the individual development of the NICs, a look at the two other country groups, LA and G7, is helpful. Here we find that the investment ratio in these countries remained constant within a certain bandwidth or even trended slightly downwards as is especially the case for countries with particularly high productivity growth and technological progress, such as Italy and Germany. Compared to the NICs, these two country groups do exhibit a low rate of capital accumulation, which is only about 40 percent of that of the NICs. Despite their similarity in investment, the G7 and LA groups differ considerably, with respect to productivity development.

For the G7, we obtain a continuous improvement of productivity mainly due to technological progress, which, as can be seen in Table 5, was accomplished in the range of relative capital-intensive production with an average capital intensity of 42,566 in the period 1960–1990 (increasing from 32,560 for 1960–1973 to 50,350 in 1973–1990; all statements in international dollars of the year 1985 per worker). Contrariwise, the LA countries producing relatively labor-intensive with an average capital intensity of 16,754 (increasing from 14,190 for 1960–1973 to 18,743 for 1973–1990) show an increasing average productivity in the first subperiod and a declining one during the second. For the later period, this result is mainly due to a backward-shifting frontier on the range of relative labor-intensive production and thus due to technological regress. Thus, there seems to be a considerable difference of productivity development with respect to the range of capital intensity.

In a next step, we relate the performance of the NICs to this marked difference between the development in the G7 and LA countries. Doing this within the NICs, we can distinguish two subgroups. A first one contains Japan and Singapore, which succeeded in restructuring their production from highly labor-intensive in the first subperiod (JPN 14,837, SGP 7,991) to a capital intensity within the G7 range of the second subperiod (JPN 41,041, SGP 34,311). By this, both countries overtook the LA countries in capital intensity of production. Hong Kong, South Korea, and Taiwan, however, which started out with the lowest capital intensities in the first subperiod, only achieved capital intensities in the second subperiod which were within the range of the LA countries (HKG 7,566 to 17,793, KOR 3,187 to 14,562, OAN 4,412 to 16,600).

With this assignment of the NICs, their respective technological progress and efficiency change have to be interpreted with respect to the local shifts of the corresponding parts of the world technology frontier in the range of high and low capital intensity of production.

In the first subperiod, for all NICs (except Japan) the relative labor-intensive part of the frontier serves as reference. During this period, the frontier improved and all four countries get assigned a positive *TP*. Except Hong Kong, all NICs were not able to keep up with this progress and experienced an efficiency loss. In the subperiod 1973–1990, the labor-intensive range of the world technology frontier serves again as reference for the NICs, except for Singapore. Since during this period the frontier in this range worsened, Hong Kong, Taiwan, and Korea experienced a considerable efficiency gain by catching up to the frontier. Finally, Hong Kong even caught up completely and became best-practice. Singapore, however, developed into the capital-intensive range of the frontier, though only at the end of the second subperiod where catching-up to a relatively fast improving frontier had not been possible. Consequently, compared to the other NICs, Singapore performed worse in efficiency change.

Looking at technological progress for the two subgroups in the second subperiod, we find just the reversed development pattern. Singapore gets affected by the positive progress in the capital-intensive range of the frontier, at least at the end of the second subperiod. The other NICs, however, are affected by the technological regress of the labor-intensive frontier part. Consequently, Singapore performs better with respect to assigned technological progress. By this, Singapore is the first of the NICs to follow the development Japan had taken years before.

With respect to the assimilation hypothesis, this difference in development pattern among the NICs is of considerable importance. Japan, years before, and Singapore, now, succeeded in adopting a technology similar to the G7 countries. Their further learning and assimilation of technological potentials will thus be affected by the technological progress driven by the G7. For the other NICs, however, their ability to learn and assimilate labor-intensive technologies tends to become to a lesser degree dependent on catching-up than on shifting the labor-intensive part of the frontier by themselves (especially Hong Kong). Another possibility, of course, would be to increase capital intensity and to enter the capital-intensive range of the world technology frontier with re-opened opportunities for productivity improvements driven by catching-up. The first of the NICs to behave in this way might be South Korea.

A final remark on the NICs performance pattern refers to the LA countries. The substantial shift of the LA countries towards a negative development pattern during the second subperiod might be a consequence of the unstable political conditions and misguided economic policy (high inflation rates, debt crisis) there. Differences also show up in a comparison of the national innovation systems of the East Asian and Latin American countries by Freeman (1995) or Etzkowitz and Brisolla (1999), who emphasize just the increased efforts of the NICs towards education and research and development in the 1980s.

Looking at our results, one could argue that our choice of variables excerts some influence on the productivity figures. With respect to capital, we are well aware of the standard measurement problems involved and follow the generally accepted perpetual inventory method based on the investment data from the Penn World Table. The lack of data for capital utilization rates gives us no opportunity to adjust for variable capacity utilization.

Concerning labor input, two issues need to be discussed. First, instead of the number of workers we alternatively should have taken into account the total number of hours worked per year which is more adequate for a productivity analysis. It has, however, proved to be impossible to obtain complete and consistent time series of working hours data from the *Yearbooks of Labor Statistics* because of numerous gaps in the data series and structural breaks due to changing sampling procedures. However, we can state the general tendency that working hours have declined especially in some G7 countries (Germany, France) and recently also in Hong Kong and South Korea, whereas they stayed stationary on different levels in most of the other countries and have even slightly increased in the case of Singapore. From this point of view, we do not expect any qualitative changes of our results if we included working hours.

Second, a similar argument applies with respect to human capital. If we included a human capital indicator in the productivity analysis, the NICs would again perform worse compared to the other countries. The reason for that is that the NICs have accumulated human capital much more rapidly than our other sample countries. For example, the number of years of schooling in the population aged 15 and over from Barro and Lee (1996) has risen between the years 1960 and 1990 by a factor of 1.87 in the NICs, compared to 1.20 in the G7 and 1.62 in the

LA countries. The augmentation of labor input by human capital would thus lead to higher growth of labor input and, as the output measure does not change at all, to lower total factor productivity growth compared to the above results, especially for the NICs.[18]

## V. Conclusion

The analysis above has considered the phenomenon of productivity change in selected economies during the period 1960–1990. Starting point was the discussion, whether the high growth rates of the NICs are mainly due to their high rates of capital accumulation or to effects of innovation and assimilation, respectively. To shed further light on this, we have calculated indicators of technological progress and change of technological efficiency, applying the decomposition of the Malmquist productivity index. Splitting the period of investigation in the two subperiods 1960–1973 and 1973–1990, we are in principle able to confirm Krugman's hypothesis for the first subperiod, regarding total factor productivity. In the NICs (with the exception of Hong Kong) extraordinary high rates of capital accumulation appear to be combined with decreasing or stagnant productivity. During the second subperiod, however, we find productivity gains (with the exception of Korea).

The decomposition of total factor productivity change shows a dominating technological progress in the first subperiod independent from capital intensity, whereas in the second subperiod technological progress applies only to capital-intensive technologies. Compared to the Latin American countries, the NICs achieved substantially larger efficiency gains in the second subperiod. This result may be traced back to technological improvements, which have been embodied in the accumulated capital stock of the first subperiod and which reveal their productivity-driving effects with a certain time lag. Here the assimilation arguments of Nelson and Pack (1999) find some empirical underpinning.

Based on this purely descriptive statistical analysis, we will concentrate our future research effort on the explanation of the so far obtained time series for productivity change and technological progress with econometric methods. In this way, we attempt to include certain aspects of quality change of the production factors in our framework of analy-

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[18] Not to include human capital as an ordinary production factor is also justified by the results of Benhabib and Spiegel (1994), who point to the role of human capital as a factor to explain TFP and not as an input in the aggregate production function.

sis, which are up to now still contained in the measures of productivity change and technological progress. Important explanatory variables for productivity change and technological progress include, for instance, human capital formation, external effects of investment in infrastructural objects, research and participation in world trade in order to be able to realize spillover effects. Also influences with impeding effects on the diffusion of technological innovation like a strong governmental regulation of the economic process will become a subject of analysis. All these growth determinants are emphasized by neoclassical endogenous growth theory (see, e.g., Barro and Sala-i-Martin 1995) as well as by theoretical approaches in evolutionary tradition (see, e.g., Nelson 1992; Verspagen 1991). By this, we hope to be able to take account of the characterization of technological progress as a "measure of our ignorance" (Abramovitz 1956: 11), which applies to a different extent both to the growth-accounting residual and to the movements of frontier production functions.

## Appendix

List of the 87 countries which are included in the Malmquist index calculations (together with their World Bank country codes in parentheses); the results in this paper are reported for the boldface-typed countries.

Cameroon (CMR)
Central Afr. R. (CAF)
Chad (TCD)
Egypt (EGY)
Gabon (GAB)
Gambia (GMB)
Ghana (GHA)
Guinea (GIN)
Kenya (KEN)
Lesotho (LSO)
Madagascar (MDG)
Malawi (MWI)
Mali (MLI)
Mauritius (MUS)
Morocco (MAR)
Mozambique (MOZ)
Namibia (NAM)
Nigeria (NGA)
Senegal (SEN)
Seychelles (SYC)
South Africa (ZAF)
El Salvador (SLV)
Guatemala (GTM)
Honduras (HND)
Jamaica (JAM)
**Mexico (MEX)**
Nicaragua (NIC)
Panama (PAN)
**U.S.A. (USA)**
**Argentina (ARG)**
Bolivia (BOL)
**Brazil (BRA)**
**Chile (CHL)**
**Colombia (COL)**
Ecuador (ECU)
Guyana (GUY)
Paraguay (PRY)
**Peru (PER)**
Uruguay (URY)
**Venezuela (VEN)**
Bangladesh (BGD)
China (CHN)
Malaysia (MYS)
Pakistan (PAK)
Philippines (PHL)
**Singapore (SGP)**
Sri Lanka (LKA)
Syria (SYR)
**Taiwan (OAN)**
Thailand (THA)
Austria (AUT)
Belgium (BEL)
Denmark (DNK)
Finland (FIN)
**France (FRA)**
**Germany (DEU)**
Greece (GRC)
Iceland (ISL)
Ireland (IRL)
**Italy (ITA)**
Luxembourg (LUX)
Netherlands (NLD)
Norway (NOR)

| | | |
|---|---|---|
| Togo (TGO) | **Hong Kong (HKG)** | Portugal (PRT) |
| Tunisia (TUN) | India (IND) | Spain (ESP) |
| Uganda (UGA) | Indonesia (IDN) | Sweden (SWE) |
| Zambia (ZMB) | Iran (IRN) | Switzerland (CHE) |
| Zimbabwe (ZWE) | Israel (ISR) | Turkey (TUR) |
| **Canada (CAN)** | **Japan (JPN)** | **U. K. (GBR)** |
| Costa Rica (CRI) | Jordan (JOR) | Australia (AUS) |
| Dominican Rep. (DOM) | **Korea Rep. (KOR)** | New Zealand (NZL) |

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Abstract: Total Factor Productivity, the East Asian Miracle, and the World Production Frontier. – The post WWII growth of the East Asian Tiger states has stimulated the discussion about its determinants. Young and Krugman hold that high capital accumulation rather than gains in efficiency or technological progress has spurred growth. Nelson and Pack, however, have recently criticized the methods of measuring technological progress. Applying the nonparametric approach to frontier production function determination and the Malmquist index of total factor productivity change, the authors take up this criticism. They calculate productivity indicators for a sample of 18 American, Asian, and European countries. For the Tiger states, their results confirm that capital accumulation was the main source of growth in 1960–1973, whereas they find evidence for an increasing importance of efficiency improvements for the growth in 1973–1990. JEL no. O47, O57

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Zusammenfassung: Totale Faktorproduktivität, das ostasiatische Wunder und die Weltproduktionsgrenze. – Die Wachstumserfahrung in den so genannten ostasiatischen Tiger-Staaten nach dem Zweiten Weltkrieg, gekennzeichnet durch hohe Wachstumsraten, hat die Diskussion über die verursachenden Faktoren stimuliert. Alwyn Young und Paul Krugman vertraten die Auffassung, dass Kapitalakkumulation anstatt der Effizienzverbesserungen oder des technologischen Fortschritts das Wachstum in diesen Ländern angetrieben hat. Richard Nelson und Howard Pack haben dagegen kürzlich die Methoden zur Messung des technologischen Fortschritts kritisiert. Durch die Anwendung des nichtparametrischen Ansatzes zur Bestimmung von Randproduktionsfunktionen und des Malmquist-Index der totalen Faktorproduktivität tragen wir dieser Kritik Rechnung. Damit berechnen wir Produktivitätsindikatoren für eine Stichprobe von 18 Ländern Amerikas, Asiens und Europas. Im Fall der Tiger-Staaten bestätigen unsere Resultate Krugmans Hypothese für die Jahre 1960–1973. Während der Jahre 1973–1990 finden wir jedoch Evidenz für eine gestiegene Bedeutung von Effizienzverbesserungen für das Wachstum in diesen Ländern.