Accounting for South-Korean GDP Growth: Index-Number and Econometric Estimates

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Revised June 1997

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JEL Classification: O4, C43, F11, D2

Running head: South-Korean GDP Growth

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Accounting for South-Korean GDP Growth: Index-Number and Econometric Estimates

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Abstract

In this paper, we estimate the contribution of each one of the major determinants of South-Korean nominal GDP growth: technological change, movements in the terms of trade, increases in the endowments of labor and capital, and changes in domestic output prices. We use an index-number technique as well as an econometric approach. Both have a tight theoretical foundation, being based on the GDP function approach to modeling the production sector of an open economy.

1 Introduction

For much of the postwar period, the Republic of Korea has experienced phenomenal economic growth. Thus, from 1970 to 1991, nominal GDP growth has averaged close to 23 per cent annually. Of course, much of this advance is explained by price increases, but real growth has nevertheless been substantial, well over 8 per cent on average. Needless to say, this extraordinary performance has not gone unnoticed among economists. Thus, over a decade and a half ago, Christensen and Cummings (1981) gave a very careful account of the main reasons behind South-Korean economic growth.[2] More recently, a number of authors have compared the performance of South Korea — and of other newly industrialized countries from the region — with that of countries from other parts of the world.[3]

Much of the earlier work on South-Korean growth has focused on the effects of technological change and increases in domestic factor endowments. While

[1] This paper was presented at the International Conference on the Economic Development and Transformation of the East Asian Economies, held at the Chinese University of Hong Kong, July 27–28, 1997. We are grateful to Jaime de Melo and an anonymous referee for useful comments and suggestions. The usual disclaimer obviously applies. This research was partially supported by the Swiss National Science Foundation under grant #12-45777.95.

[2] For the sake of brevity, we will use the names "Korea" and "South Korea" interchangeably to designate the Republic of Korea.

[3] See Pack and Page (1994), and Young (1994a, 1994b), for instance.

these are indeed almost always and everywhere the main engines of real economic growth, it strikes us that previous work has generally neglected the impact of terms-of-trade changes. This is all the more surprising that Korea is a very open economy, with the GDP shares of imports and exports often nearing 50 per cent, and that foreign trade has often been cited as a major factor explaining the performance of the Korean economy.[4] As noted by Diewert and Morrison (1986), an improvement in the terms of trade is similar to a technological advance since it makes it possible for a country to increase its net output for any given amount of domestic inputs. A deterioration, on the other hand, is equivalent to technological regress, and it reduces the net amount of goods that a country obtains for a given effort. Furthermore, the impact of a change in the prices of traded goods on a country's real income is affected by the position of its trade account. An increase in the relative price of traded goods will make the country worse off if it is running a trade deficit, and better off if it is running a surplus.

South Korea has experienced large fluctuations in both its terms of trade and the position of its trade account throughout the seventies and the eighties. We show in Figure 1 an index of the Korean terms of trade, and, in Figure 2, the position of Korea's trade account as a percentage of its GDP. One sees that, although the terms of trade were basically the same in 1991 as they were in 1970, there were some very spectacular swings. Thus, the terms of trade fell dramatically following the two oil crises, in 1975 and again in 1980. The terms of trade did improve on average during the eighties. At the same time, Korea's trade account has been in a deficit position more often than not. In fact, the deficits were particularly severe in the seventies. Thus, when the terms-of-trade deterioration was at its worst, the trade deficit reached about 9 per cent of GDP, thereby magnifying the negative impact of the price change. These developments are likely to have left a significant mark on the country's overall growth picture.

[Figure 1 about here]
[Figure 2 about here]

The fact that the terms of trade do change makes it more difficult to identify the other determinants of growth, technological change for a start. The contri-

[4] See Pack and Page (1994), among others.

bution of technological progress is generally measured by Solow residuals, but this is clearly inappropriate in the case of an open economy subject to terms-of-trade shocks. Solow residuals are typically obtained from a one-output two-input Cobb-Douglas representation of the technology. Not only is this measure unsatisfactory because it is based on a rather antiquated functional form and because it aggregates all outputs, but by abstracting from imports and exports, it is obviously incapable of incorporating terms-of-trade effects. Earlier work on Korea has generally also been based on the Cobb-Douglas framework, at least implicitly so. Thus, Mankiw, Romer and Weil (1992) explicitly use the Cobb-Douglas functional form, whereas Young (1994a, 1994b) measures total factor productivity growth by simply subtracting a constant proportion of the rate of growth of the capital stock from the growth rate of output per worker. One important exception is provided by Christensen and Cummings (1981) who use a Tornqvist — or Translog — index of total factor productivity; they make no attempt, however, to isolate the effect of terms-of-trade changes.

There is no doubt that in general much of growth can be attributed to increases in domestic factor endowments. South Korea has seen its labor force grow very substantially during the post-war period, both as the result of increases in its population and increases in its labor-force participation rate. Moreover, the very rapid pace of investment has led to a significant rise in the Korean capital stock. The contribution of labor and capital in explaining overall growth can, however, only be correctly assessed if the technological-change and terms-of-trade effects have been adequately accounted for.

The purpose of this paper is to sort out some of these effects, and to do so within a formal model of aggregate production. That is, we want to assess the contribution of each one of the major factors explaining South-Korean nominal GDP growth: technological change, movements in the terms of trade, increases in the endowments of labor and capital, and changes in domestic output prices. We will use both the index-number and the econometric growth-accounting techniques proposed by Kohli (1990). Both have a solid theoretical foundation, being based on the GDP (or GNP) function approach to modeling the production sector of an open economy; see Kohli (1978, 1991) and Woodland (1982).

The paper proceeds as follows. We provide a brief description of the aggregate technology in the next section. Section 3 presents our decomposition of economic growth, whereas Sections 4 and 5 present our index-number and econometric estimates, respectively. Section 6 concludes.

2 Description of the Aggregate Technology

In conformity with standard practice in international trade theory, we treat the endowments of labor (L) and capital (K) together with the prices of imports and outputs as given. Imports (M) are treated as an input to the technology. This view is consistent with the fact that much of world trade is in raw materials and intermediate products, and that even imported "finished" goods are still subject to a number of changes — such as unloading, transportation, storage, insurance, repackaging, marketing, and retailing — before they are ready to meet final demand. They must thus transit through the domestic production sector, where they are combined with domestic labor and capital. This means that a significant proportion of the final price tag of goods of foreign origin is actually accounted for by *domestic* value added. The quantity of imports being variable, it is most convenient to think of them as a negative output. The other output components are: exports (X), and domestic sales (D). The quantity vectors, measured at time t, are denoted by $\mathbf{x}_t \equiv [x_{jt}], j \in \{L, K\}$, and $\mathbf{y}_t \equiv [y_{it}], i \in \{M, X, D\}$, respectively. The corresponding price vectors are $\mathbf{w}_t \equiv [w_{jt}]$ and $\mathbf{p}_t \equiv [p_{it}]$. Let $T(t)$ be the production possibilities set at time t. We assume free disposals, constant returns to scale, and convexity. Under these conditions, the technology can also be represented by the following GDP function:[5]

$$\pi(\mathbf{p}_t, \mathbf{x}_t, t) \equiv \max_{\mathbf{y}_t} \{\mathbf{p}_t' \mathbf{y}_t : (\mathbf{y}_t, \mathbf{x}_t) \in T(t)\}. \tag{1}$$

Given the assumptions made above, the GDP function is linearly homogeneous and convex in output (including import) prices; it is nondecreasing in the prices of exports and domestic sales, and nonincreasing in the price of imports; it is linearly homogeneous, concave, and nondecreasing in domestic factor quantities.[6]

[5] See Kohli (1978, 1991) and Woodland (1982) for details.

[6] See Diewert (1974).

It is well known that, under competitive conditions, differentiation of the GDP function with respect to output prices yields the import demand and output supply functions, while differentiation with respect to factor quantities produces the inverse input demand — or factor price — functions:[7]

$$y_i(\mathbf{p}_t, \mathbf{x}_t, t) = \frac{\partial \pi(\cdot)}{\partial p_i} \tag{2}$$

$$w_j(\mathbf{p}_t, \mathbf{x}_t, t) = \frac{\partial \pi(\cdot)}{\partial x_j}, \qquad i \in \{M, X, D\};\ j \in \{L, K\}. \tag{3}$$

The Translog functional form is well suited to represent the GDP function; omitting the time subscript, it is as follows:[8]

$$\begin{aligned} \ln \pi = {} & \alpha_0 + \sum \alpha_i \ln p_i + \sum \beta_j \ln x_j + \frac{1}{2} \sum\sum \gamma_{ih} \ln p_i \ln p_h + \\ & \frac{1}{2} \sum\sum \phi_{jk} \ln x_j \ln x_k + \sum\sum \delta_{ij} \ln p_i \ln x_j + \\ & \sum \delta_{iT} \ln p_i t + \sum \phi_{jT} \ln x_j t + \beta_T t + \frac{1}{2} \phi_{TT} t^2, \\ & \qquad i, h \in \{M, X, D\};\ j, k \in \{L, K\}, \end{aligned} \tag{4}$$

where $\sum \alpha_i = 1$, $\sum \beta_j = 1$, $\gamma_{ih} = \gamma_{hi}$, $\phi_{jk} = \phi_{kj}$, $\sum \gamma_{ih} = 0$, $\sum \phi_{jk} = 0$, $\sum_i \delta_{ij} = 0$, $\sum_j \delta_{ij} = 0$, $\sum \delta_{iT} = 0$, and $\sum \phi_{jT} = 0$.

In the Translog case, it is most convenient to derive the output supply and inverse input demand functions (2)–(3) in terms of shares:

$$s_i = \alpha_i + \sum \gamma_{ih} \ln p_h + \sum \delta_{ij} \ln x_j + \delta_{iT} t, \qquad i \in \{M, X, D\} \tag{5}$$

$$s_j = \beta_j + \sum \delta_{ij} \ln p_i + \sum \phi_{jk} \ln x_k + \phi_{jT} t, \qquad j \in \{L, K\}, \tag{6}$$

where $s_i \equiv p_i y_i / \pi$ and $s_j \equiv w_j x_j / \pi$ are the GDP shares of output i and factor j, respectively.

3 Accounting for Growth in the Open Economy

Following Diewert and Morrison (1986), we define the following *productivity index* in order to capture the GDP effect of the change in technology between time $t-1$

[7] See Diewert (1974).

[8] See Christensen, Jorgenson and Lau (1973) and Diewert (1974). The last two terms ensure that the GDP function is fully flexible with respect to technological change, to use the terminology of Diewert and Wales (1992).

and time t:

$$R_{t,t-1} \equiv \left[\frac{\pi(\mathbf{p}_{t-1}, \mathbf{x}_{t-1}, t)}{\pi(\mathbf{p}_{t-1}, \mathbf{x}_{t-1}, t-1)} \cdot \frac{\pi(\mathbf{p}_t, \mathbf{x}_t, t)}{\pi(\mathbf{p}_t, \mathbf{x}_t, t-1)} \right]^{\frac{1}{2}}. \quad (7)$$

$R_{t,t-1}$ can be interpreted as the geometric mean of Laspeyres and Paasche productivity indexes; it thus has the Fisher form, so to speak.

Next, consider the GDP effect of a change in the terms of trade between times $t-1$ and t. Again following Diewert and Morrison (1986), we can define the following *terms-of-trade GDP adjustment index*, $A_{t,t-1}$, devised to capture the GDP effect of a change in the terms of trade between time $t-1$ and time t:

$$A_{t,t-1} \equiv \left[\frac{\pi(p_{Mt}, p_{Xt}, p_{Dt-1}, \mathbf{x}_{t-1}, t-1)}{\pi(p_{Mt-1}, p_{Xt-1}, p_{Dt-1}, \mathbf{x}_{t-1}, t-1)} \cdot \frac{\pi(p_{Mt}, p_{Xt}, p_{Dt}, \mathbf{x}_t, t)}{\pi(p_{Mt-1}, p_{Xt-1}, p_{Dt}, \mathbf{x}_t, t)} \right]^{\frac{1}{2}}. \quad (8)$$

$A_{t,t-1}$ too can be interpreted as the geometric mean of Laspeyres and Paasche indexes.

The productivity and the terms-of-trade indexes are defined for given prices of nontraded goods, and for given factor endowments; they measure the change in GDP that is attributable to technological progress and to the change in the terms of trade exclusively. A change in domestic factor endowments is obviously likely to affect GDP as well. To assess the contribution of factor j, Kohli (1990) defined the following *input quantity effect*:[9]

$$X_{j\,t,t-1} \equiv \left[\frac{\pi(\mathbf{p}_{t-1}, x_{jt}, x_{kt-1}, t-1)}{\pi(\mathbf{p}_{t-1}, x_{jt-1}, x_{kt-1}, t-1)} \cdot \frac{\pi(\mathbf{p}_t, x_{jt}, x_{kt}, t)}{\pi(\mathbf{p}_t, x_{jt-1}, x_{kt}, t)} \right]^{\frac{1}{2}}, \quad (9)$$

$$j, k \in \{L, K\}, j \neq k.$$

$X_{j\,t,t-1}$ thus measures, *ceteris paribus*, the contribution of factor j to GDP growth between times $t-1$ and t.

Finally, we can evaluate the GDP contribution of nontraded good prices. Kohli (1990) defined the following *nontraded good price effect*:[10]

$$P_{N\,t,t-1} \equiv \left[\frac{\pi(p_{Mt-1}, p_{Xt-1}, p_{Dt}, \mathbf{x}_{t-1}, t-1)}{\pi(p_{Mt-1}, p_{Xt-1}, p_{Dt-1}, \mathbf{x}_{t-1}, t-1)} \cdot \frac{\pi(p_{Mt}, p_{Xt}, p_{Dt}, \mathbf{x}_t, t)}{\pi(p_{Mt}, p_{Xt}, p_{Dt-1}, \mathbf{x}_t, t)} \right]^{\frac{1}{2}}. \quad (10)$$

[9] Morrison and Diewert (1990) define a similar effect, but in terms of the sales function.

[10] A similar effect, but defined in terms of the sales function, is introduced by Morrison and Diewert (1990).

$P_{N\,t,t-1}$ thus measures the growth in GDP that is due to domestic price changes alone, for given terms of trade, given factor endowments, and a given technology.

Each one of the five effects defined in this section — $R_{t,t-1}$, $A_{t,t-1}$, $X_{L,\,t,t-1}$, $X_{K,\,t,t-1}$, and $P_{N,\,t,t-1}$ — captures one of the major causes of GDP growth. We should also emphasize that these effects are valid for large changes in prices, quantities, and technology — not merely for infinitesimal changes. In the next two sections, we will turn to the task of actually measuring these effects. Moreover, we will see that, under certain conditions, these five effects will give a *complete* decomposition of observed nominal GDP growth.

4 Index-Number Estimates

The GDP function is generally unknown, and thus (7)–(10) are not very useful for obtaining estimates of $R_{t,t-1}$, $A_{t,t-1}$, $X_{L,\,t,t-1}$, $X_{K,\,t,t-1}$, and $P_{N,\,t,t-1}$. However, it turns out that *if the GDP function has the Translog form*, i.e. if $\pi(\cdot)$ is given by (4), $R_{t,t-1}$ can be calculated from the data alone in the following way (Diewert and Morrison, 1986):

$$R_{t,t-1} = \frac{\Gamma_{t,t-1}}{P_{t,t-1} \cdot X_{t,t-1}}, \tag{11}$$

where

$$\Gamma_{t,t-1} \equiv \frac{\sum p_{it} y_{it}}{\sum p_{it-1} y_{it-1}} \tag{12}$$

$$P_{t,t-1} \equiv \exp\left[\sum \frac{1}{2}(s_{it} + s_{it-1}) \ln \frac{p_{it}}{p_{it-1}}\right] \tag{13}$$

$$X_{t,t-1} \equiv \exp\left[\sum \frac{1}{2}(s_{jt} + s_{jt-1}) \ln \frac{x_{jt}}{x_{jt-1}}\right], \tag{14}$$

$$i \in \{M, X, D\}, j \in \{L, K\}.$$

$\Gamma_{t,t-1}$ is (one plus) the rate of increase in nominal GDP between times $t-1$ and t; $P_{t,t-1}$ is the Tornqvist *output price index*, and $X_{t,t-1}$ is the Tornqvist *fixed input quantity index*.

Moreover, Diewert and Morrison (1986) showed that, as long as the GDP function has the Translog form, $A_{t,t-1}$ can be calculated from knowledge of the data alone:

$$A_{t,t-1} = \exp\left[\frac{1}{2}(s_{Mt} + s_{Mt-1}) \ln \frac{p_{Mt}}{p_{Mt-1}} + \frac{1}{2}(s_{Xt} + s_{Xt-1}) \ln \frac{p_{Xt}}{p_{Xt-1}}\right]. \qquad (15)$$

Note that (15) is similar to a Tornqvist price index, except that the weights — the GDP shares of imports and exports — do not add up to one. In fact, if trade were balanced, the weights would add up to zero.[11]

In the same vein, still assuming that $\pi(\cdot)$ is given by (4), Kohli (1990) has shown that $X_{j\,t,t-1}$ can be measured as:

$$X_{j\,t,t-1} \equiv \exp\left[\frac{1}{2}(s_{jt} + s_{jt-1}) \ln \frac{x_{jt}}{x_{jt-1}}\right], \qquad j \,\epsilon\, \{L, K\}, \qquad (16)$$

whereas $P_{N\,t,t-1}$ can be obtained as:

$$P_{N\,t,t-1} = \exp\left[\frac{1}{2}(s_{Dt} + s_{Dt-1}) \ln \frac{p_{Dt}}{p_{Dt-1}}\right]. \qquad (17)$$

Finally, it turns out that if the GDP function is Translog, the following gives a *complete* and *exact* decomposition of GDP growth (Kohli, 1990):

$$\Gamma_{t,t-1} = R_{t,t-1} \cdot A_{t,t-1} \cdot X_{L\,t,t-1} \cdot X_{K\,t,t-1} \cdot P_{N\,t,t-1}. \qquad (18)$$

The product of the first two terms on the right hand side make up Diewert and Morrison's (1986) welfare change index. Multiplying this by the labor and capital quantity effects, one obtains the change in GDP after one allows for changes in factor endowments; this can be interpreted as the change in *real net output*, or, alternatively, since none of the domestic prices has yet been allowed to vary, the change in *real national income*. Finally, multiplying by the nontraded good price effect, we get nominal GDP growth.

We report in Table 1 estimates of the decomposition of South-Korean GDP growth based on (18), using annual data for the period 1970–1991.[12] Geometric averages for the entire sample period are shown at the bottom of the table.

[11] In calling $A_{t,t-1}$ a *terms-of-trade GDP adjustment index*, we adopt the terminology of Diewert and Morrison (1986). It perhaps would be more accurate, however, to call this a *traded-good price effect* since, as it can be seen from (15), an equiproportionate change in p_M and p_X, leaving the terms of trade unchanged, will be registered by $A_{t,t-1}$ unless trade happens to be balanced on average.

[12] See the Appendix for a description of the data.

[Table 1 about here]

Focusing first on the figures for the entire period, we find that nominal GDP has increased at an average annual rate of 22.8 per cent, approximately. Increases in domestic prices account for over 60 per cent of the increase in GDP. Dividing $\Gamma_{t,t-1}$ by $P_{N\,t,t-1}$, we can calculate that the average growth rate of real net output (i.e. real national income) is about 8.1 per cent per annum. The two main causes of growth are clearly technological change and capital accumulation: these two factors account for about 4.0 per cent and 3.1 per cent of GDP growth, respectively. The contribution of employment is nevertheless substantial, adding almost 1.9 per cent to GDP growth annually. The terms-of-trade effect, on the other hand, has been unfavorable on average: if it were not for the adverse changes in the terms of trade, real net output would have increased by an extra 0.9 per cent annually. This adds up to about 18 per cent over the entire sample period.

Considering next the individual effects, we first see that the rate of technological change has been very volatile during the sample period. Thus, it has been as high as 8.5 per cent (in 1974), and as low as minus 7.8 per cent (in 1980).

The direct effect of changes in the terms of trade on GDP is shown in the second column of Table 1 by the estimates of $A_{t,t-1}$. While small on average, this effect has been far from trivial. At times, it has contributed very substantially to GDP growth, like in 1976 when it added 3.5 per cent to GDP growth, and in 1986 when it added 2.9 per cent. In 1980, on the other hand, the adverse movement in the terms of trade shaved 9.7 per cent off GDP growth; the following year, growth was reduced by an additional 3.1 per cent. In 1974–75, the two year effect added up to about minus 10.9 per cent. These two periods coincide with the two oil shocks, which appear to have taken a very severe toll of South-Korean economic growth.

The contribution of employment has been remarkably strong for most of the sample period. In 1973, for instance, the employment effect added 6.2 per cent to GDP growth, which is truly amazing. In fact, the employment effect is positive for all but two years, 1979 and 1990. It is important to stress that $X_{L\,t,t-1}$ does not measure the growth in employment, but rather the contribution of labor growth to GDP growth. It reflects both the increase in the endowment of labor and changes in the GDP share of labor. As indicated by (6), these changes are mostly due to technological change, to movements in relative factor endowments, and changes in relative output prices.[13]

Estimates of the capital quantity effect are reported in column 4. Capital accumulation is a major cause of South-Korean real economic growth, adding up to 5.3 per cent to GDP growth (in 1979). In fact, the contribution of capital has been positive in every year of our sample. Moreover, there is no indication that its role is weakening.

Multiplying the indexes of the first four columns of the table by one another, we get the real net output. As suggested earlier, this index (not shown here) is largely driven by the technological change and the capital quantity effects. Real net output growth was particularly high during the sixties, topping 9 per cent in 1963 and 1968. It has been positive in all but two years, 1982 and 1990.

Looking at the domestic price effect, finally, we see that it is rather substantial and volatile, more often than not dominating the movements of nominal GDP. The effect was largest in 1974 when it reached 38.6 per cent, and in 1980 when it exceeded 34.7 per cent. It was weakest in the late eighties. It must be emphasized that, strictly speaking, $P_{N\,t,t-1}$ is not a price index. As shown by (17), the weights used to compute $P_{N\,t,t-1}$ normally do not add up to unity.[14]

Our results can be summarized graphically. Since GDP growth is blurred by the domestic price effect, we will focus on real variables. Thus, Figure 3 gives the total decomposition of real net output growth. The thin line at the bottom of the graph shows the contribution of employment growth. The second (dashed) line is obtained by adding to it the contribution of capital accumulation. We next add the contribution of the terms-of-trade movements (dotted line), and, finally, of the advances in the technology to obtain the path of real net output (fat line). It is clearly visible that all factors, except for the terms of trade, have very much contributed to GDP growth. This is particularly true for technological change. The terms of trade effect has, however, been a drag on income growth.

[13] This strong component is in sharp contrast with the situation in most European countries where the contribution of employment has generally been *negative*; see Kohli (1996).

[14] As shown in Figure 1, the South-Korean trade account has been in a deficit position for most of the seventies and eighties; consequently, s_D was greater than one during most of the sample period; it was as large as 1.18 in 1970.

[Figure 3 about here]

5 Econometric Estimates

An attractive feature of the GDP growth decomposition presented in the previous section is that, being based on an index-number approach, it essentially only depends on the data. In particular, no detailed knowledge of $\pi(\cdot)$ is needed, as long as one knows that technology can indeed be represented by a Translog GDP function similar to (4). Nevertheless, econometric estimates of the parameters of (4) can be obtained without too much difficulty.[15] For this purpose, we have estimated GDP function (4) together with the system of derived output supply and inverse input demand equations — equations (5) and (6). We have used the algorithm of Berndt, Hall, Hall and Hausman (1974) as implemented in TSP, Version 4.3; this is essentially a nonlinear version of the iterative Zellner (1962) method. Since the input shares as well as the output shares add up to unity, two equations had to be left out for estimation purposes, but the results do not depend on which equations are left out.

Initial experiments revealed that the estimated GDP function failed to satisfy the required convexity and concavity conditions. This is not unusual in a model of this type. Convexity in prices and concavity in fixed inputs were therefore imposed locally. This was done for 1987, using the reparameterization of Lau (1974) and Schmidt, Wiley, and Bramble (1973), as proposed by Diewert and Wales (1987).[16] The resulting parameter estimates, together with their asymptotic t-values, are reported in Table 2. The logarithm of the likelihood function (LL) and the pseudo R-squared (R_p^2) proposed by Baxter and Cragg (1970) are also reported. It turns out that imposing the curvature conditions locally is sufficient for the estimated function to satisfy all regularity conditions for all observations.

[Table 2 about here]

[15] See Kohli (1978), (1991) for the econometric estimation of GNP/GDP functions. Of related interest is the study by Mohabbat and Dalal (1983) who estimate a joint cost function for South Korea.

[16] See Kohli (1991) for details.

Since we do now have estimates of the parameters of the GDP function, it is worthwhile to pause and to examine the implied price, quantity and time elasticities as defined by Kohli (1978, 1991, 1994). Thus, in the GDP function setting, there are eight types of elasticities (and semi-elasticities) which can be identified. Consider first the supply of output (including the demand for imports). We can define the elasticities and semi-elasticities of output supply with respect to the prices of the variable components, with respect to the quantities of the domestic factors, and with respect to time:[17].

$$\varepsilon_{ih} \equiv \frac{\partial \ln y_i}{\partial \ln p_h} \tag{19}$$

$$\varepsilon_{ij} \equiv \frac{\partial \ln y_i}{\partial \ln x_j} \tag{20}$$

$$\varepsilon_{iT} \equiv \frac{\partial \ln y_i}{\partial t}, \qquad i, h \in \{M, X, D\};\ j \in \{L, K\}. \tag{21}$$

Similarly, there are three types of elasticities of inverse factor demands. Thus, we can identify the elasticities and semi-elasticities of factor payments with respect to output prices, factor endowments, and time:

$$\varepsilon_{ji} \equiv \frac{\partial \ln w_j}{\partial \ln p_i} \tag{22}$$

$$\varepsilon_{jk} \equiv \frac{\partial \ln w_j}{\partial \ln x_k} \tag{23}$$

$$\varepsilon_{jT} \equiv \frac{\partial \ln w_j}{\partial t}, \qquad i \in \{M, X, D\};\ j, k \in \{L, K\}. \tag{24}$$

Next, define the (unobservable) instantaneous rate of technological change (μ) as the derivative of the logarithm of GDP with respect to time:

$$\mu \equiv \frac{\partial \ln \pi(\cdot)}{\partial t}. \tag{25}$$

Like $\pi(\cdot)$, μ will typically be function of output prices, factor endowments, and time. In fact, it can easily be seen from (4), that, in the Translog case, it is as

[17] Even though this model differs from the Heckscher-Ohlin-Samuelson model of international trade in some key respects, it is convenient to refer to elasticities (20) as Rybczynski elasticities, since the effects they measure correspond precisely to the Rybczynski (1955) experiment. Similarly, we will refer to elasticities (22) below as Stolper-Samuelson elasticities, in reference to Stolper-Samuelson (1941).

follows:

$$\mu = \beta_T + \sum \delta_{iT} \ln p_i + \sum \phi_{jT} \ln x_j + \phi_{TT} t, \qquad i \in \{M, X, D\};\ j \in \{L, K\}. \tag{26}$$

This makes it possible to define the final two sets of semi-elasticities:[18]

$$\varepsilon_{Ti} \equiv \frac{\partial \mu}{\partial \ln p_h} \tag{27}$$

$$\varepsilon_{Tj} \equiv \frac{\partial \mu}{\partial \ln x_j}, \qquad i \in \{M, X, D\};\ j \in \{L, K\}. \tag{28}$$

It is a simple matter to compute these elasticities from the parameters of the Translog GDP function.[19] Their values are reported in Table 3 for a selected number of years. Estimates of μ are also shown. One sees that the own price elasticity of the demand for imports (ε_{MM}) has been increasing (in absolute value) throughout the seventies, but it has fallen somewhat in recent years. Except for early on in the sample, it is considerably larger, however, than the own price elasticity of the supply of exports (ε_{XX}). Imports appear to be a complement for exports and domestic sales, in the sense that an increase in the price of either output will pull along the demand for imports. One can see from the quantity elasticities of inverse factor demands that an increase in the endowment of either domestic factor has only a small impact on factor rental prices. Of considerable interest are the estimates of the Rybczynski elasticities. These show that an increase in relative capital intensity will favor domestic sales, but will actually penalize imports as well as exports. Consequently, as shown by the Stolper-Samuelson elasticities, an improvement in the terms of trade will favor labor and hurt capital; an increase in the price of goods intended for the domestic market, on the other hand, benefits both factors.

[Table 3 about here]

[18] These are semi-elasticities, since μ is measured in absolute terms, rather than in logarithms. For the sake of completeness, we can also define the effect of the passage of time on the instantaneous rate of technological change, $\varepsilon_{TT} \equiv \partial\mu/\partial t$. In the Translog case, this effect is constant and equal to ϕ_{TT}.

[19] See Kohli (1994). It turns out that in the Translog case, ε_{Ti}, ε_{Tj}, and ε_{TT} are constant; this is not incompatible with flexibility, however, since these are transforms of elements of the Hessian of $\pi(\cdot)$.

Looking next at the time semi-elasticities of output supplies and inverse factor demands, we find that the passage of time stimulates both imports and exports, and favors labor over capital. Of much interest are the effects of price changes and changes in factor endowments on the rate of technological change: our estimates indicate that an improvement in the terms of trade increases the rate of technological change, whereas an increase in relative capital intensity reduces it. The instantaneous rate of technological change, finally, is found to have fallen from about 4.2 per cent in 1971 to 2.3 per cent in 1991; judging from our estimates, this decline is largely due to the phenomenal increase in the Korean stock of capital during the sample period.

The parameter estimates shown in Table 2 can now be used to obtain an *econometric* decomposition of GDP growth. For instance, we can calculate $A_{t,t-1}$ from (8) directly, without having to use (15). Similarly, we can calculate $X_{Lt,t-1}$, $X_{Kt,t-1}$, and $P_{Nt,t-1}$ directly from (9) and (10), without having to rely on (16) and (17). Not only will this exercise yield a decomposition of GDP growth that abstract from errors in optimization, but it will also enable us to decompose the technological change index into secular and transitory components. Since our decomposition of GDP is based on the Translog estimates, rather than on the data directly, it is the fitted, or the potential, value of GDP, rather than the observed one, that we are explaining. Let $\Pi_{t,t-1}$ be defined as (one plus) the rate of growth of potential GDP:

$$\Pi_{t,t-1} = \frac{\pi(\mathbf{p}_t, \mathbf{x}_t, t)}{\pi(\mathbf{p}_{t-1}, \mathbf{x}_{t-1}, t-1)}. \tag{29}$$

The counterpart of (18) therefore is:

$$\Pi_{t,t-1} = S_{t,t-1} \cdot A_{t,t-1} \cdot X_{Lt,t-1} \cdot X_{Kt,t-1} \cdot P_{Nt,t-1}, \tag{30}$$

where the terms on the right-hand side are now calculated from the Translog estimates, rather than from (11), (15), (16) and (17), and where $S_{t,t-1}$ is defined as the *secular* component of technological change. Naturally, $\Pi_{t,t-1} \neq \Gamma_{t,t-1}$ in general. The *unexplained* residual, $U_{t,t-1}$, is defined as:

$$U_{t,t-1} \equiv \frac{\Gamma_{t,t-1}}{\Pi_{t,t-1}}. \tag{31}$$

Observed GDP growth can therefore be decomposed as follows:

$$\Gamma_{t,t-1} = S_{t,t-1} \cdot U_{t,t-1} \cdot A_{t,t-1} \cdot X_{Lt,t-1} \cdot X_{Kt,t-1} \cdot P_{Nt,t-1}. \tag{32}$$

Before reporting empirical estimates of (32), let us briefly turn to the practical task of computing the indexes from the Translog parameters. Substituting (4) into (7), we get:

$$\ln(S_{t,t-1}) = \frac{1}{2}\Sigma\delta_{iT}\ln(p_{it}p_{it-1}) + \frac{1}{2}\Sigma\phi_{jT}\ln(x_{jt}x_{jt-1}) + \beta_T + \frac{1}{2}\phi_{TT}(2t-1), \tag{33}$$
$$i, h\epsilon\{M, X, D\}; j, k\epsilon\{L, K\}.$$

Similarly, substituting (4) into (8), (9), and (10), we obtain:

$$\begin{aligned}
\ln(A_{t,t-1}) &= \frac{1}{2}\Sigma\Sigma\gamma_{ih}[\ln(p_{it})\ln(p_{ht}) - \ln(p_{it-1})\ln(p_{ht-1})] + \\
&\quad \Sigma\ln\left(\frac{p_{it}}{p_{it-1}}\right)[\alpha_i + \frac{1}{2}\gamma_{iD}\ln(p_{Dt}p_{Dt-1}) + \\
&\quad \frac{1}{2}\Sigma\delta_{ij}\ln(x_{jt}x_{jt-1}) + \frac{1}{2}\delta_{iT}(2t-1)], \qquad (34)\\
&\qquad\qquad i, h\epsilon\{M, X\}; j\epsilon\{L, K\};\\
\ln(X_{jt,t-1}) &= \ln\left(\frac{x_{jt}}{x_{jt-1}}\right)[\beta_j + \frac{1}{2}\Sigma\phi_{jk}\ln(x_{kt}x_{kt-1}) + \\
&\quad \frac{1}{2}\Sigma\delta_{ij}\ln(p_{it}p_{it-1}) + \frac{1}{2}\phi_{jT}(2t-1)], \qquad (35)\\
&\qquad\qquad i, h\epsilon\{M, X, D\}; j, k\epsilon\{L, K\};\\
\ln(P_{Nt,t-1}) &= \frac{1}{2}\gamma_{DD}[\ln(p_{Dt})\ln(p_{Dt}) - \ln(p_{Dt-1}\ln(p_{Dt-1})] + \\
&\quad \ln\left(\frac{p_{Dt}}{p_{Dt-1}}\right)[\alpha_D + \frac{1}{2}\Sigma\gamma_{Dm}\ln(p_{mt}p_{mt-1}) + \\
&\quad \frac{1}{2}\Sigma\delta_{Dj}\ln(x_{jt}x_{jt-1}) + \frac{1}{2}\delta_{DT}(2t-1)], \qquad (36)\\
&\qquad\qquad m\epsilon\{M, X\}; j\epsilon\{L, K\}.
\end{aligned}$$

We report in Table 4 estimates of the decomposition of GDP growth according to (32). Comparing the figures of Table 4 with those of Table 1, one sees that for most components the estimates are very close.[20] This reflects the fact that the fit

[20] Naturally, the numbers for $\Gamma_{t,t-1}$ are the same in both tables since they are based on observed data; see (14).

of the model is quite good; hence, it makes little difference whether we use actual shares or potential shares as a basis for our calculations. However, unlike the index-number approach, the econometric approach allows for the decomposition of technological change into a secular — or expected — term, measured by $S_{t,t-1}$, and a random — or unexpected — term, captured by $U_{t,t-1}$. While the product of these two components comes close to the index number measure of $R_{t,t-1}$ reported in Table 1, the decomposition into these two factors is of considerable interest. Looking at the averages for the entire period, one sees that about four tenth of one percentage point of GDP growth is unaccounted for by the model, while the secular rate of technological change comes close to 3.5 per cent on average. This rate tends to fall through time, from about 4.2 per cent in the early seventies, to about 2.4 per cent in the early nineties. This measure of technological change is fairly smooth since it does not incorporate the unexplained component ($U_{t,t-1}$). Note, however, that $S_{t,t-1}$ is not simply a function of time: as shown by (33), it also depends on changes in the terms of trade, in factor endowments, and in domestic prices. The estimates of ε_{TM} and ε_{TX} in Table 3 show that an improvement in the terms of trade tends to increase the rate of technological change. An increase in labor intensity tends to have the same effect; see the estimate of ε_{TL}.[21] As to the unexplained component of GDP growth, we observe that it can be quite important at times. Its (logarithmic) mean is close to zero (0.00433), but its standard deviation is about 3.6 per cent.

[Table 4 about here]

6 Concluding Comments

Our results show that technological change has been very volatile in South Korea during the seventies and eighties, averaging about 3.5 per cent. This is very high by world standards, although our econometric estimates indicate that the secular rate of technological change did tend to fall through time, from about 4.2 per cent in 1971 to about 2.4 per cent in 1991. It is noteworthy that this decline is

[21] These effects are distinct from — and in addition to — the direct effect of a change in the terms of trade on GDP growth as measured by $A_{t,t-1}$, or the GDP effect of a change in factor endowments as captured by $X_{L\,t,t-1}$.

not monotonic; it depends on changes in factor intensities as well as on changes in the terms of trade and in domestic prices. The terms-of-trade effect has been quite volatile too. Thus, it penalized real growth by over 7 per cent in 1980, while it added close to 4 per cent in 1976, according to our econometric estimates. These large effects reflect both changes in the terms of trade and changes in the trade deficit. The terms-of-trade effect has been negative on average, reducing real growth by about 0.8 per cent annually. This effect has cost Korea between 14 per cent and 18 per cent of GDP over the past two decades. The contribution of employment has been very vigorous, and, as one might have expected it, the contribution of capital accumulation is substantial. In fact, well over half of real Korean growth is explained by increases in domestic factor endowments.

Our approach clearly rests on some very strong assumptions, not least competitive behavior and constant returns to scale. Given the drastic structural changes the Korean economy went through during the past twenty years, often in the face of strong government involvement, and considering the fact that the labor market evolved from a state of almost unlimited supply at subsistence wage to a situation of relative shortage, our results must be viewed as tentative. However, the standard approach which relies on Solow residuals derived from a Cobb-Doulgas production function is subject to the same charges, and then some. By allowing for additional inputs and outputs, by using a flexible functional form, and by explicitly taking foreign trade into account, we firmly believe that our extension is a step in the right direction.

Appendix: Description of the Data

The purpose of this appendix is to give a brief description of the construction of the data. Additional details can be found in Werner (1994).

While we have referred to π as GDP, we must now be more precise. In fact, our measure of π differs from GDP on two accounts. First, we only consider the private sector; that is, we include sales of goods and services to the government sector, but government production activities are excluded. Second, all data are measured from the producers' viewpoint. This means that output prices are net of indirect taxes, but include subsidies; moreover, import prices incorporate import duties. Thus, it would be more precise to describe π as private GDP at producer prices. Alternatively, π can be interpreted as the total income of domestic factors employed in the private sector.

We require data on prices and quantities for all inputs (imports, labor and capital) and outputs (exports and domestic sales). Our main statistical source are the Korean national accounts, as they can be found in various publications of the Bank of Korea. Imports are defined are total imports minus payments to foreign factors. The price of imports is inflated by customs duties paid. Exports are defined as total exports minus factor income receipts from abroad.

Domestic sales are defined as the sum of consumer expenditures, investment, and government purchases. Aggregation is carried through by computing a Tornqvist — or Translog — quantity index. The price of domestic sales is inflated by indirect taxes, whereas subsidies are imputed to both domestic sales and exports.

Labor income is defined as total labor compensation excluding the government sector. The quantity of labor services is obtained by multiplying an index of employment by the number of weekly hours worked; the relevant series are drawn from Christensen and Cummings (1981) until 1973, and from International Labour Office (ILO) sources thereafter. The price of labor services is obtained by deflation.

The revenue of capital is obtained as a residual using the GDP identity. To get a measure of the capital stock, we proceed as follows. We begin by cumulating the series for investment in structures and investment in equipment; the depreciation rates we use are 5 per cent and 15 per cent, respectively. As starting values, we use the 1970 figures obtained by Christensen and Cummings (1981). We then compute a Tornqvist quantity index of these two series. For this, one needs a price index for both types of capital services. We construct a theoretical price index using the Jorgensonian formula, using a medium-run rate of interest for equipment, and a long-run rate of interest for structures; both rates of interest are taken from International Monetary Fund sources. The user cost of aggregate capital, finally, is obtained by deflation.

All output (including import) prices together with the quantities of labor and capital are normalized to one for 1985; t is a time trend with unit annual increments and a 1985-value set to zero.

References

Bank of Korea (1984) *National Income Accounts*, Seoul: Bank of Korea.

Bank of Korea (1987) *National Accounts, 1970–1986*, Seoul: Bank of Korea.

Bank of Korea *Economic Statistics Yearbook*, Seoul: Bank of Korea, various issues.

Berndt, Ernst R., Bronwyn H. Hall, Robert E. Hall, and Jerry A. Hausman (1974) "Estimation and Inference in Nonlinear Structural Models," *Annals of Economic and Social Measurement* 3/4, 653–665.

Baxter, Nevins D. and John G. Cragg (1970) "Corporate Choice Among Long-Term Financial Instruments," *Review of Economics and Statistics* 52, 225-235.

Christensen, Laurits R. and Dianne Cummings (1981) "Real Product, Real Factor Input, and Productivity in the Republic of Korea, 1960–1973," *Journal of Development Economics* 8, 285–302.

Christensen, Laurits R., Dale W. Jorgenson, and Larry J. Lau (1973) "Transcendental Logarithmic Production Frontiers," *Review of Economics and Statistics* 55, 28–45.

Diewert, W. Erwin (1974) "Applications of Duality Theory," in Michael D. Intriligator and David A. Kendrick (eds.) *Frontiers of Quantitative Economics*, Vol. 2, Amsterdam: North-Holland.

Diewert, W. Erwin and Catherine J. Morrison (1986) "Adjusting Output and Productivity Indexes for Changes in the Terms of Trade," *Economic Journal* 96, 659–679.

Diewert, W. Erwin and Terence J. Wales (1987) "Flexible Functional Forms and Global Curvature Conditions," *Econometrica* 55, 43–68.

Diewert, W. Erwin and Terence J. Wales (1992) "Quadratic Spline Models for Producer's Supply and Demand Functions," *International Economic Review* 33, 705–722.

International Labour Office *Yearbook of Labour Statistics*, Geneva: International Labour Office, various issues.

International Monetary Fund *International Financial Statistics*, Washington, DC: International Monetary Fund, various issues.

Kohli, Ulrich (1978) "A Gross National Product Function and the Derived Demand for Imports and Supply of Exports," *Canadian Journal of Economics* 11, 167–182

Kohli, Ulrich (1990) "Growth Accounting in the Open Economy: Parametric and Nonparametric Estimates," *Journal of Economic and Social Measurement* 16, 125–136.

Kohli, Ulrich (1991) *Technology, Duality, and Foreign Trade: The GNP Function Approach to Modeling Imports and Exports*, London: Harvester Wheatsheaf.

Kohli, Ulrich (1994) "Technological Biases in U.S. Aggregate Production," *Journal of Productivity Analysis* 5, 5–22.

Kohli, Ulrich (1996) "Growth Accounting in the Open Economy: International Comparisons," mimeo, University of Geneva, Switzerland.

Kydland, Finn E. and Edward C. Prescott (1982) "Time to Build and Aggregate Fluctuations," *Econometrica* 50, 1345–1370.

Lau, Lawrence J. (1974) "Applications of Duality Theory: Comments," in Michael D. Intriligator and David A. Kendrick (eds.) *Frontiers of Quantitative Economics*, Vol. 2, Amsterdam: North-Holland.

Mankiw, N. Gregory, David Romer, and David N. Weil (1992) "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics* 152, 407–437.

Mohabbat, Khan A. and Ardeshir J. Dalal (1983) "Factor Substitution and Import Demand for South Korea: A Translog Analysis," *Weltwirtchaftliches Archiv* 119, 709–723.

Morrison, Catherine and W. Erwin Diewert (1990) "Productivity Growth and Changes in the Terms of Trade in Japan and the United States," in Charles R. Hulten (ed.) *Productivity Growth in Japan and the United States*, Chicago, IL: University of Chicago Press.

Pack, Howard and John M. Page Jr. (1994) "Accumulation, Exports, and Growth in the High-Performing Asian Economies," *Carnegie-Rochester Conference Series on Public Policy* 40, 199–236.

Prescott, Edward C. (1986) "Theory Ahead of Business Cycle Measurement," *Carnegie-Rochester Conference Series on Public Policy* 25, 11–44.

Rybczynski, T.M. (1955) "Factor Endowments and Relative Commodity Prices," *Economica* 22, 336-341.

Solow, Robert M. (1957) "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics* 39, 312–320.

Stolper, Wolfgang F. and Paul A. Samuelson (1941) "Protection and Real Wages," *Review of Economic Studies* 9, 58–73.

Wiley, D.E., W.H. Schmidt, and W.J. Bramble (1973) "Studies of a Class of

Covariance Structure Models," *Journal of the American Statistical Association* 68, 317–323.

Werner, Augustin (1994) "Analyse de la croissance du PNB de la Corée du Sud: Estimations paramétriques et non paramétriques," mimeo, University of Geneva, Switzerland.

Woodland, Alan D. (1982) *International Trade and Resource Allocation*, Amsterdam: North-Holland.

Young, Alwyn (1994a) "Lessons from the East Asian NICS: A Contrarian View," *European Economic Review* 38, 964–973.

Young, Alwyn (1994b) "Accumulation, Exports, and Growth in the High Performing Asian Economies: A Comment," *Carnegie-Rochester Conference Series on Public Policy* 40, 237–250.

Zellner, Arnold (1962) "An Efficient Method for Estimating Seemingly Unrelated Regressions and Tests for Aggregations Bias," *Journal of the American Statistical Association* 57, 348–368.

Table 1: South-Korean GDP Growth Accounting
Index-Number Estimates
(yearly rates and geometric averages)

	$R_{t,t-1}$	$A_{t,t-1}$	$X_{L\,t,t-1}$	$X_{K\,t,t-1}$	$P_{N\,t,t-1}$	$\Gamma_{t,t-1}$
1971	1.04985	0.98463	1.03312	1.00816	1.16643	1.25584
1972	1.05729	0.98630	1.02983	1.01062	1.14436	1.24199
1973	1.07928	0.98264	1.06220	1.00940	1.13785	1.29385
1974	1.08549	0.94324	1.00617	1.01425	1.38642	1.44863
1975	1.03210	0.94409	1.00467	1.01985	1.29011	1.28801
1976	1.05695	1.03533	1.03904	1.02233	1.16522	1.35445
1977	1.07085	1.00688	1.02034	1.03157	1.13070	1.28320
1978	1.02622	1.00380	1.03242	1.04163	1.20494	1.33483
1979	1.01103	0.97518	0.99827	1.05339	1.24266	1.28836
1980	0.92193	0.90320	1.00552	1.04840	1.34735	1.18271
1981	1.03775	0.96871	1.01647	1.03060	1.17805	1.24061
1982	1.00247	1.01089	1.01156	1.02471	1.06704	1.12086
1983	1.05476	1.00997	1.01814	1.02630	1.08122	1.20353
1984	1.06979	1.00298	1.00106	1.03493	1.03525	1.15083
1985	1.02446	0.99211	1.01897	1.03713	1.04711	1.12471
1986	1.05269	1.02918	1.03091	1.03391	1.01179	1.16837
1987	1.05579	1.01241	1.02853	1.03983	1.02491	1.17164
1988	1.05318	1.00881	1.01377	1.04332	1.04915	1.17897
1989	1.01903	1.01800	1.01702	1.03670	1.03370	1.13061
1990	1.05249	0.99473	0.98773	1.03602	1.10105	1.17961
1991	1.03329	0.99952	1.01905	1.04430	1.09967	1.20864
1971–1991	1.03974	0.99060	1.01867	1.03075	1.13575	1.22826

Explanations:

$R_{t,t-1}$: index of technological change
$A_{t,t-1}$: terms-of-trade adjustment index
$X_{L\,t,t-1}$: labour quantity effect
$X_{K\,t,t-1}$: capital quantity effect
$P_{N\,t,t-1}$: nontraded good price effect
$\Gamma_{t,t-1}$: nominal GDP growth index (actual data).

Table 2: Translog GDP Function
Parameter Estimates
(t-values in parentheses)

α_0	11.40880	δ_{ML}	-0.35545
	(693.96)		(-4.82)
α_M	-0.47192	δ_{XL}	0.53670
	(-35.82)		(9.93)
α_X	0.48031	δ_{MT}	-0.02578
	(40.65)		(-7.31)
β_L	0.65205	δ_{XT}	0.04697
	(58.13)		(14.60)
γ_{MM}	-0.25540	ϕ_{LT}	0.01101
	(-2.53)		(2.73)
γ_{MX}	0.08986	β_T	0.02968
	(1.21)		(8.03)
γ_{XX}	0.29222	ϕ_{TT}	0.00006
	(6.95)		(0.11)
ϕ_{LL}	0.11364		
	(1.33)		
LL	181.06		
R_p^2	0.86396		

Table 3: Price and Quantity Elasticities of Output Supply and Inverse Input Demands

	1970	1975	1980	1985	1991
i) Price elasticities of import demand and output supply					
ε_{MM}	-0.408	-0.940	-0.881	-0.924	-0.736
ε_{MX}	-0.200	0.196	0.162	0.239	0.151
ε_{MD}	0.608	0.744	0.719	0.685	0.585
ε_{XM}	0.523	-0.243	-0.201	-0.260	-0.155
ε_{XX}	1.754	0.144	0.169	0.109	0.148
ε_{XD}	-2.278	0.098	0.032	0.152	0.007
ε_{DM}	-0.149	-0.325	-0.297	-0.309	-0.226
ε_{DX}	-0.213	0.035	0.011	0.063	0.003
ε_{DD}	0.363	0.290	0.287	0.247	0.224
ii) Quantity elasticities of inverse factor demands					
ε_{LL}	-0.213	-0.211	-0.223	-0.208	-0.184
ε_{LK}	0.213	0.211	0.223	0.208	0.184
ε_{KL}	0.315	0.316	0.310	0.317	0.324
ε_{KK}	-0.315	-0.316	-0.310	-0.317	-0.324
iii) Rybczynski elasticities					
ε_{ML}	1.823	1.345	1.372	1.362	1.548
ε_{MK}	-0.823	-0.345	-0.372	-0.362	-0.548
ε_{XL}	5.451	1.994	2.064	1.849	2.045
ε_{XK}	-4.451	-0.994	-1.064	-0.849	-1.045
ε_{DL}	0.442	0.433	0.415	0.430	0.458
ε_{DK}	0.558	0.567	0.585	0.570	0.542
iv) Stolper-Samuelson elasticities					
ε_{LM}	-0.886	-1.070	-1.061	-1.057	-0.948
ε_{LX}	1.011	1.281	1.285	1.319	1.223
ε_{LD}	0.875	0.789	0.776	0.738	0.725
ε_{KM}	0.590	0.410	0.400	0.429	0.590
ε_{KX}	-1.218	-0.953	-0.921	-0.925	-1.099
ε_{KD}	1.628	1.543	1.521	1.496	1.509

Table 3, continued

	1970	1975	1980	1985	1991
v) Time semi-elasticities of output supplies					
ε_{MT}	0.131	0.092	0.088	0.083	0.089
ε_{XT}	0.467	0.160	0.161	0.137	0.146
ε_{DT}	0.024	0.019	0.012	0.007	0.002
vi) Time semi-elasticities of inverse input demands					
ε_{LT}	0.060	0.057	0.050	0.046	0.040
ε_{KT}	0.014	0.011	0.005	-0.000	-0.007
vii) Price semi-elasticities of technological change					
ε_{TM}	-0.026	-0.026	-0.026	-0.026	-0.026
ε_{TX}	0.047	0.047	0.047	0.047	0.047
ε_{TD}	-0.021	-0.021	-0.021	-0.021	-0.021
viii) Quantity semi-elasticities of technological change					
ε_{TL}	0.011	0.011	0.011	0.011	0.011
ε_{TK}	-0.011	-0.011	-0.011	-0.011	-0.011
ix) Instantaneous rate of technological change					
μ	0.042	0.038	0.031	0.028	0.023

Table 4: South-Korean GDP Growth Accounting
Econometric Estimates
(yearly rates and geometric averages)

	$S_{t,t-1}$	$U_{t,t-1}$	$A_{t,t-1}$	$X_{L\,t,t-1}$	$X_{K\,t,t-1}$	$P_{N\,t,t-1}$	$\Gamma_{t,t-1}$
1971	1.04238	1.00593	0.98191	1.03392	1.00788	1.17050	1.25584
1972	1.04305	1.01326	0.98158	1.03239	1.00943	1.14881	1.24199
1973	1.04523	1.03549	0.97515	1.06355	1.00906	1.14230	1.29385
1974	1.04555	1.03816	0.95076	1.00587	1.01582	1.37379	1.44863
1975	1.04170	0.99598	0.94915	1.00444	1.02174	1.27447	1.28801
1976	1.03983	1.01393	1.03908	1.03852	1.02283	1.16394	1.35445
1977	1.04015	1.02873	1.00632	1.02130	1.02921	1.13370	1.28320
1978	1.03887	0.98784	1.00367	1.03340	1.03956	1.20635	1.33483
1979	1.03670	0.97525	0.98053	0.99828	1.05423	1.23485	1.28836
1980	1.03338	0.88011	0.92344	1.00526	1.05245	1.33104	1.18271
1981	1.03101	1.00181	0.97618	1.01545	1.03368	1.17224	1.24061
1982	1.03028	0.97386	1.00946	1.01104	1.02648	1.06633	1.12086
1983	1.02982	1.02457	1.00877	1.01787	1.02690	1.08178	1.20353
1984	1.02965	1.04070	1.00211	1.00109	1.03374	1.03561	1.15083
1985	1.02893	0.99623	0.99163	1.01941	1.03586	1.04784	1.12471
1986	1.02903	1.02182	1.03079	1.03236	1.03158	1.01222	1.16837
1987	1.03000	1.02693	1.01195	1.03142	1.03411	1.02625	1.17164
1988	1.02948	1.02455	1.00912	1.01508	1.03716	1.05212	1.17897
1989	1.02855	0.98762	1.02009	1.01696	1.03697	1.03464	1.13061
1990	1.02692	1.02226	0.99552	0.98824	1.03933	1.09895	1.17961
1991	1.02446	1.00877	1.00085	1.01844	1.04711	1.09575	1.20864
1971–1991	1.03450	1.00434	0.99239	1.01912	1.03064	1.13414	1.22826

Explanations:

- $S_{t,t-1}$: index of technological change, secular component
- $U_{t,t-1}$: index of technological change, unexplained component
- $A_{t,t-1}$: terms-of-trade adjustment index
- $X_{L\,t,t-1}$: labour quantity effect
- $X_{K\,t,t-1}$: capital quantity effect
- $P_{N\,t,t-1}$: nontraded good price effect
- $\Gamma_{t,t-1}$: nominal GDP growth index (actual data).