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Real Exchange Rates in Growing Economies: How Strong Is the Role of the Nontradables Sector?

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Real Exchange Rates in Growing Economies: How Strong Is the Role of the Nontradables Sector?

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Abstract

This paper emphasizes the importance of total factor productivity (TFP) developments in the nontradables sector to quantitatively demonstrate that the time-honored Balassa-Samuelson hypothesis does not generally apply to episodes of economic growth. Though the Balassa-Samuelson hypothesis postulates that strong economic growth should, in general, be accompanied by a real appreciation in exchange rates, this paper does not find such systematic links. This is because some growth spurts are marked by equal TFP gains in both the tradables and nontradables sectors, and others by larger TFP gains in the nontradables sector.

JEL Classification Numbers: C22; F31; O24; O47

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Contents Page

I. Introduction

The effect of productivity growth on real exchange rates (RERs), particularly over the long run, has long attracted the attention of economists. The stylized fact is that economic growth should be accompanied by a real appreciation in exchange rates, and this is usually attributed to the Balassa-Samuelson hypothesis (BSH). The BSH assumes that the tradable sector of rich countries is more productive than those of poor countries, but that productivity is equally low in the nontradables sector across countries. Higher productivity in the tradables sector of rich countries implies higher production costs than in poor countries, because resources are bid up in domestic markets. Assuming the price of tradable goods is more or less aligned across countries, only the price of nontradable goods can increase in rich countries. Thus, rich countries with higher productivity in the tradables sector will tend to have higher nontradable prices — in other words, a real appreciation in exchange rates.[2] Indeed, the BSH is consistent with postwar growth in Japan, where the tradables sector was mainly responsible for the nation's economic growth and RERs appreciated.[3]

The BSH is based on the following two assumptions. The first is a theory and assumes that RERs appreciate when productivity gains are higher in the tradables sector. The second is empirical and assumes that productivity gains in the tradables sector should be mainly responsible for economic growth. The majority of literature has focused only on the first claim of the BSH, paying little attention to the second claim. This study's objective is to revisit the BSH and examine if the hypothesis as a whole, combining the two claims, is consistent with the data—that is, it examines whether there is a connection between economic growth in the long run, on the one hand, and real exchange rates, on the other hand.

The origin of the BSH goes back to Harrod (1933), where the national level of efficiency in producing goods is assumed to be affected by the difference in technology or by the endowment of natural resources. The former link is developed by Balassa (1964), while the latter link is extended by Bhagwati (1984). Balassa (1964) relates a country's price levels, as indicated by the ratio of purchasing power parity to nominal exchange rates, to national income per capita; the underlying assumption is that the tradables sector represents a large share of the country's productivity gains because productivity growth in the nontradables sector is supposed to be stagnant across countries. Hence, higher levels of national income per capita should reflect larger productivity differences between the tradables and nontradables sectors, leading to higher price levels. Bhagwati (1984) takes a different approach and develops the link between national price levels and the endowment of natural

[2] Cross-country comparisons by Balassa (1964) demonstrate a positive correlation between price levels and income levels.

[3] Previous work quantitatively confirms the existence of large gaps in productivity improvements between the tradables and nontradables sectors in Japan. See Miyajima (2004).

resources.[4] Bhagwati's model consists of two countries (rich and poor), two inputs (labor and capital), and three final goods. The poor country can produce only two final goods, which are relatively labor intensive, provided that initial endowment disparities are large enough that factor prices do not equalize. This leads to relatively low national price levels in the poor country. Samuelson (1994), however, asserts that Bhagwati's model requires restrictions to reach such conclusions and therefore favors the logic of technology differences. In this respect, Obstfeld and Rogoff (1999) maintain that productivity differences are essential to explaining large inter-country wage differences, even though endowment differences might be part of the story. Indeed, little related research seems to investigate natural resources as a main explanatory variable, and my work therefore focuses on gaps in productivity gains between the tradables and nontradables sectors as the long-run determinant of RERs.[5]

Though the BSH is important in understanding economic growth and we seem to take it for granted, some studies question the general applicability of the BSH. Ito, Isard, and Symansky (1997), one of the few papers to examine the BSH in its original setting, finds no systematic link between economic growth and RERs among Asia Pacific Economic Cooperation (APEC) countries. Harberger (2003) also confirms a weak link at best between GDP growth and a real appreciation in exchange rates.[6] Motivated by such findings, this paper contributes to the literature by revisiting the BSH in its original setting.

To examine the BSH, I restate its argument in two parts for clarity's sake. The first is a theory and assumes that RERs appreciate when productivity gains are higher in the tradables sector. The second is empirical: productivity gains in the tradables sector are assumed to be mainly responsible for economic growth. The BSH combines these two and postulates that economic growth should be accompanied by a real appreciation in exchange rates. To summarize, the BSH jointly assumes $C1$ and $C2$, where

$C1$ = gaps in productivity gains between the two sectors are systematically linked with RERs; and

[4] Bhagwati (1984) is directly motivated by Kravis, Heston and Summers (1982), a work on international comparisons of national income and price structure. Kravis, Heston, and Summers confirm the finding of Balassa (1964) in that the price level of services is typically lower in poor countries, which is considered to be the consequence of smaller gaps in productivity growth between the tradables and nontradables sectors.

[5] According to Officer (1976b), Clague and Tanzi (1972) included the ratio of natural resources to other factors of production as one of the principal explanatory variables.

[6] For instance, when RERs are regressed on a time trend, Harberger (2003) obtains 18 positive coefficients and 7 negative coefficients. The results of other regressions are found to be similar. Regarding significance (up to the 5 percent level), 13 positive and 5 negative coefficients are significant, while 5 positive and 2 negative coefficients are not.

$C2$ = gaps in productivity gains between the two sectors are systematically linked with economic growth.

This paper extends the literature to quantitatively show that the BSH is not the rule that applies to most episodes of strong economic growth. This is because, although $C1$ holds in the data, $C2$ does not. A novel aspect of this paper is that it examines $C2$ independently and demonstrates that the BSH does not generally hold, because $C2$ does not hold.

On the technical front, total factor productivity (TFP) gains for 15 developed countries are estimated on the basis of a version of growth accounting, proposed by Harberger (1998), that assumes no specific form of production function. Moreover, this method accounts for quality improvements in labor inputs and changes in the composition of heterogeneous capital inputs.[7] This stands in contrast to the previous literature, which has paid little attention to the estimation of TFP itself.

The most important innovation, however, is that I focus on productive industries in TFP estimations and exclude the public and services sector from the analysis. This is the single most important assumption that allows me to conclude that $C2$ and, hence, the BSH do not hold. No other work explicitly makes such adjustments.

This paper first confirms, using several econometric methods, a systematic link between gaps in TFP gains between the tradables and nontradables sectors and RERs ($C1$). Such findings contrast with the existing literature, which has so far provided mixed results. Officer (1976a) finds little evidence supporting $C1$, and results from Chinn (1997) and Canzoneri, Cumby, and Diba (1996) are inconclusive, though Hsieh (1982); De Gregorio, Giovannini, and Kruger (1994); De Gregorio, Giovannini, and Wolf (1994); and De Gregorio and Wolf (1994) report more favorable findings. In regression analysis, this paper follows the literature, which has paid a significant amount of attention to stationarity of the data, since some researchers use the data in first differences in order to purge persistence while others use the cointegrating method. Because of the mixed results in the literature so far, my empirical work first tests $C1$ using various econometric techniques in an effort to find clearer conclusions.

In a second step, this paper examines the link between sectoral gaps in TFP gains and economic growth ($C2$). Estimating TFP gains in the tradables and nontradables sectors for each country during continuous economic growth, I find that $C2$ does not hold in the data.

The BSH is not a universal property. Because a nation's TFP growth is not typically led by the tradables sector, economic growth is not typically accompanied by a real appreciation in

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[7] Harberger (1997) demonstrates that this so-called two-deflator method is as reliable as one of the most sophisticated methods of modern growth accounting established by Jorgenson and his co-authors, which cross-classifies factor and intermediate inputs in order to account for quality differences. See, for instance, Jorgenson and Stiroh (2000).

exchange rates. Some growth spurts are marked by equal TFP growth in both sectors, or even by higher TFP growth in the nontradables sector.

The reminder of this paper is structured as follows. Section II shows evidence to motivate this paper. Section III lays out the theoretical framework, and Section IV explains how the data are constructed. Section V econometrically tests *C*1 and examines *C*2. Section VI concludes.

II. Evidence

As motivation, this section provides evidence that casts doubt on the BSH. In particular, we examine the long-run trend in RERs during episodes of strong economic growth. If the BSH holds, we should find that RERs have appreciated during most of the cases.

Based on the data from *World Development Indicators*, 2002, 44 episodes of strong and continued real GDP growth are identified, where growth rates reach an annual rate of 4 percent or more for at least eight consecutive years. Growth rates of real GDP are allowed to be lower than 4 percent if (i) this occurs only for one period and (ii) following periods demonstrate strong growth momentum, such as several years of growth of more than 4 percent.[8]

RERs are defined as nominal exchange rates multiplied by the ratio of the international price of tradable goods to the domestic GDP deflator, in the spirit of tradable-nontradable real exchange rates.[9] RERs are

$$e_i = E_i \frac{p_{wT}}{P_i},$$

where E_i is nominal exchange rates, defined as the domestic currency per U.S. dollar, p_{wT} is the international price of tradable goods, expressed in terms of U.S. dollars, and P_i is the GDP deflator of country i.[10] The idea behind this specification is that RERs should not

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[8] Harberger (2003) implements a similar exercise, which looks for periods in which economic growth exceeds 5 percent per year over a period of at least one decade. So as not to count periods of huge spurts in GDP as secular growth, Harberger also insists that the initial and final years of the period should display growth rates of at least 4 percent. He finds 25 episodes of extended rapid growth.

[9] See Harberger (1989) and Calvo and Vegh (1991).

[10] The international price of tradable goods is estimated as a weighted average of WPI in France, Germany, Japan, the United Kingdom, and the United States, all expressed in terms of U.S. dollar. These are the five SDR countries defined by the IMF, and these countries are assumed to represent a large share of activities in international markets (Harberger, 1989). The most recent SDR weights are used for the estimation.

include the price of nontradable goods in the foreign countries because the latter does not affect how domestic markets adjust themselves to shocks. A fall in the value of RERs means a real appreciation.

Two sets of statistics are estimated to test the BSH. First, the following regression equation is estimated episode by episode:

$$\log(e_{it}) = \alpha_i + \beta_i \log(gdp_{it}) + \varepsilon_{it}, \tag{1}$$

where e_{it} is the level of RERs and gdp_{it} is the level of real GDP. *i* and *t* denote country and period. As another measure of the long-run trend of RERs, annual rates of change in RERs are also estimated. Because this exercise focuses on episodes of strong GDP growth, the BSH predicts that the dominant sign of β_i, as well as that of annual rates of change, should be negative; a real appreciation in exchange rates (lower e_{it}) should be associated with strong GDP growth (higher gdp_{it}).

The inability to find conclusive evidence to confirm a systematic link between strong economic growth and a real appreciation in exchange rates casts doubt on the BSH. Table 1 reports estimated values of β_i and rates of change in RERs. The frequency of these estimates are further summarized below, which demonstrates no dominance in signs; there are 19 positive and 25 negative β_i estimates when all observations are included, and 16 positive and 15 negative estimates when only significant observations are counted. With respect to rates of change, there are 21 positive and 23 negative observations.

Summary Statistics of Table 1

	Beta Coefficients		Changes in RERs
	All observations	Significant observations	All observations
Positive	19	16	21
Negative	25	15	23

Such findings provide the motivation to critically examine the BSH. In doing so, this paper examines *C*1 and *C*2 separately; the link between sectoral gaps in TFP gains and RERs (*C*1) is tested through econometric estimations, and the link between sectoral gaps in TFP gains and economic growth (*C*2) is examined.

III. Theoretical Framework

This section lays out two frameworks: the standard model of the BSH and a version of growth accounting for TFP estimations.

A. Balassa-Samuelson Hypothesis (BSH)

The mechanism of the BSH may be demonstrated on the basis of a two-sector model using Cobb-Douglas production technology with capital and labor inputs:

$$Y_{iTt} = A_{iTt} L^{\alpha}{}_{iTt} K^{1-\alpha}{}_{iTt} \tag{2}$$

$$Y_{iNt} = A_{iNt} L^{\beta}{}_{iNt} K^{1-\beta}{}_{iNt}\ , \tag{3}$$

where Y is value added, K is capital inputs, L is labor inputs, A is TFP, and T (or N) denotes the tradables (or nontradables) sector. i and t denote country and time. From profit maximization, it can be shown that the price of nontradable goods (p_N) in terms of the price of tradable goods (p_T=1) depends on gaps in TFP growth between the tradables and nontradables sectors:

$$d\log p_{iNt} = \frac{\beta}{\alpha} d\log A_{iTt} - d\log A_{iNt}\ . \tag{4}$$

At this stage, equation (4) illustrates the mechanism of $C1$. As a special case, the BSH refers to the situation where RERs appreciate ($d\log p_N > 0$) because the tradables sector is responsible for most of a nation's TFP growth ($d\log A_T > d\log A_N \approx 0$). Note that, because it is likely to be $(\beta/\alpha)>1$, the relative price of nontradable goods would increase even under balanced growth ($d\log A_T = d\log A_N$).

As an extension of equation (4), assume that there are three goods: exportable, importable, and nontradable goods. Only exportable and nontradable goods are assumed to be produced in domestic markets. The prices of exportable goods (p_E) and nontradable goods (p_N) are expressed in terms of the price of importable goods (p_M =1), and from profit maximization:

$$d\log p_{iNt} = \frac{\beta}{\alpha}(d\log A_{iEt} + d\log p_{iEt}) - d\log A_{iNt} \tag{5}$$

Equation (5) shows how p_E can significantly affect p_N in countries where primary commodities constitute a large share of exports through terms of trade shocks. In an effort to insulate our analysis from being driven by shocks to primary commodity markets, adjustments will be made for agriculture and mining in productivity estimations.[11]

[11] This is similar to Chen and Rogoff (2003).

The impact of changes in the relative price, p_N / p_T , on RERs can be estimated on the basis of the following disaggregation. Assume that the GDP deflator is a geometric average of p_T and p_N, $P = (p_N)^{\Lambda}(p_T)^{1-\Lambda}$; the log of RERs can be separated as follows:

$$\log e_{it} = \log(\frac{E_{it} \cdot p_{wTt}}{p_{iTt}}) + \Lambda \log(\frac{p_{iTt}}{p_{iNt}}), \tag{6}$$

where Λ is the volume share of value added in the nontradables sector. Hence, the log of RERs consists of two components: (i) $\log(E_{it} \cdot p_{wTt} / p_{iTt})$ and (ii) $\Lambda \log(p_{iTt} / p_{iNt})$.

If the second term is most responsible for movements in RERs in the long run, the first term in equation (6) may be replaced with a constant.[12] To focus on a systematic link in the long-run, I modify equation (6) as follows:

$$\log e_{it} = \varphi + \Lambda \log(\frac{p_{iTt}}{p_{iNt}}), \tag{7}$$

where φ is a constant.

Combined with equation (4), comparative statistics of RERs in equation (7) with respect to sectoral TFP in the home country are

$$e_{it} = f(\overset{-}{A}_{iTt}, \overset{+}{A}_{iNt}). \tag{8}$$

Thus, the link between RERs and gaps in TFP gains between the two sectors in the home country is consistent with $C1$; this relationship will be econometrically examined in Section V-A. The next task is to estimate sectoral productivity, A_T and A_N in equation (8).

B. TFP Estimation

As noted above, the construction of the TFP index is based on the concept of a growth-accounting method proposed by Harberger (1998), the so-called two-deflator method. The two deflators are the standard wage and the GDP deflator. The first deflator, the standard

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[12] Engel (1999) finds that a large share of the movements in RERs is accounted for by the tradable component. Similar results are found in my data by estimating the mean square error statistics as in Engel (1999). Such a finding, however, does not conflict with this paper's main results that the long-run trend in RERs is largely accounted for by the nontradable component.

wage, measures wages of low-skilled workers; this measure is incorporated into the estimation of standard labor, a version of the constant quality index for labor inputs.[13] With this conversion, workers with different skills can be expressed in the same units: one managing director is equivalent to ten junior economists, one senior economist is equivalent to five junior economists, and so on. After such conversions, all workers can be aggregated, since they are all expressed in the same standard labor units. Quality changes in labor inputs are, hence, fully imputed to labor contributions. The second deflator, the GDP deflator, is used to deflate all variables so that they are expressed in the same real GDP units. Changes in the composition of heterogeneous capital inputs are accounted for by estimating the return to capital in each period. In order to capture the impact of TFP gains perceived by final consumers, estimated TFP indices are further adjusted for the relative price of value added. Detailed descriptions of the two-deflator method can be found in Appendix I.[14] The TFP index constructed here is used only for the purpose of TFP comparisons over the period for a given country, and not for cross-country comparisons.

The TFP index proposed below incorporates the essence of the two-deflator method, as we do not assume any specific form of production function and simply start from an accounting relationship, $Y = wL + (\rho + \delta)K$ — that is, value added is exhausted between labor and capital inputs. After some manipulations, detailed in Appendix I, we obtain the following TFP index:

$$TFP_{ijt} = \frac{Y_{ijt}}{\overline{w}^{*} L^{*}_{ijt} + \overline{(\rho + \delta)} K_{ijt}}, \tag{9}$$

where Y_{ijt} is value added, L_{ijt}^{*} is standard labor, K_{ijt} is capital stock, ρ_{ijt} is the net return to capital, δ_{ijt} is the rates of depreciation, and i, j, and t denote country, industry, and period. $\overline{w}^{*}$ and $\overline{(\rho + \delta)}$ are both fixed weights estimated on the basis of the standard wage and the return to capital and rates of depreciation.

The TFP index is constructed for each country, for both the tradables and nontradables sectors. Nominal value added in the tradables and nontradables sectors is deflated by the price of value added in each sector. This is equivalent to first deflating by the GDP deflator,

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[13] Changes in labor quality are accounted for through the labor income-based approach, as opposed to the cost-based approach. The former approach assumes that wages equal to marginal product of labor and that wages capture the return on all investments in the formation of human capital. The latter approach uses years of education to capture human capital accumulation by assuming that the stock of human capital is linearly related to the number of years spent at school.

[14] See also Harberger (1998).

and then by the relative price of value added in terms of the GDP deflator in order to account for price adjustments.[15] All other variables are simply deflated by the GDP deflator.

IV. Data

Data availability remains a major constraint on the choice of sample countries. In this project, the data are acquired from data sets compiled by the OECD,[16] one of the few data sets available that contain all the necessary information for the estimation of TFP. The 15 sampled countries comprise Australia (AUS), Austria (AST), Belgium (BEL), Canada (CAN), Finland (FIN), France (FRA), Germany (DEU), Italy (ITA), Japan (JPN), Korea (KOR), the Netherlands (NDL), Norway (NOR), Sweden (SWE), the United Kingdom (UK), and the United States (US). Most of the data are collected for the period 1970–2000.

Most important, this paper focuses only on productive industries, and excludes public and personal services from the analysis. Such an exclusion is very important in determining this paper's main findings, and this paper is the first research to explicitly make such an exclusion.[17] Appendixes II and III depict the process of data construction.

V. Estimation Results

After a brief discussion about stationarity of the data, the link between sectoral gaps in TFP gains and RERs ($C1$) is tested on the basis of several econometric methods. First, the static OLS (SOLS) regressions are estimated country by country, using the time-series data both in levels and first differences. Because the main focus of this exercise is to test how TFP gains affect RERs in the long run, the data in levels are supposed to capture the relationships of interest. In contrast, the data in first differences are net of persistence, and are relevant to understand instantaneous responses. Second, the dynamic OLS (DOLS) regressions are estimated using the time-series data in levels for robustness checks.[18] For further robustness checks, level regressions are estimated in a panel framework. Finally, as the highlight of this paper, the BSH ($C1$+$C2$) is examined by focusing on the link between sectoral gaps in TFP gains and economic growth ($C2$).

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[15] While one may argue that quality differences in output should be accounted for, this paper does not make such adjustments. This is simply because, as it is not clear how quality differences in output can be adjusted, such adjustments would remain arbitrary at best.

[16] OECD STAN data.

[17] Such adjustments are consistent with the assumption of profit-maximizing firms.

[18] Chen and Rogoff (2003) use a similar set of regressions. They estimate several OLS using the data in levels and first differences. They consider alternative underlying data-generating processes, and estimate SOLS and DOLS as robustness checks.

A. Testing Link Between Sectoral Gaps in TFP Gains and RERs *(C1)*

Stationarity

Estimated results indicate that almost all country-wise time-series data contain unit roots in levels, while few remain so in first differences. In the Johansen test of the cointegrating relationship, the null hypothesis of no cointegration is rejected in only a small number of cases for level data.[19] Time-series data in levels are thus found to be nonstationary and not cointegrated, while the data in first differences are stationary. However, the level data are found to be stationary in a panel framework, perhaps due to the higher power of test.

Static OLS

SOLS are estimated with three different dependent variables: in addition to $\log(e_{it})$, its decomposed factors as in equation (6) — $\log(E_{it} \cdot p_{wTt} / p_{iTt})$ and $\Lambda \log(p_{iTt} / p_{iNt})$ — are regressed on measured TFP.

***Dependent variable: log*(e_{it})**

The data are used in terms of both levels and first differences. Regression equations are specified as follows :

$$\log(e_{it}) = \alpha_i + \beta_i \log(\frac{TFP_{iTt}}{TFP_{iNt}}) + \varepsilon_{it} \tag{10}$$

$$\log(e_{it}) = \alpha_i + \beta_i \log(TFP_{iTt}) + \gamma_i \log(TFP_{iNt}) + \varepsilon_{it} \,. \tag{11}$$

In equation (10), β_i is expected to be negative because RERs should appreciate (its value falls) as a result of higher productivity gains in the tradables sector. Equation (11) aims at

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[19] The tests are conducted as follows. The stationarity of the data is tested by the augmented Dickey-Fuller (ADF) test for the unit root. The ADF test uses the following equation:

$$\Delta y_t = \alpha x_t + \beta y_{t-1} + \sum \gamma_i \Delta y_{t-1} + \varepsilon_t \ ,$$

where x is a set of exogenous variables that consists of the trend and the intercept. The ADF test is conducted with one lag for the following six series: log(*e*), log(*E*pwT/pT*), Λlog(*pT/pN*), log(*TFP(T)/(TFP(N)*), log(*TFP(T)*) and log(*TFP(N)*). Almost all of the series are nonstationary in levels, but only some of them remain so in first differences. The cointegrating relationship is tested using the Johansen test, and the cointegrating relationship is found in only 15 percent of cases.

capturing the idea of $C1$ better, by separating the TFP ratio into two components, where β_i and γ_i are expected to be negative and positive, respectively.

Table 2 summarizes estimated results using SOLS on the basis of the three sets of dependent variables — $\log(e_{it})$, $\log(E_{it} \cdot p_{wTt} / p_{iTt})$, and $\Lambda \log(p_{iTt} / p_{iNt})$. Table 2 is separated in two parts, with Table 2a reporting results using $\log(TFP_{iTt}/TFP_{iNt})$ as independent variables and Table 2b with a set of [$\log(TFP_{iTt})$, $\log(TFP_{iNt})$] as independent variables. Regressions are estimated using the data both in levels and first differences.

The first row of Table 2a reports the results from equation (10) using the data in levels. Consistent with $C1$, negative coefficients dominate and are mostly significant at the 5 percent level. The first row of Table 2b shows that, on the basis of equation (11), the frequency of signs of coefficients is more or less consistent with what one would expect, while the dominance of signs is weak. In addition, the same two regression equations are estimated using the data in first differences. The second row of Table 2a and 2b shows that the frequency of signs is opposite to what was found on the basis of level data, with most estimates insignificant.

In order to examine the impact of TFP gains on different components of RERs, the latter are decomposed into tradables and nontradables components. Recall that equation (6) decomposed RERs as follows:

$$\log e_{it} = \log(\frac{E_{it} \cdot p_{wTt}}{p_{iTt}}) + \Lambda \log(\frac{p_{iTt}}{p_{iNt}})$$

In what follows, regressions are thus estimated with two different dependent variables: $\log(E_{it} \cdot p_{wTt} / p_{iTt})$ and $\Lambda \log(p_{iTt} / p_{iNt})$.

Dependent variable: log(** $E_{it} \cdot p_{wTt} / p_{iTt}$ **)

The first two specifications using this dependent variable are

$$\log(\frac{E_{it} \cdot p_{wTt}}{p_{iTt}}) = \alpha_i + \beta_i \log(\frac{TFP_{iTt}}{TFP_{iNt}}) + \varepsilon_{it} \tag{12}$$

$$\log(\frac{E_{it} \cdot p_{wTt}}{p_{iTt}}) = \alpha_i + \beta_i \log(TFP_{iTt}) + \gamma_i \log(TFP_{iNt}) + \varepsilon_{it}\,. \tag{13}$$

With respect to equations (12) and (13), there is no prior about how TFP_N should affect the left-hand side. Although p_T may fall when TFP_T increases, the way the whole

$\log(E_{it} \cdot p_{wTt} / p_{iTt})$ moves depends on the correlation between $E_{it} \cdot p_{wTt}$ and p_{iTt}. In theory, prices of tradable goods are supposed to be equalized in the world market, but this occurs infrequently in reality due to many impediments. Hence, $E_{it} \cdot p_{wTt}$ and p_{iTt} are expected to move together, with correlation coefficients smaller than unity.[20]

The second row in Table 2a and 2b reports that, using the data in levels on the basis of equation (12) or (13), productivity gains do not systematically affect the left-hand side in the long run: p_{iTt} may be affected by TFP_T, but the impact is blurred, perhaps due to a high degree of co movements between $E_{it} \cdot p_{wTt}$ and p_{iTt}. When data are used in first differences, TFP_T exhibits positive but weak relationships with $\log(E_{it} \cdot p_{wTt} / p_{iTt})$, which is consistent with the initial conjecture: p_{iTt} is somewhat affected by TFP_T, and such a link becomes pronounced because of a decreased degree of co movements between $E_{it} \cdot p_{wTt}$ and p_{iTt}.

Dependent variable: Λlog (p_{iTt} / p_{iNt})

Finally, this dependent variable is regressed on the same measured TFP:

$$\Lambda \log(\frac{p_{iTt}}{p_{iNt}}) = \alpha_i + \beta_i \log(\frac{TFP_{iTt}}{TFP_{iNt}}) + \varepsilon_{it} \tag{14}$$

$$\Lambda \log(\frac{p_{iTt}}{p_{iNt}}) = \alpha_i + \beta_i \log(TFP_{iTt}) + \gamma_i \log(TFP_{iNt}) + \varepsilon_{it}. \tag{15}$$

Compared with equations (10) and (11), the dependent variable for both of which is $\log(e_{it})$, equations (14) and (15) are supposed to test $C1$ more explicitly by focusing on the relative price. In terms of coefficients, because p_T (or p_N) is expected to fall when TFP_T (or TFP_N) increases, the signs for β and γ are expected to be negative and positive, respectively.

The findings here suggest that domestic prices of nontradable goods in tradable goods move in the way that $C1$ predicts. The third row in Table 2a and 2b shows that, on the basis of level data, the frequency of signs is consistent with the prior, as in post cases β and γ are negative and positive, respectively, and significant. The frequency of signs remains similar even with the data in first differences, though with fewer significant observations.

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[20] Based on data for 14 OECD countries, correlation coefficients of these variables are mostly clustered around 0.9 in levels and around 0.3 in first differences. Hence, in equations (19) and (20), β is expected to be positive, especially using the data in first differences. There is no prior in terms of the sign of γ.

Dynamic OLS

The OLS regressions yield consistent estimates when the data are cointegrated. In this case, the DOLS regressions, with leads and lags of independent variables in first differences, make the estimates more efficient than the SOLS.[21] The DOLS are

$$q_t = \mu + \varphi z_t + \varsigma \Delta z_{t+1} \delta \Delta z_t + \varepsilon_t , \tag{16}$$

where z is the independent variables, q is the dependent variables, and $\Delta z_t = z_t - z_{t-1}$. Although the data are mostly not integrated, the DOLS regressions are estimated for equations (10), (11), and (12)–(15), with one lead and lag, using only the data in levels for robustness checks.

The first row in Table 3a and 3b shows that, when $\log(e_{it})$ is regressed on measured *TFP* as in equation (10) and (11), the estimated results support $C1$ better than do the SOLS results: the coefficients on the TFP ratio are largely negative and significant. When measured TFP is separated in the tradables and nontradables sectors, the negative (positive) link between TFP growth in the tradables (nontradables) sector and RERs is even more articulated.

The second row of Table 3a and 3b shows a lack of dominance in the frequency of signs when $\log(E_{it} \cdot p_{wTt} / p_{iTt})$ is regressed on measured TFP as in equations (19) and (20). While the number of significant estimates increases slightly, compared with the SOLS results, the overall picture remains unchanged.

Finally, the third row reports that, when $\Lambda \log(p_{iTt} / p_{iNt})$ is regressed on measured productivity, as in equations (14) and (15), the results remain virtually unchanged from the SOLS results strongly supporting $C1$.

Panel Data

For further robustness checks, we estimate regressions in a panel framework in which the data are constructed on the basis of the country-wise time series data. First, Table 4a shows that the data become stationary,[22] perhaps because the power of the test increases by pooling the data. Second, the OLS regressions are estimated in a panel framework in levels with fixed effects for countries. Table 4b shows that the estimated coefficients on measured TFP have the expected signs with high significance, confirming the results of the time-series regressions in the previous subsection.

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[21] Dynamic OLS (DOLS) were proposed by Stock and Watson (1993). Besides Chen and Rogoff (2003), Lee and Tang (2003), for instance, also use the DOLS in an effort to increase efficiency.

[22] The unit root null is rejected for all series at least at the 10 percent level.

B. Examining Link Between Sectoral Gaps in TFP Gains and Economic Growth *(C2)*

This subsection compares sectoral TFP gains during periods of continuous economic growth for each country. To examine *C*2, periods are chosen during which GDP grew continuously with few breaks. Therefore, given that C*1* holds, for the BSH (C*1*+C*2*) to hold, TFP gains in the tradable sector should systematically be higher than those in the nontradable sector across countries.

Figure 1 depicts the results by sorting the countries according to gaps in TFP growth between the tradables and nontradables sectors moving from the largest on the left to the smallest on the right. The figure reveals the lack of a systematic link between sectoral gaps in TFP gains and economic growth.[23] For instance, for NOR, which is located on the right end, the nontradables sector performs the best relative to the tradables sector in terms of estimated rates of productivity growth. The BSH is not consistent with the data. Although the BSH predicts a concentration of TFP gains in the tradables sector across all countries, this prediction holds only in eight out of fifteen countries: TFP gains in the tradables sector are larger in three countries, and meaningfully so in five countries. For the remaining seven countries, the prediction does not hold: TFP gains are relatively higher in the nontradables sector in four countries, and meaningfully so in two countries. TFP gains are balanced in the two sectors in only one country, France.

Such findings, however, are driven by the exclusion of nonproductive industries from the analysis. At the initial stage, where the data were not adjusted for nonproductive industries, estimated TFP gains were found to be more or less concentrated in the tradables sector across countries consistent with the BSH.

This paper's finding is robust to conditioning the results to initial GDP levels: the sectoral concentration in TFP gains is not systematically linked to initial GDP levels. To see this, Table 6 sorts countries in ascending order according to GDP per capita in 1970 and 1975, expressed relative to the United States. The first set of estimates are converted to U.S. dollars by period-average market exchange rates. Among the countries in which TFP gains are larger in the nontradables sector (marked *N* in the table) GDP per capita in 1970 is low for AUS, the UK, and DEU, while high for NOR, CAN, and US. The findings remain unchanged when the estimates are converted by PPP, as in the second set of estimates.

Evidence abounds of relatively large productivity gains in the nontradables sector in OECD countries. According to an official report, the wholesale, and finance and insurance sectors in Australia were the major contributors to the 1990s productivity acceleration, particularly during the 1993–94 to 1998–99 productivity cycles, and remained so during 2002–03 though to a lesser degree.[24] In Norway, productivity growth in the manufacturing sector is reported

[23] Table 5 summarizes measured TFP gains in the two sectors and estimation periods for each country. The sample includes US. *T* and *NT* stand for the tradables and nontradables sectors, respectively, and rates of growth are in terms of average per annum.

[24] Australian Government Productivity Commission (2004).

to be lower than that in the services sector, which can be explained partly by the protection of some segments of the manufacturing sector from foreign competition.[25] In the United States, it is argued that TFP growth can be traced in substantial part to information technology industries, which produce computers, semiconductors, and other high-tech gear. The evidence is equally clear in computer-using industries in the United States such as the finance, insurance, and real estate sectors. Moreover, the trade sector in the United States is responsible for almost 20 percent of aggregate TFP growth during the period 1958–96.[26]

VI. Final Remark

This paper was motivated by previous literature that had cast doubt on the time-honored Balassa-Samuelson hypothesis (BSH). It quantitatively demonstrates that the BSH ($C1+C2$) is not the rule that applies to most episodes of strong economic growth. This is because, though I found a systematic link between sectoral TFP gains and RERs ($C1$), I did not find a systematic link between sectoral gaps in TFP gains and economic growth ($C2$). This paper is the first work to examine $C2$ as an independent assumption.

Perhaps because of the predictions of the BSH, economic growth tends to be associated with TFP growth in the tradables sector. However, some growth spurts are marked by equal TFP growth in both sectors and others, by higher TFP growth in the nontradables sector. Although the data for TFP estimations and regression analysis are limited to the OECD countries in this paper, these findings have particular relevance, since different kinds of growth have differing predictions for the response of external sectors. In particular, these findings confirm what Harberger (2003) stresses after demonstrating a lack of systematic link between GDP growth and a real appreciation in exchange rates: "This observation should be enough to make economists and policymakers very cautious about assuming a natural connection between the long-term movements of GDP on the one hand and the real exchange rate on the other."

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[25] Høj and Wise (2004).

[26] Jorgenson and Stiroh (2000).

I. TFP Estimations

This appendix first explains the mechanism of a method of growth accounting proposed by Harberger (1998), the two-deflator method, which was originally developed to estimate TFP growth. In a second step, we show how the TFP index is constructed on the basis of the two-deflator method.

A. TFP Growth

The two-deflator method starts from an accounting relationship, $Y = wL + (\rho + \delta)K$. Labor inputs are measured in the standard labor units by estimating the ratio of the wage bill to the standard wage:

$$L^* = \frac{wL}{w^*}.$$

This relationship can be justified as follows. $L^{k*}{}_{ijt}$, the k th labor of country i and industry j expressed in terms of standard labor units, is the ratio of $w^k{}_{ijt}$, the wage of the k th worker, to $w^*{}_{it}$, the standard wage:

$$L^{k*}{}_{ijt} = \frac{w^k{}_{ijt}}{w^*{}_{it}}.$$

Standard labor can be aggregated over all types of labor k:

$$\sum_k L^{k*}{}_{ijt} = \sum_k \frac{w^k{}_{ijt}}{w^*{}_{it}}.$$

Using the equivalence $\sum_k w^k{}_{ijt} = w_{ijt} L_{ijt}$,

$$\sum_k L^{k*}{}_{ijt} = \frac{w_{ijt} L_{ijt}}{w^*{}_{it}}.$$

Hence, the total number of $L^*{}_t$ for industry j is given by

$$L^*{}_{ijt} = \frac{w_{ijt} L_{ijt}}{w^*{}_{it}}.$$

In this framework, we can effectively account for each individual worker's quality even within one industry. Now, from the accounting relationship and the definition of standard labor,

$$Y = w^* L^* + (\rho + \delta) K .$$

The above equation, expressed in changes with respect to inputs and divide all terms by Y, yields

$$\frac{dY_{ijt}}{Y_{ijt}} = \frac{w_{it}^{\ *} dL_{ijt}^{\ *}}{Y_{ijt}} + \frac{(\rho_{ijt} + \delta_{ijt}) dK_{ijt}}{Y_{ijt}},$$

where Y_{ijt} is GDP, $w_{it}^{\ *}$ is the standard wage, $L_{ijt}^{\ *}$ is standard labor, K_{ijt} is capital stock, ρ_{ijt} is the net return to capital, δ_{ijt} is the rates of depreciation, and i, j, and t denote country, industry, and period. Note that the standard wage is within a country (no j subscript). TFP growth can be estimated by using the prices in the period before $w_{it-1}^{\ *}$ and $(\rho_{ijt-1} + \delta_{ijt-1})$:

$$\frac{dY_{ijt}}{Y_{ijt}} = \frac{w_{it-1}^{\ *} dL_{ijt}^{\ *}}{Y_{ijt}} + \frac{(\rho_{ijt-1} + \delta_{ijt-1}) dK_{ijt}}{Y_{ijt}} + dTFP_{ijt} .$$

By rearranging, we obtain

$$dTFP_{ijt} = \frac{dY_{ijt}}{Y_{ijt}} - \underbrace{\frac{w_{it-1}^{\ *} dL_{ijt}^{\ *}}{Y_{ijt}}}_{\text{Labor contributions}} - \underbrace{\frac{(\rho_{ijt-1} + \delta_{ijt-1}) dK_{ijt}}{Y_{ijt}}}_{\text{Capital contributions}} .$$

For the industry-level productivity estimation, the relative price of value added for industry j needs to be accounted for as follows:

$$dTFP_{ijt} - \frac{dp_{ijt}}{p_{ijt}} = \frac{dy_{ijt}}{y_{ijt}} - \frac{w_{it-1}^{\ *} dL_{ijt}^{\ *}}{Y_{ijt}} - \frac{(\rho_{ijt-1} + \delta_{ijt-1}) dK_{ijt}}{Y_{ijt}},$$

where p_{ijt} is the price of value added for industry j relative to the GDP deflator of country i, and y_{ijt} is the quantity of value added for industry j.

B. TFP Levels

TFP levels are estimated based on the following formula:

$$TFP_{ijt} = \frac{Y_{ijt}}{\overline{w}^{*}{}_{i} L^{*}{}_{ijt} + \overline{(\rho + \delta)}_{i} K_{ijt}},$$

where $\overline{w}^*$ and $\overline{(\rho+\delta)}$ are both fixed weights estimated on the basis of the standard wage and the return to capital and rates of depreciation. As L^* is measured in units of standard labor, it is appropriate to weight it by fixed weights estimated using the standard wage. To estimate such weights, recall that the standard wage in country i for t = 1 .. S is denoted as follows:

$$(w^*_{i1},\ w^*_{i2},\ ...,\ w^*_{iS}).$$

Some weights common across sectors and time within country i need to be estimated based on this set of the standard wage. As one alternative, we take the average over the first three years:

$$\overline{w^*}_i = \frac{1}{3}\sum_{t=1}^{3} w_{it}^* .$$

Labor inputs in standard labor units of the tradables and nontradables sectors in country i for time $t = 1,..,S$ are

$$(L^*_{iT1},\ L^*_{iT2},\ ...,\ L^*_{iTS})$$
$$(L^*_{iN1},\ L^*_{iN2},\ ...,\ L^*_{iNS}).$$

Using the weights estimated above, $\overline{w}^*_i$, we obtain

$$(\overline{w^*}_i L^*_{iT1},\ \overline{w^*}_i L^*_{iT2},\ ...,\overline{w^*}_i L^*_{iTS})$$
$$(\overline{w^*}_i L^*_{iN1},\overline{w^*}_i L^*_{iN2},\ ...,\overline{w^*}_i L^*_{iNS}).$$

As for the weights for capital inputs $\overline{(\rho+\delta)}_i$, the return to capital for the economy as a whole is averaged over all periods:

$$\overline{(\rho+\delta)}_i = \frac{1}{T}\sum_{t=1}^{T}(\rho+\delta)_{it} .$$

Real capital stock in all industries is weighted by a constant $\overline{(\rho+\delta)}_i$:

$$(\overline{(\rho+\delta)}_i K_{iT1},\ \overline{(\rho+\delta)}_i K_{iT2},\ ...,\ \overline{(\rho+\delta)}_i K_{iTS})$$
$$(\overline{(\rho+\delta)}_i K_{iN1},\ \overline{(\rho+\delta)}_i K_{iN2},\ ...,\ \overline{(\rho+\delta)}_i K_{iNS}).$$

Thus, TFP levels are estimated by combining the real value added and factor inputs estimated above.

II. Capital Stock, Standard Wages, and Other Adjustments

Capital stock is constructed using the perpetual inventory method:

$$K_{t+1} = (1-\delta)K_t + I_t,$$

where I_t is investment in period t. Rates of depreciation are assumed to be 7 percent across the countries throughout periods. The initial capital stock is estimated by

$$K_1 = \frac{I_1}{(\lambda+\delta)},$$

where λ is the growth rate of real GDP specific to each country. This representation assumes that capital stock at the steady states grows at the same rate as the economy as a whole.

Value added is reduced by some fraction in order to account for the fact that it includes the return on land, while investment — and, hence, capital stock — does not. One of my dissertation chapters includes extensive estimations in this regard for the United States, and such estimated figures are assumed to be applicable to the OECD countries sampled in this paper. The fraction of value added reduced is 30 percent for agriculture; 10 percent for mining; 5 percent for manufacturing, electricity, trade, and telecommunications; and 2 percent for construction, finance, and government.

The standard wage is approximated by textile worker wages in each country. These wages are a good proxy of the standard wage for purposes of international comparison because textile workers are low skilled and homogenous across countries in terms of capacity. An alternative may be to use two-thirds of GDP per capita, which was done in my previous work due to data limitations. Mulligan and Sala-i-Martin (1997 and 2000) also use the labor income-based approach in their estimations of human capital. They estimate wages of zero-schooling workers, which is the counterpart of the standard wage used in this paper. A good measure of the standard wage should be able to maintain its standard profile over time. In this regard, textile worker wages appear to be superior to two-thirds of GDP per capita, and it is not clear whether the zero-schooling workers in Mulligan and Sala-i-Martin maintain the standard profile throughout the periods of analysis.

III. Industry Classifications

Industries in each country need to be classified into the tradables and nontradables sectors. The rule of thumb appears to be to classify agriculture, mining, and manufacturing into the tradables sector, and the rest into the nontradables sector. However, there are exceptional cases, such as agriculture for Japan, the products of which are tradable but not traded due to protection. In this particular case, agriculture and mining in Japan are included in the nontradables sector.[27] Mining in BEL, FRA, and NDL were excluded from this exercise due to data limitations.

In AUS, FIN, and NOR, primary commodities constitute a significant share of exports: agriculture, forestry, and mining products for AUS, forestry products for FIN, and oil for NOR. Based on equation (5), to keep this paper's analysis from being driven by shocks to primary commodity markets, the following sectors are excluded from the analysis: agriculture and mining for AUS, agriculture for FIN, and mining for NOR.

TFP growth in public and personal services is assumed to be zero. In practice, the data for the nontradables sector are first estimated by subtracting the tradables sector from the economy as a whole. To estimate TFP for the productive nontradables sector, TFP growth of public and private services is assumed to be zero.

[27] While one may argue that agriculture in Europe is equally protected and subsidized, it is included in the tradable sector. In the literature, few adjustments at all seem to have been made to account for protection, and the tradables (*T*) and nontradables (*N*) sectors are defined simply as follows. In Balassa (1964), *T* = agriculture and manufacturing and *NT* = services. Officer (1976a) defines *T* = agriculture, mining, and manufacturing and *N* = other sectors. Hsieh (1982) sets *T* = manufacturing and *N* = other sectors. De Gregorio, Giovannini, and Wolf (1994), De Gregorio and Wolf (1994), and Chinn (1997) define *T* = agriculture, mining, manufacturing, and transportation and *N* = other sectors. In Ito, Isard, and Symansky (1997), *T* = manufacturing and *N* = services. Canzoneri, Cumby, and Diba (1996) set *T* = agriculture and manufacturing and *N* = more or less other sectors.

Table 1. Long-Term Trends in Real Exchange Rates (RERs)

	Country	Start	End	Real GDP Growth (In percent)	Beta Coefficients[1/]	Changes in RERs (In percent)
1	Austria	1963	1974	4.61	-0.5464 **	-0.74
2	Bahamas, The	1961	1969	9.85	-0.1674 **	-3.92
3	Bhutan	1981	2000	6.89	0.5203 **	0.92
4	Botswana	1961	1992	10.82	0.0435 **	-0.18
5	Brazil	1966	1980	8.23	-0.1030 *	-0.53
6	Chile	1984	1998	7.39	-0.1423	0.10
7	China	1977	2000	9.01	0.5389 **	3.21
8	Colombia	1964	1974	5.91	0.5457 **	0.37
9	Congo, Rep. of	1968	1975	7.72	0.0357	0.05
10	Costa Rica	1962	1979	6.53	-0.0055	0.08
11	Côte d'Ivoire	1966	1978	8.57	-0.1840 *	-0.29
12	Dominican Republic	1969	1981	7.84	0.2110 **	0.78
13	Ecuador	1970	1981	8.28	-0.1503	-0.31
14	Equatorial Guinea	1992	2000	22.68	-0.2155 **	-0.82
15	France	1961	1974	5.24	-0.2738 **	-0.45
16	Gabon	1961	1976	11.76	-0.3736	-0.53
17	Greece	1961	1979	6.36	-0.1538 **	-0.20
18	Guatemala	1961	1980	5.58	0.2087 **	0.95
19	India	1977	2000	5.28	0.5346 **	0.62
20	Indonesia	1968	1997	7.39	0.1197 *	-0.01
21	Japan	1961	1973	9.65	-0.4092 **	-0.67
22	Korea, Rep. of	1963	2000	7.80	-0.3488 **	-0.25
23	Lao PDR	1989	2000	6.96	-0.1357	-0.18
24	Malaysia	1961	1984	7.08	0.0831 **	0.91
25	Malaysia	1987	2000	7.41	-0.0070	-0.02

Table 1. Long-Term Trends in Real Exchange Rates (RERs)

	Country	Start	End	Real GDP Growth (In percent)	Beta Coefficients 1/	Changes in RERs (In percent)
26	Maldives	1985	2000	8.86	-0.1238	-0.02
27	Malta	1965	1981	9.48	0.4254 **	1.51
28	Mauritius	1981	2000	5.68	-0.1489 **	0.10
29	Mexico	1961	1981	6.80	-0.1259 **	-0.92
30	Myanmar	1974	1984	5.67	0.8926 **	1.45
31	Pakistan	1961	1970	7.22	-0.2427 **	-0.67
32	Pakistan	1973	1992	6.09	0.3481 **	0.66
33	Panama	1961	1973	7.58	0.1006 *	9.45
34	Papua New Guinea	1961	1973	6.69	-0.4483	-15.49
35	Paraguay	1967	1981	7.85	-0.1127 *	-0.35
36	Philippines	1961	1981	5.32	0.4629 **	1.23
37	Portugal	1961	1973	6.87	-0.2720 **	-0.26
38	Saudi Arabia	1961	1980	10.26	-0.8359 **	-9.69
39	Singapore	1965	1984	9.95	-0.0098	-0.41
40	Spain	1961	1974	7.15	-0.4985 **	-0.53
41	Sri Lanka	1973	1986	5.17	1.1047 **	1.28
42	Thailand	1961	1996	7.72	0.0954 **	0.03
43	Uganda	1987	2000	6.46	0.2691	0.59
44	Vietnam	1987	2000	6.83	0.4423	0.94

Source: *World Bank, World Development Indicators.*

1/ Beta coefficients above represent β_i in the database following regression

$$\log(e_{it}) = \alpha_i + \beta_i \log(gdp_{it}) + \varepsilon_{it},$$

while changes in RERs are annual rates of change in RERs averaged over the periods indicated in the columns “Start” and “End.”

Table 2. Frequency of Signs: SOLS[1/]

2a. $\log(e_{it}) = \alpha_i + \beta_i \log(TFP_{iTt}/TFP_{iNt}) + \varepsilon_{it}$

Dependent Variable		SOLS Beta (+)	SOLS Beta (-)
$\log(e_{it})$	Levels	2 (2)	12 (10)
	1st Diff.	9 (9)	5 (2)
$\log(E_{it} \cdot p_{wTt}/p_{tTt})$	Levels	8 (1)	6 (2)
	1st Diff.	11 (4)	3 (1)
$\Lambda \log(p_{iTt}/p_{iNt})$	Levels	0 (0)	14 (13)
	1st Diff.	1 (1)	13 (9)

2b. $\log(e_{it}) = \alpha_i + \beta_i \log(TFP_{iTt}) + \gamma_i \log(TFP_{iNt}) + \varepsilon_{it}$

Dependent Variable		SOLS Beta (+)	SOLS Beta (-)	SOLS Gamma (+)	SOLS Gamma (-)
$\log(e_{it})$	Levels	4 (4)	10 (3)	8 (4)	6 (1)
	1st Diff.	9 (9)	5 (2)	4 (1)	10 (1)
$\log(E_{it} \cdot p_{wTt}/p_{tTt})$	Levels	8 (1)	6 (2)	5 (1)	9 (3)
	1st Diff.	11 (1)	3 (1)	4 (0)	10 (1)
$\Lambda \log(p_{iTt}/p_{iNt})$	Levels	1 (1)	13 (11)	13 (9)	1 (1)
	1st Diff.	1 (0)	13 (8)	10 (5)	4 (0)

1/ Figures in parentheses represent observations significant at the 5 percent level.

Table 3. Frequency of Signs: DOLS[1/]
(1 lead, 1 lag)

3a. $\log(e_{it}) = \alpha_i + \beta_i \log(TFP_{iTt}/TFP_{iNt}) + [1lead, 1lag] + \varepsilon_{it}$

Dependent Variable		DOLS	
		Beta (+)	Beta (-)
$\log(e_{it})$	Levels	1 (1)	13 (11)
$\log(E_{it} \cdot p_{wTt} / p_{iTt})$	Levels	7 (12)	7 (4)
$\Lambda \log(p_{iTt} / p_{iNt})$	Levels	0 (0)	14 (13)

3b. $\log(e_{it}) = \alpha_i + \beta_i \log(TFP_{iTt}) + \gamma_i \log(TFP_{iNt}) + [1lead, 1lag] + \varepsilon_{it}$

Dependent Variable		DOLS			
		Beta (+)	Beta (-)	Gamma (+)	Gamma (-)
$\log(e_{it})$	Levels	5 (5)	9 (8)	10 (7)	4 (3)
$\log(E_{it} \cdot p_{wTt} / p_{iTt})$	Levels	6 (5)	8 (4)	7 (3)	7 (4)
$\Lambda \log(p_{iTt} / p_{iNt})$	Levels	1 (1)	13 (11)	13 (11)	1 (1)

1/ Figures in parentheses represent observations significant at the 5 percent level. Coefficients n the lead and lag are not reported.

Table 4. Panel Data Regressions

4a. Unit Root Test[1/]

$\log(e_{it})$	$\log(E_{it} \cdot p_{wTt} / p_{iTt})$	$\Lambda \log(p_{iTt} / p_{iNt})$	$\log(TFP_T / TFP_N)$	$\log(TFP_T)$	$\log(TFP_N)$
-5.4227	-6.3374	-3.6523	-3.3972	-5.1112	-4.5163
1%	1%	5%	10%	1%	1%

Critical Values

1%	5%	10%
-3.9850	-3.4228	-3.1340

1/ The unit root null is rejected for all series at the significance level indicated below the test statistics.

4b. Regressions[1/]

Independent Variables		Dependent Variables: $\log(e_{it})$		$\log(E_{it} \cdot p_{wTt} / p_{iTt})$		$\Lambda \log(p_{iTt} / p_{iNt})$	
$\log(TFP_T / TFP_N)$	coeff.	-0.628 **		0.057		-0.671 **	
	std.	0.057		0.046		0.029	
$\log(TFP_T)$	coeff.		-0.727**		0.019		-0.733 **
	std.		0.051		0.046		0.022
$\log(TFP_N)$	coeff.		0.285**		-0.143**		0.435 **
	std.		0.067		0.060		0.029
Adj. R^2		0.558	0.642	0.432	0.440	0.847	0.908

1/ Regressions are estimated with country-fixed effects (coefficients are not reported).

Table 5. Sectoral TFP Growth
(In Percent)

Country [1/]	TFP Growth [2/]		Periods	
	T	NT	Start	End
AST	1.63	0.54	1970	1999
AUS	1.12	1.49	1970	2000
BEL	2	1.65	1970	2000
CAN	0.78	2.14	1970	1999
DEU	1.93	2.17	1970	1990
FIN	2.4	1.09	1970	1991
FRA	2.63	2.62	1970	2000
ITA	1.64	1.35	1970	1999
JPN	3.98	1.94	1970	1991
KOR	1.74	-1.18	1970	1997
NDL	2.38	1.81	1970	2000
NOR	0.44	1.95	1970	1998
SWE	2.27	0.85	1980	1999
UK	1.39	1.89	1970	1999
US	0.46	0.66	1970	2000

1/ Estimated values of the annual rate of TFP growth, an average over periods, are reported for the tradables and nontradables sectors.
2/ Australia (AUS), Austria (AST), Belgium (BEL), Canada (CAN), Finland (FIN), France (FRA), Germany (DEU), Italy (ITA), Japan (JPN), Korea (KOR), the Netherlands (NDL), Norway (NOR), Sweden (SWE), the United Kingdom (UK), and the United States (US).

Table 6. GDP per Capita as Initial Conditions and Sectoral TFP Growth
(In ratio relative to the United States: *US* = 1)

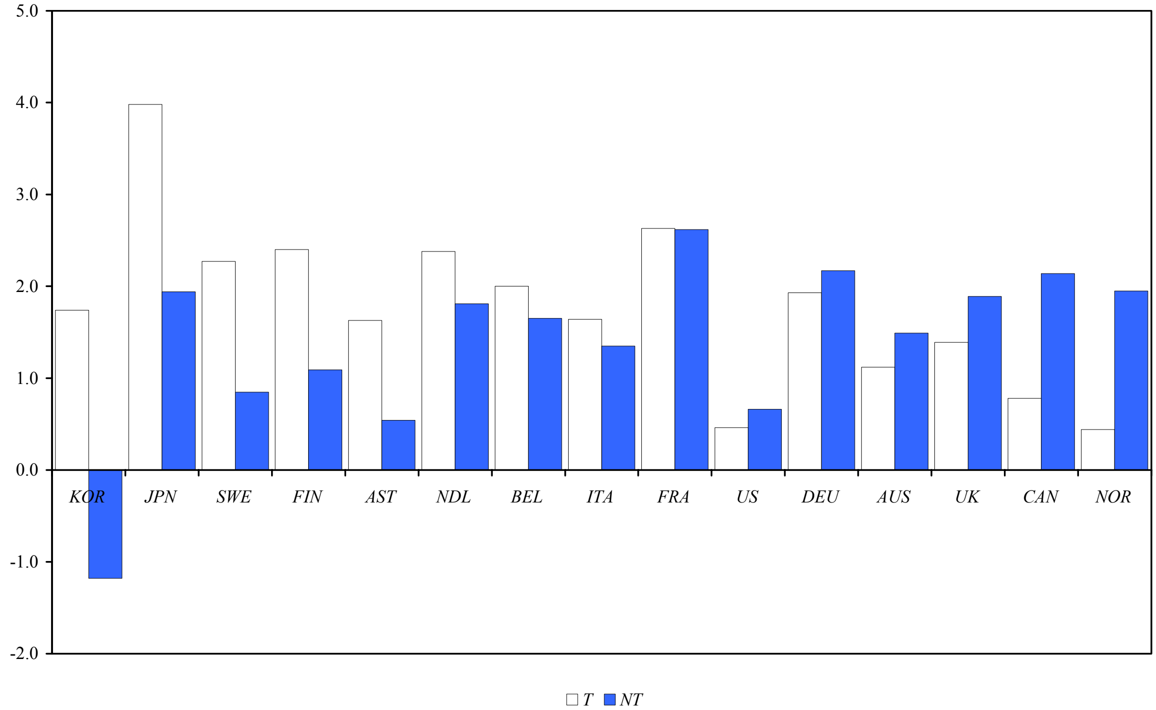
Using Market Exchange Rates in 1970 [1/]			Using Purchasing Power Parity in 1975 [1/]		
Country [2/]	Sector	GDP per Capita relative to *US*	Country [2/]	Sector	GDP per Capita relative to *US*
KOR	*T*	0.05	KOR	*T*	0.27
JPN	*T*	0.40	ITA	*T*	0.89
ITA	*T*	0.40	**NOR**	***N***	**0.92**
AUS	***N***	**0.40**	FIN	*T*	0.93
UK	***N***	**0.44**	JPN	*T*	0.94
DEU	***N***	**0.47**	**DEU**	***N***	**0.99**
FIN	*T*	0.48	**US**	***N***	**1.00**
BEL	*T*	0.53	AST	*T*	1.01
NDL	*T*	0.54	**FRA**	**-**	**1.01**
FRA	**-**	**0.58**	**AUS**	***N***	**1.01**
AST	*T*	0.66	NDL	*T*	1.05
NOR	***N***	**0.66**	BEL	*T*	1.06
CAN	***N***	**0.80**	**UK**	***N***	**1.08**
SWE	*T*	0.86	**CAN**	***N***	**1.16**
US	***N***	**1.00**	SWE	*T*	1.29

Sources: World Bank, World Development Indicators, IMF, International Financial Statistics, and the author's estimation.

1/ GDP per capita is first estimated in U.S. dollar terms and then expressed relative to the United States. Both market exchange rates (period averages) and PPP are used to convert local currencies to U.S. dollars. T or N denotes the sector for which

2/ Australia (AUS), Austria (AST), Belgium (BEL), Canada (CAN), Finland (FIN), France (FRA), Germany (DEU), Italy (ITA), Japan (JPN), Korea (KOR), the Netherlands (NDL), Norway (NOR), Sweden (SWE), the United Kingdom (UK), and the United States (US).

Figure 1. Growth Rates of Sectoral TFP[1/2/]
(In percent)



Sources: OECD STAN, the author's estimation.
1/: Estimated values of the annual rate of TFP growth reported in Table 5 are presented. Countries are sorted from left to right according to gaps in sectoral TFP growth. Such gaps are the largest in favor of the tradables sector for KOR located on the left end, and the smallest for NOR, located on the right end.
2/: Australia (AUS), Austria (AST), Belgium (BEL), Canada (CAN), Finland (FIN), France (FRA), Germany (DEU), Italy (ITA), Japan (JPN), Korea (KOR), the Netherlands (NDL), Norway (NOR), Sweden (SWE), the United Kingdom (UK), and the United States (US).

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