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Does Productivity Growth Lead to Appreciation of the Real Exchange Rate?

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Does Productivity Growth Lead to Appreciation of the Real Exchange Rate?

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Abstract

We revisit the time-honored link between productivity and the real exchange rate. Consistent with the traditional view, we find that higher labor productivity tends to lead to appreciation of the real exchange rate. Contrary to the traditional view, however, we find that the positive productivity effect is transmitted through the real exchange rate based on tradable prices, rather than through relative prices between tradables and nontradables. Moreover, higher total factor productivity is found, if anything, to lead to depreciation of the real exchange rate. These last two pieces of evidence provide support for the emerging view that limited tradability of goods and services provides scope for the strategic pricing decision, which has material consequences for the aggregate real exchange rate.

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I. Introduction

While the effect of monetary and financial fundamentals on the exchange rate continues to remain an elusive topic for research, the effect of productivity on the real exchange rate has long been viewed as a reasonably stable axis, at least in the long run. A rise in the relative productivity of the tradable sector leads to an increase in the relative price of nontradables, which will contribute to real appreciation. Combined with the conventional wisdom that productivity growth in tradables drives aggregate productivity growth, it is often said that productivity growth leads to real appreciation.

Since the link between (tradable) productivity and the real exchange rate—often traced back to Harrod (1939)—was formulated by Samuelson (1964) and Balassa (1964), this celebrated Harrod-Balassa-Samuelson (HBS) effect has formed the cornerstone of the theory of real exchange rate determination. In textbooks, Obstfeld and Rogoff (1996) introduce relative productivity as the first determinant of the real exchange rate beyond purchasing power parity (PPP). In academic literature, numerous papers have built on the real exchange rate defined as and measured by the relative price between nontradables and tradables. In financial markets, for example, the exchange rate model of Goldman Sachs takes relative productivity as the core determinant of the equilibrium exchange rate (Goldman Sachs, 2002).

The relevant literature has also been marked by voluminous empirical research. Earlier papers include the original paper of Balassa (1964), and those of Officer (1976), Hsiesh (1982), and Marston (1987). They relied either on cross-section data (Balassa and Officer) or time-series data for a handful of countries (Hsiesh and Marston). More recently, several studies have used a panel that comprised decades of data for Organization for Economic Cooperation and Development (OECD) countries. On a positive note, De Gregio and others (1994) and Canzoneri and others (1999) provided a renewed support for the time-honored HBS effect. Consistent with the prediction of the HBS effect, both studies confirmed a positive association between the relative price between nontradable and tradable sectors and the relative productivity between tradable and nontradable sectors.

However, the support provided in recent years was accompanied by evidence that called for substantive qualifications of the original thesis. Examining the real exchange rates in Asia Pacficic Economic Cooperation (APEC) countries, Isard and Symansky (1996) observed that exchange rate fluctuations in the past three decades have largely been driven by movements in the cross-country ratios of tradables prices. This casts a shadow over an implicit presumption behind the HBS effect— namely, that purchasing power parity held for tradables prices between countries. This finding was echoed in Canzoneri, Cumby, and Diba (1999), who, while confirming the positive association between relative productivity and relative price between traded and nontraded sectors within countries, found a large and persistent deviation from purchasing power parity in prices of tradable goods between countries. Skeptical evidence on the performance of the HBS effect was also produced by direct tests of the HBS effect carried out by Chinn and Johnston (1999) and Fitzgerald (2003). These found little evidence of the presence of a long-term relationship between the real exchange rate and the productivity differential between countries.

In addition, the advent of New Open Macroeconomics (NOEM) has shed light on several implicit assumptions behind the traditional HBS effect. These general-equilibrium models pay greater attention to international pricing than traditional open-macro models, in order to provide a coherent analysis of monetary influence on the exchange rate and macroeconomic interactions. In the process, rather than postulating purchasing power parity in tradables as a starting point, they began to model alternative pricing practices that allow a systematic deviation from purchasing power parity in tradables prices.[2]

In this paper, we revisit the link between the productivity and the real exchange rate, paying attention to several issues that have been raised in recent years. We start by setting down a simple accounting framework for the real exchange rate, to motivate our empirical analysis in terms of the NOEM models as well as the traditional literature. We decompose the exchange rate into two parts: the real exchange rate based on tradables prices and the international differential between internal relative prices between nontradable and tradable sectors. Following theoretical discussion of the effect of productivity on these two components of the exchange rate, the empirical section explores the long-term relationship between productivity and the real exchange rate by employing a panel cointegration technique. The cointegration approach enables us to maintain the focus on the long-term relationship without being swayed by cyclical variations embedded in the exchange rate and productivity measures.

To preview the results, we confirm the positive association between relative price and relative productivity, within countries, using both labor productivity and total factor productivity (TFP).[3] However, we find the positive association between relative price and relative productivity does not always translate into a positive association between the real exchange rate and the productivity *differential* between countries. When productivity is measured by labor productivity, the correlation between the exchange rate and the productivity differential remains positive, largely working through wage differentials. When TFP is used to measure productivity, however, the correlation between the exchange rate and the productivity differential is not statistically significant, and their signs are, at times, negative.[4] We thus note that the two measures of productivity are not interchangeable, especially when their cross-country differentials are used for the exchange rate analysis. Our results thus send a warning signal against relying upon the conventional approach that did not distinguish the two measures of productivity in the exchange rate analysis.

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[2] A good survey is provided by Engel (2002). The surveyed papers did not aim to address the productivity effect on the real exchange rate, but make explicit the deviation from PPP.

[3] Both measures of productivity have been used in the literature. Earlier papers relied on labor productivity, but more recent papers relied on TFP except for the paper by Canzoneri and others (1999), which used labor productivity as a more comprehensive measure of productivity. The distinction between the two measures of productivity has not received much attention, but our results show that the distinction is anything but inconsequential for the exchange rate analysis.

[4] This is consistent with results obtained by Chinn and Johnston (1999) using TFP data.

Under both productivity measures, one interesting contrast to the traditional HBS effect emerges. The traditional version of the HBS effect requires that the tradables prices abide by purchasing power parity, implying that the tradable-based real exchange rate remains sufficiently close to a constant value—though not necessarily unity—on average. According to our results, even for labor productivity that affects the real exchange rate in a direction consistent with the HBS effect, the effect works more through tradables-based real exchange rates than through the inter-country differential in relative prices between tradables and nontradables. Also with TFP, which provides less support for the HBS effect, most of the action occurs through the tradables-based real exchange rate, rather than through the differential in relative prices between nontradables and tradables.

To investigate the mechanism through which productivity affects the tradables-based real exchange rate, we delve into the link between the real exchange rate and TFP. The choice of TFP as a measure of productivity in this inquiry was made for two reasons. First, the theoretical models in recent literature lend themselves more easily to the TFP interpretation of productivity. More importantly, TFP was the chosen measure of productivity in several papers that explored the likely effect of imperfect competition on the real exchange rates—Cheung, Chinn, and Fujii (1999); Fitzgerald (2003); and MacDonald and Ricci (2002). In contrast to these papers, which attempted to gauge the importance of imperfect competition itself, we assess the likely contribution of two channels that interact with but do not have to be confined to imperfect competition: the nontradables component reflected in the measured price of tradables, and the home bias in the goods basket used in constructing price indices. Though these are somewhat ambiguous, our results generally point toward models with explicit price discrimination by firms when tradable prices include substantial nontradable components, as was explored in Corsetti and Dedola (2002).

II. Real Exchange Rate Accounting

To organize our discussion, we set up an accounting framework. The real exchange rate (Q) is defined as follows.

$$Q = \frac{EP^*}{P} \tag{1}$$

The foreign price level is P*, the domestic price level is P, and the nominal exchange rate is E—the price of foreign currency denominated in home currency. Price level is assumed to be a geometric average of the prices of traded and nontraded goods, and the price of traded goods is in turn assumed to be the geometric average of prices of home-produced tradables (sold at P_T^H in the home market and sold at $P_T^{H^*}$ in the foreign market) and foreign-produced tradable goods (P_T^F and $P_T^{F^*}$).

$$P = (P_T)^{\alpha}(P_N)^{1-\alpha}$$
$$P^* = (P_T^*)^{\alpha^*}(P_N^*)^{1-\alpha^*}$$

$$P_T = \left(P_T^F\right)^{\beta}\left(P_T^H\right)^{1-\beta}$$
$$P_T^* = \left(P_T^{F*}\right)^{\beta^*}\left(P_T^{H*}\right)^{1-\beta^*}$$

For P and P*, α and α^* are weights of tradables in each country. For P_T and P_T^*, β and β^* are weights of foreign-produced tradables in each country. Values of β's and β^*'s, and their difference from ½ more specifically, reflect the extent of home bias. Relative weights on traded goods (α and α^*) are likely to be similar across countries that are similarly open to trade, while β and β^* can differ, for example, reflecting brand preferences within the same industry.

Incorporating these components, the real exchange rate can be written as the product of the real exchange rate based on traded goods and the ratio of internal relative prices between traded and nontraded goods.

$$Q = \frac{EP_T^*}{P_T}\frac{\left(P_N^*/P_T^*\right)^{1-\alpha^*}}{\left(P_N/P_T\right)^{1-\alpha}} \tag{2}$$

We will denote the real-exchange rate based on tradables as Q_T and the internal relative price differential as Q_N.

$$Q_T = \frac{EP_T^*}{P_T} \tag{3}$$
$$Q_N = \frac{\left(P_N^*/P_T^*\right)^{1-\alpha^*}}{\left(P_N/P_T\right)^{1-\alpha}} \tag{4}$$

The traditional HBS effect applies when the home and foreign produced tradables are perfect substitutes, and thus the law of one price holds for tradable price aggregates ($Q_T = 1$). For brevity, this "aggregated" law of one price will be called ALOP in the remainder of this paper. Under the ALOP, a productivity improvement in the tradable sector will drive up the wage for the whole economy and thus the labor cost for the nontradable sector. The relative price of the nontradable sector will rise accordingly, resulting in real appreciation through QN.

If the ALOP does not hold for traded aggregates, productivity can affect the real exchange rate through both Q_T and Q_N, possibly undermining the HBS effect that works through Q_N. The necessary condition here is the ALOP for traded aggregates, which is not synonymous with the law of one price for individual goods. To discuss the possible channels through which productivity affects Q_T, we rewrite Q_T as follows.

$$Q_T = \frac{EP_T^*}{P_T} = \left(\frac{EP_T^{F*}}{P_T^F}\right)^{\beta} \left(\frac{EP_T^{H*}}{P_T^H}\right)^{1-\beta} \left(\frac{P_T^{H*}}{P_T^{F*}}\right)^{\beta-\beta^*} \tag{5}$$

There are two channels through which the ALOP fails and thus tradables-based real exchange rate can differ from one, even in the long run. Pricing to market by home or foreign producers can create a wedge in the prices of tradables between two markets ($EP_T^{F*} \neq P_T^F$ in the case of foreign-produced goods). The cause of the pricing-to-market behavior is another matter, which we will discuss later. Alternatively, both the prices and the weights on home and foreign goods can differ ($P_T^{H*} \neq P_T^{F*}$ and $\beta \neq \beta^*$). Even if the prices differ between home and foreign goods, it will not affect the tradables-based real exchange rate if the weights on home and foreign goods are identical between two countries.[5]

Empirically, several recent papers documented substantial evidence that QT deviated from one. Isard and Symansky (1996) and Engel (1999) showed that QT was the major source of variation in the real exchange rate of many economies, in the long run as well as the short run. Cheung and others (1999) documented large persistence in sectoral exchange rates, which would correspond to EP_T^{F*} / P_T^F (or EP_T^{H*} / P_T^H). These papers provided ample ground for questioning the empirical validity of ALOP even for traded aggregates, but did not explore the specific cause of the deviation.

Nominal rigidity alone does not seem to be sufficient for explaining this failure of the ALOP. With rigid domestic and foreign prices, fluctuations in the real exchange rate are largely driven by the nominal exchange rate movements. However, the magnitude of the real exchange rate deviation induced by nominal rigidity would be bound within a limit in the long run, for most of the short-run deviation would disappear in the long run when long-run neutrality holds for the effect of nominal shocks.[6] This calls for a complementary approach that explores other causes of long-run deviation from the ALOP, including those that are widely regarded to be capable of having sizeable long-term effects. We focus on productivity, a shock that is both real—rather than nominal—and permanent-nonstationary—rather than being stationary .

On theoretical grounds, new open macro models have begun to shed light on the not-so-simple mechanism by which productivity affects the real exchange rate, in the long run as well as the short run. Two channels are particularly relevant to our exploration. One is the home bias effect, in which home-produced goods and services carry a larger weight in the representative basket for price indices. The other is the presence of nontradables processing component—often motivated as the distribution service—in the price of tradables.

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[5] An observed difference in prices of goods produced in home and foreign markets does not necessarily invalidate the premise of HBS effect.

[6] In the recent new open macro literature, the long-run non-neutrality of nominal shocks on the real exchange rate has been proved theoretically possible but its empirical magnitude is viewed to be limited.

Under both channels, tradables productivity can affect QN through the same mechanism as in the HBS effect which can coexist with them. The difference resides in the effect of sectoral productivities on QT. According to the home bias (HB) effect, even if the law of one price holds product by product, QT will not equal one because baskets of goods differ between home and foreign. The nontradables processing (NP) effect refers to the inevitable involvement of nontradables in the distribution and production of tradable goods. With or without further market segmentation, the presence of nontradable component implies that the law of one price does not have to hold for each tradable product and QT will not be equal to one. Moreover, nontradables productivity will affect QT, a unique effect. These contrasts are summarized in the text table.

	Tradables productivity	Nontradables productivity
HBS: Harrod-Balassa-Samuelson	QN	QN
HB: Home Bias	QN, QT	QN
NP: Nontradables Processing	QN, QT	QN, QT

The likely direction—namely, the sign of non-zero coefficients—of productivity effects on the real exchange rate can be gleaned from several models that have been recently proposed. McDonald and Ricci (2002) analyze a static model and point out that the productivity improvement could lead to real exchange rate depreciation, once the HBS effect through QN is controlled for. Benigno and Thoenissen (2002) calibrate a dynamic model that includes home bias for the U.K. economy to find that productivity improvement leads to the depreciation of the real exchange rate. From both static and dynamic models, it appears that productivity improvement will lower the price of home goods, and that this terms-of-trade effect will translate into real depreciation of QT when home goods account for a bigger share of the home consumption basket. Although the law of one price can hold for each product, prices of each product can differ following an asymmetric productivity shock, and QT will reflect the prices of products which account for a bigger share of the consumption basket.

The effect is more intricate in models with nontradable components in the production and distribution of tradable goods. Corsetti and Dedola (2002) analyze a general equilibrium model where tradable-goods price reflects the cost of nontradable distribution service. Because the presence of nontradable price component in the price of tradables creates a wedge between home and foreign markets, firms price-to-market and the law of one price does not have to hold even for each product. In addition, tradable productivity and nontradable productivity will both influence QT. Tradable productivity improvement at home tends to generate real depreciation, as the effect works through the terms-of-trade effect, subject to the pricing decision of firms. Nontradables productivity improvement also tends to generate real depreciation in QT, as the productivity improvement lowers the nontradable markup added into the home market price of goods, for both imported and domestically produced goods.

Of course, predictions of these new models depend on several modeling assumptions that have been adopted to analyze the consequence of price rigidities on various open macro questions. Their empirical predictions regarding the effect of productivity on the real exchange rate thus

need to be taken with a grain of salt.[7] In this paper, we thus focus on whether the coefficients on productivity terms are different from zero, putting less emphasis on the signs and magnitudes of coefficient estimates that could vary with specific models.

III. Data

The principal source of data is the International Sectoral Database (ISDB, 1998 edition) and the Structural Analysis Industrial Database (STAN) of the Organization for Economic Cooperation and Development (OECD). It contains sectoral data for OECD countries, of which we use data for 12 countries: Belgium, Canada, West Germany, Denmark, Finland, France, Italy, Japan, the Netherlands, Sweden, the United Kingdom and the United States. These countries had the most extensive coverage of variables of our interest, which are TFP, price, wage, output, employment, capital stock and gross fixed capital formation at nine 2-digit ISIC industry levels. The nine industries are combined into tradables and nontradables sectors. In accordance with the classification by DeGregrio and Wolf (1994), tradables sector comprises agriculture, manufacturing, mining and transport ; and nontradables sector comprises utilities, construction, retail, financial services and community services.

The data on nominal exchange rates are taken from the *International Financial Statistics* of the IMF. Besides the sectoral general price deflator data from ISDB and STAN, we also use the consumer price data from Datastream's OECD database as another measure of sectoral prices. For productivity measures, we use both labor productivity and total factor productivity (TFP). The default TFP data that we use are those provided by the ISDB until 1992. We also extend the TFP data to 1996 for several years, according to the standard approach that we discuss later.

To measure labor productivity, we first divide the real value added by the total employment for each industry in each country from 1970 to 1997. Since the real value added data are normalized at 1995 and thus are not comparable across industries, we normalize the ratio of the real value added to employment, by setting it equal to one for each industry at the start of the series (1970) and deflate the rest of the series accordingly. To obtain the labor productivity indexes for tradables and nontradables, we aggregate industry level productivities of four tradable industries and five nontradable industries, using each industry's employment share as weights.

IV. Specification

In light of recent theoretical models reviewed in Section II, we investigate the effect of productivity not only on the real exchange rate but also on its two components (QT and QN). This strategy leads to several combinations, depending on the exchange rate and productivity measures used. To facilitate the discussion of our results and the comparison with the literature, we define a few terms to be used repeatedly. We use "relative" to refer to price or productivity

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[7] Probably the most comprehensive model in this line of research can be found in Pesenti (2002), and Hunt and Rebucci (2003) applied a version of the model to analyze the effect of productivity shock on the U.S. exchange rate and current account for a particular parametrization. The full implication of that model under alternative parameter assumptions still remains to be investigated.

ratios between tradable and nontradable sectors, and use "differential" to refer to inter-country differences in any variable. For example, *relative productivity* means the ratio of tradable productivity to nontradable productivity in a country, while tradables *productivity differential* (between country A and B) means the difference between country A's tradables productivity and country B's tradables productivity. A somewhat cryptic expression *relative productivity differential* (between country A and B) means the difference between country A's *relative productivity*—the ratio between tradable and nontradable productivities—and country B's *relative productivity*.

Our dependent variables are logs of the real exchange rate (Q), tradables-based real exchange rate (QT), and the relative price differential (QN). The independent variables—also in logs—are productivity differentials in tradables and in nontradables, relative productivity differential, and real wage differential. Working with exchange rates for 12 countries, we can potentially examine 132 bilateral exchange rates, and look for the common pattern that emerges from the data. Instead, we look for the common pattern directly by examining the data as a panel. A representative equation that we estimate is a panel regression of the following type (we suppress time subscript for brevity in this equation, which will be t, different from T for tradables).

$$\log Q_{Ti} = \beta_{0i} + \beta_1 \left(\log Z_T^* - \log Z_{Ti}\right) + \beta_2 \left(\log Z_N^* - \log Z_{Ni}\right) + \beta_3 \left(\log w^* - \log w_i\right) + \varepsilon_i \qquad (6)$$

In this equation, the tradables-based real exchange rate is regressed on the productivity differential in the tradable sector ($\log Z_T^* - \log Z_{Ti}$), the productivity differential in the nontradable sector ($\log Z_N^* - \log Z_{Ni}$), and the wage differential ($\log w^* - \log w_i$). All cross-country differentials—in productivity or price—are calculated with the U.S. as the numeraire country, denoted by superscript *. (There are some regression results that have other countries as the numeraire country, but these will be noted when they appear.) The equation is also estimated with two productivity terms combined into the relative productivity differential as follows.

$$\log Q_{Ti} = \beta_{0i} + \beta_1 \left[\left(\log Z_T^* - \log Z_N^*\right) - \left(\log Z_{Ti} - \log Z_{Ni}\right)\right] + \beta_2 \left(\log w^* - \log w_i\right) + \varepsilon_i \qquad (7)$$

We vary dependent variables among three Q's and independent variables between labor productivity and TFP. For each pair, the equations are estimated both with and without the wage channel included.

Measured productivity variables are bound to contain cyclical components, while most of our theoretical priors are based on long-run effects of productivity. To focus on long-term relationship in the data, we resort to cointegration methodology. This econometric choice is facilitated by the result that all variables are found to be nonstationary (panel unit root tests reported in Table 1).[8] Cointegrating relationship was estimated by the panel version of dynamic OLS (DOLS) in line with Kao and Chiang (2000) and Mark and Sul (2001). The specific

[8] Two series that look least nonstationary are the differentials in real wages and in nontradable labor productivities.

combination of dependent and independent variables changes with each specification, but all regressions are of the following format, where independent variable z_{it} refers to the vector that comprises productivity and wage variables as discussed in equations (6) and (7).

$$q_{it} = \beta_{0i} + \beta_1 z_{it} + \sum_{k=-m}^{m} \beta_2 \Delta z_{it+k} + \varepsilon_{it} \tag{8}$$

By including leads and lags of the differenced series, DOLS addresses an asymptotic bias contained in the OLS estimates. This econometric choice is based on Kao and Chiang (2000). Comparing two proposed solutions—FMOLS and DOLS—to the finite-sample bias of OLS estimators, they find that DOLS outperforms FMOLS in two aspects. First, DOLS reduces bias better than FMOLS, while being computationally simpler at the same time. Second, the t-statistic from DOLS approximates the standard normal density much better than the t-statistic from OLS or FMOLS. Following their suggestion, we use DOLS and evaluate the t-statistic relative to the standard normal distribution. Since the coefficients on these leads and lags are of no particular interest in terms of long-run relationship, we omit these terms when we present estimation results in the remainder of the paper.

V. Core Evidence on Productivity Effects

A. Internal Relative Prices and Relative Productivity

We first investigate the relationship between relative prices and relative productivities within each country. This is the first building block of the HBS effect and its empirical validity has been confirmed by both DeGregorio and others (1994) and Canzoneri and others (1999). We estimate equations of type (6) and (7), using both labor productivity and TFP as measures of productivity. The results based on TFP are reported in Table 2. First and second columns are based on regressions of type (6), with wage effects included in the regression for the second column.

$$\log P_{Tit} - \log P_{Nit} = \beta_{0i} + \beta_1 \log Z_{Tit} + \beta_2 \log Z_{Nit} + \beta_3 \log w_{it} + \varepsilon_{it} \tag{9}$$

The tradable productivity growth brings about real appreciation—a rise in the relative price of nontradables—with strong statistical significance, while the nontradable productivity growth does not have a statistically significant effect. Third and fourth columns are based on regression of type (7), with wage effects included in the fourth column.

$$\log P_{Tit} - \log P_{Nit} = \beta_{0i} + \beta_1 \left(\log Z_{Tit} - \log Z_{Nit}\right) + \beta_2 \log w_{it} + \varepsilon_{it} \tag{10}$$

Higher relative productivity in the tradable sector appreciates the real exchange rate whether the wage effect is included or not, though mainly on the force of tradables productivity growth as seen in the first and second columns. In contrast to the robust effect of productivity on the relative price, the wage effect is not very strong in equations (9) and (10). In the second column, higher real wage is found to lead to real depreciation—a decline in the relative price of nontradables. In the fourth column, however, the wage effect is not statistically significant.

Table 3 reports the results obtained using labor productivity. The results without wage effects are similar to those of using TFP. When we regress internal relative prices on sectoral productivities as in equation (9) without wage effect (the first column), tradable productivity growth appreciates the real exchange rate while nontradable productivity growth depreciates the real exchange rate. When we regress relative price on relative productivity as in equation (10) without wage effect (the third column), higher relative productivity appreciates the real exchange rate. This result is not surprising given that in the first column, the effects of sectoral productivities were both statistically significant but with opposite signs. This much is similar to the results in Table 2, based on TFP.

Unlike TFP, however, labor productivities appear to work exclusively through the wage channel. When wage effects are included (the second and fourth columns of Table 3), productivity effects lose their previously strong statistical significance. These results are consistent with the logic of the HBS effect, but illustrate the difference between effects of labor productivity and TFP on relative prices between nontradables and tradables, and eventually on the real exchange rate. This difference—hitherto little noted—results in a much sharper contrast in their effects on the real exchange rate in ensuing sections.

The positive correlation between relative price and relative productivity is only one building block for the HBS effect to be able to explain the effect of productivity on the real exchange rate. We need to verify that real exchange rates are correlated with cross-country differentials in sectoral or relative productivity. These lead us to regressions of type (6) and (7) for Q, QT, and QN. Equations of type (6) are:

$$\log Q_i = \beta_{0i} + \beta_1\left(\log Z_T^* - \log Z_{Ti}\right) + \beta_2\left(\log Z_N^* - \log Z_{Ni}\right) + \beta_3\left(\log w^* - \log w_i\right) + \varepsilon_i \qquad \text{(6A)}$$

$$\log Q_{Ti} = \beta_{0i} + \beta_1\left(\log Z_T^* - \log Z_{Ti}\right) + \beta_2\left(\log Z_N^* - \log Z_{Ni}\right) + \beta_3\left(\log w^* - \log w_i\right) + \varepsilon_i \qquad \text{(6B)}$$

$$\log Q_{Ni} = \beta_{0i} + \beta_1\left(\log Z_T^* - \log Z_{Ti}\right) + \beta_2\left(\log Z_N^* - \log Z_{Ni}\right) + \beta_3\left(\log w^* - \log w_i\right) + \varepsilon_i \qquad \text{(6C)}$$

Under the most strict version of the HBS effect, slope coefficients in QT regression should all equal zero, while the slope coefficients in Q and QN regressions should be similar. Under the HB or NP effects, slope coefficients in QT regressions are expected to differ from zero. Similar zero restrictions should apply to equations of type (7), where regressors are relative productivity differentials and wage differentials.

B. Labor Productivity Differential

We start with labor productivity differentials, which are plotted against the real exchange rates in Figure 1. Before proceeding further, we note here the sign convention adopted in all remaining figures and tables, which contrasts with that of Tables 2 and 3. In the remainder of the paper, Q's are defined in such a way that positive coefficients refer to *appreciation* in the real exchange rate. In Figure 1, relative productivity differentials are plotted against three Q's, for 10 countries from 1970 to 1997. The positive association between productivity and the exchange rate shows up for all three Q's but least strongly for QN, somewhat unfavorably for the HBS effect.

The results of econometric estimation are reported in Table 4. All combinations of variables reported in Table 4 are found to be cointegrated according to the augmented Dickey-Fuller test suggested by Kao (1999). To start with the first panel that shows coefficient estimates for equation (6) without wage effect, coefficient estimates exhibit a pattern that is not very supportive of the HBS effect. Contrary to the HBS effect, productivity differentials have no statistically significant effect on QN, while they have statistically significant effects on QT, invalidating another building block of the HBS effect.

The statistically significant effect of productivity differentials on Q and QT bodes well for the NP and HB effects. For both Q and QT, higher tradables labor productivity leads to real appreciation, while higher nontradables productivity leads to real depreciation. Moreover, the coefficient estimates on tradables and nontradables productivities are opposite in sign and similar in magnitude. The statistically significant effect of nontradables productivity differential on QT suggests that the NP effect is preferred over the HB effect.[9]

We read the combined results as pointing to the NP effect, away from the HBS effect. On the basis of the evidence on Q and QT alone, we cannot readily distinguish between the HBS effect and the NP effect. To interpret the HBS effect more flexibly, the presence of nontradables component in the measured tradables prices would imply that the HBS effect could work through QT, too. Distinction between them is made possible by the evidence associated with QN. Under the HBS effect, productivity is expected to have stronger effect on QN than on QT, while the opposite is true in the data. This leads us to lean toward the NP effect, away from the HBS effect.

Consistent with the results of the previous section, labor productivity effects appear to work exclusively through wages. The estimates allowing for wage effect, reported in the second panel, show that the direct effect of labor productivity is not statistically significant once wage effect is controlled for. In regressions with all three real exchange rate measures, the wage differential is the only statistically significant variable.

The estimated effect of relative productivity differentials, reported in the third and fourth panels, are fully consistent with those of sectoral productivity differentials reported in the first and second panels. When wage effects are not included, an increase in the relative productivity differential appreciates QT and Q, but does not have statistically significant effect on QN. Once wage effects are included, a higher wage differential appreciates the real exchange rate, and the relative productivity differential has no statistically significant effect.

Going back to the question raised in the title of this paper, we have seen that a higher tradables labor productivity tends to appreciate the real exchange rate (Q), when wage effects are not factored in. The effects of labor productivity, however, are channeled entirely through the wage rate: the direct effects of productivity are not statistically significant once wage effects are allowed. This evidence on Q fits nicely with the classic version of the HBS effect, which was indeed first formulated in terms of labor productivity. However, the evidence on the link between productivity and components of the real exchange rate, QT and QN, speaks more favorably for

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[9] Strictly speaking, this evidence does not preclude the HB effect, which can coexist with the NP effect. Section VII provides additional evidence for the NP effect and against the HB effect.

the NP effect than the HBS effect. Productivity differential has no statistically significant effect on QN, which should be the major conduit under the HBS effect.

C. Total Factor Productivity (TFP) Differential

We now turn to TFP as measures of productivity. Figure 2 plots three Q's and relative TFP differentials for 10 countries from 1970 to 1992, during which time TFP was calculated by OECD. In contrast to Figure 1 with labor productivity, relative TFP differentials appear to be somewhat negatively correlated with Q and QT. For QN, again in contrast to Figure 1, relative TFP differentials appear to be strongly positively correlated with QN. This contrast emerges more starkly in econometric estimates.

Table 5A reports the results based on OECD data for 10 countries during 1970–1992 period, and Table 5B reports the results based on the TFP data that was expanded for additional several years. To start with Table 5A, for all regressions reported, the ADF test statistics suggest that all variables are cointegrated. The first panel shows the results of regressions of type (6), with sectoral productivity differentials as regressors without wage effects. In contrast to the results from labor productivity, we find evidence supportive of the HBS effect in the QN regression. A faster increase in home tradable productivity leads to an appreciation in QN, while a faster increase in home nontradable productivity leads to a depreciation. As the second contrast, the effects of productivity on QT are opposite in sign to those of labor productivities. A faster tradable TFP improvement leads to a real depreciation in QT, while nontradable TFP improvement leads to a real appreciation in QT. Regardless of the sign, however, the statistically significant effect of nontradables TFP on QT suggests that the NP effect is at work. The combined effect of productivity on the aggregate real exchange rate, Q, is not statistically significant, as conflicting effects on two components (QT and QN) cancel out each other.

Controlling for the wage effect, productivity effects are qualified somewhat (the second panel). The results of QN regression continue to support the HBS effect, as tradables productivity growth leads to real appreciation, although nontradables productivity effect on QN weakens in statistical accuracy. The wage effect on QN is negative, implying that a faster real wage growth in home country tends to lower the relative price between nontradables and tradables. One possible channel, though speculative, would be a corresponding increase in the markup in the tradable sector, which would cause a faster wage growth to generate a faster increase in tradables prices than in nontradables.

In QT regression, a faster growth in tradables productivity depreciates the real exchange rate much more strongly once its appreciationary effect through wages are controlled for. A faster growth in nontradables productivity, which was found to appreciate the real exchange rate without controlling for wage effect, is now found to depreciate the real exchange rate against even the broadly construed HBS effect. The effect of tradables productivity on QT lends support to the HB and NP effects, with the observed effect of nontradables productivity on QT favoring the NP effect between the two.

For the aggregate real exchange rate (Q), faster productivity growth in both tradable and nontradable sectors are found to depreciate the real exchange rate when wage effects are controlled for. An improvement in tradables productivity appears to have twice as strong an effect on the real exchange rate as an improvement in nontradables productivity. Despite

evidence consistent with HBS effects in QN regression, productivity effects on Q appear to be driven by productivity effects on QT.

Estimated effects of relative productivity differentials, shown in third and fourth panels, are consistent with results from the first and second panels. In the estimation without wage effects, an increase in relative productivity differential appreciates QN, depreciates QT, and has no statistically significant effect on Q. Controlling for the wage effect, the estimates change little for QN and QT—appreciating QN and depreciating QT—and the relative productivity differential is found to depreciate Q with marginal statistical significance.

Table 5B reports the results from same regressions with a dataset that spans over a longer sample period. To extend the sample period, we compute the sectoral TFPs for each country for years without published TFP data in ISDB. Owing to limitations on the data on capital stock and gross fixed capital formation, this extension was possible for only 7 countries—Belgium, Canada, Finland, France, Italy, Japan and Netherlands. For these countries, we obtained from ISDB and STAN the data on value added, employment and gross fixed capital formation at sectoral levels. We then computed the labor share and the initial capital stock of each sector for the last year in which published TFP data were available from ISDB. On the basis of these labor share and initial capital stock figures, we extend the TFP series to 1996, under the assumption that the physical capital stock depreciates at the rate of 5 percent per year.

The results are qualitatively similar to those of the 10-country sample reported in Table 5A. Just to reiterate the basic pattern, there is evidence showing that the HBS effects are at work for QN. Faster home tradable productivity growth tends to appreciate QN, by lowering the home tradables price relative to the home nontradables price. In contrast, the home tradables productivity growth leads to depreciation of QT, again suggesting the NP and HB effects, although the coefficient is not statistically significant. The effects on the aggregate real exchange rate are not statistically significant. When wage effects are allowed, tradable productivity has statistically significant effect on QT. However, nontradable productivity differential does not have statistically significant effect on QT whether or not wage effects are controlled for, undermining the evidence that was supportive of NP effect over HB effect. The effects of relative productivity differentials are nearly identical to those of Table 5A.

This section's answer to the question in this paper's title is nearly the opposite of the answer in the previous section that was based on results using labor productivity. Without controlling for the wage effect, a faster TFP growth in the tradable sector did not have a statistically significant effect on the real exchange rate. The HBS effect on QN and NP/HB effect on QT, working in the opposite direction, cancelled out each other. When wage effects are controlled for, the depreciating effect through QT tends to dominate the appreciating effect through QN, and faster TFP growth in the tradable sector depreciates the real exchange rate with marginal statistical significance.

Taken together, the results so far indicate that the effect of productivity on the real exchange rate depends on the measure of productivity used. When productivity is measured by labor productivity, a higher tradables productivity tends to appreciate the real exchange rate—when wage effects are not controlled for—although it works through QT rather than QN. When

productivity is measured by TFP, a higher tradables productivity tends to depreciate the real exchange rate—when wage effects are controlled for—again largely through QT.

This observation brings out two points that are noteworthy in relation to the extant literature on productivity and the real exchange rate. First, it is important and necessary to be mindful of the distinction between labor productivity and TFP, especially in terms of cross-country differential that forms the basis of the exchange rate assessment. Second, QT deserves more emphasis even in the discussion of productivity effects on the real exchange rate. While there have been disagreements on the role of QT in transmitting nominal shocks to Q, an implicit consensus appears to have existed that QN is the more important channel in transmitting productivity shocks to the real exchange rate. In contrast to this traditional view—motivated by the HBS effect—we have seen that QT plays a dominant role in transmitting the productivity shock to the real exchange rate. Besides being a natural—if any—transmitter of the nominal shock, QT appears to be a key transmitter of the real productivity shock in the long run.

VI. Labor Productivity and TFP

The literature on the productivity and the real exchange rate, including tests of the HBS effect, have used both labor productivity and TFP as measures of productivity. Although conceptual difference between two measures is more than well understood, its empirical magnitude has not been clearly documented, and thus both measures have been used by different researchers who attempted to test the HBS effect. However, the preceding section has shown that the labor productivity and TFP often have different effects on the real exchange rate in the long run. We look more into this in two ways.

First, we repeat regressions behind panel III of Tables 4 and 5, namely regressions of three Q's on the relative productivity differentials, for four other numeraire currencies. This is to guard against the possibility that the apparent contrast between the effects of two productivity measures are fortuitous outcome of having used the U.S. dollar as the numeraire currency. Table 6A reports the results with Japan, Belgium, Canada, and France as countries of numeraire currency. The basic contrast arises in all of them, in that the effect of labor productivity contrasts with the effect of TFP. With the exception of Q's relative to Canada, labor productivity appreciates QT, has weak effect on QN, and appreciates Q. Even with Canada as the numeraire country, the statistically strong positive effect on QN is swept up by the statistically insignificant effect on QT, thereby exhibiting no statistically significant effect on Q. The effects of TFP on QT and QN are also similar to those of Table 5, except that its effect on QN is not statistically significant when Japan was the numeraire country. Most importantly, the contrast is clear between the effects of two productivity measures on QT: TFP depreciates QT, while labor productivity appreciates QT. For Q, TFP has no significant effect on or depreciates it, while labor productivity appreciates it.

Next, we examine the direct correlation between labor productivity and TFP. Assuming a Cobb-Douglas production function, we can derive the expression that links two measures of productivity and their differentials across countries.

$$\log(Y/L) = \log(A) + \gamma \log(K/L) \quad (11)$$

$$\log(Y/L) - \log(Y/L)^{*}$$
$$= \left[\log(A) - \log(A)^{*}\right] + \left[\left(\gamma - \gamma^{*}\right)\log(K/L) + \gamma^{*}\left(\log(K/L) - \log(K/L)^{*}\right)\right] \quad (12)$$

Within each country (equation (11)), two measures of productivity differential will move together unless capital-labor ratios are negatively correlated with TFP growth. Across countries (equation(12)), two measures of productivity differential will move together if factor shares and capital-labor ratios are similar across countries. Cross-country differences in factor shares will remain largely constant, but differences in capital-labor ratios can exhibit substantial variation over time. For the time span of our data, there can be divergence in the capital-labor ratio owing to different investment dynamics. Even in the very long run, capital-labor ratios can differ between countries if TFP growth occurs with different factor biases across countries.[10]

From this theoretical consideration alone, it is more likely for two measures of productivity to be correlated positively within each country, than for two measures of productivity differential to be correlated positively across countries. The actual calculation is weakly supportive of this prior (Table 6B). Overall, two productivity measures are more positively correlated within each country than two measures of productivity differentials are positively correlated across countries.

Column (1) of Table 6B shows the correlation between the log of tradable TFP and the log of tradable labor productivity from 1970 to 1992. Besides Germany, France, the Netherlands and Sweden, the correlation coefficients are positive and quite high for the sample countries, exceeding 0.95 for 5 countries. However, when we compare the tradable TFP differential and the labor productivity differential for each country (column (3)), the correlation in general is much weaker. For Finland, the correlation drops from 0.55 to about 0. The correlation decreases by about 10-16% for Canada, Denmark, Italy and Japan, while the correlation for Germany, France, the Netherlands and Sweden remains negative.

The positive correlation is even weaker for nontradables. Column (2) shows the correlation between the log of nontradable TFP and the log of nontradable labor productivity. The correlation is negative for 7 of the 11 countries. Except for Japan, none of the correlation coefficient is higher than 0.32. The correlation between the nontradable TFP differential and the nontradable labor productivity differential is reported in column (4). Now for 8 out of 10 countries, the correlation is negative. Belgium and France are the only two countries for which differentials in nontradable productivities are more positively correlated than within-country nontradable productivity measures.

Reflecting the correlations in productivity differentials for tradables and nontradables, the correlations between relative TFP differentials and relative labor productivity differentials—reported in column (5)—are only weakly positive. Figure 3 plots two productivity differentials together, attesting to their weak correlation. The weak positive correlation between the two productivity differentials could be explained by the negative or weakly positive correlation between the TFP differential and the capital-labor ratio differential. These correlations are

[10] The literature has often assumed a Hicks-neutral TFP growth.

reported in the lower panel of Table 6B. The correlation between the tradable TFP differential and the tradable capital-labor ratio differential (column (6)) is negative for 6 of the 10 countries, and with the exception of Belgium, none of the countries shows a correlation higher than 0.2. Similarly, column (7) shows weak correlation between nontradable TFP differential and nontradable capital-labor ratio differential. The correlation is negative for all the countries but Japan.

Comparison in this section suggests that cross-country differentials in labor productivity and TFP are not interchangeable. TFP is exogenous to investment dynamics and capital accumulation, while labor productivity is endogenous to investment dynamics.[11] The measured differential in labor productivity would be a combined measure of TFP differential and investment-dynamics differential. As a result, labor productivity differential would be a better measure of cross-country differences in overall cost, precisely because it has incorporated the difference in capital costs. Labor productivity may thus be a preferred choice for the econometric fit of equations that relate the real exchange to productivity. On the other hand, for the appraisal of theories on the productivity and the real exchange rate—especially those that focus on QT—the TFP differential would be a more primitive and preferred measure of productivity.

VII. Further Reflections on Q_T

Regardless of productivity measures used, QT is the key transmitter of the productivity shock to the real exchange rate. In this section, we delve further into the possible channels of productivity effects on QT, using the TFP as the measure of productivity. In addition to being a more primitive measure of productivity, TFP has been the preferred choice of literature, both empirical and theoretical, in recent years.

A. Retail Sector Productivity

The most commonly perceived channel for the effect of nontradables productivity on the real exchange rate is the distribution sector. Broadly construed, the distribution sector encompasses all stages involved between the loading deck of a manufacturing plant and the living room of a consumer. Narrowly construed, the distribution sector is often regarded as the retail sector. The most relevant margin would lie somewhere in-between, but it is still meaningful to explore how important the retail sector is. To assess its relative importance, we divide nontradable sectors into the retail sector and the rest, and examine their individual effects on Q's. Owing to the lack of retail-sector TFP data for the U.S., the sample is now for 9 countries (8 exchange rates) and Canada is used as the numeraire country. We examined the effect of retail sector productivity on both relative prices and Q's.

[11] It would be useful to employ the IMF Global Economic Model (Pesenti 2002) to analyze the interaction between them, and with real exchange rates (three Q's). Such investigation, which is beyond the scope of this paper, is one avenue for exploring the source of differences between labor productivity and TFP.

Econometric results indicate that the retail sector does not constitute the core channel for the NP effect. The effect on relative prices is reported in Table 7. When we included only retail-sector TFP (the first column), the retail-sector TFP has a statistically significant effect on the relative price between tradable and nontradables. Higher retail-sector TFP tends to lower the relative price of tradables to nontradables, thereby leading to real appreciation. However, the coefficient on the retail TFP is no longer statistically significant in the remaining three columns where we control for other effects.[12] This casts doubt on the relative importance of the retail sector in capturing the NP effect.

The negative evidence on the role of the retail sector is reinforced by Table 8 that reports the estimated effects of productivity differential on Q's. There is no case where the retail sector productivity differential has statistically significant effect on Q's. In contrast, TFP differentials of the nontradables sector excluding the retail sector are found to have statistically significant effect on QT (and Q) when wage effects are controlled for. Consistent with the results of regressions that did not distinguish the retail sector from the overall nontradable sector (Table 5A and 5B), higher nontradable TFP—excluding the retail sector here—tends to depreciate the real exchange rate, for both QT and Q.

B. Using the CPI

So far, we have used general price deflators because they were more easily available at sector levels for a larger sample of countries. In this section, we use CPI as price indices, for five countries with CPI data available at sector levels (Canada, Germany, France, Italy and Japan) for the period 1970–1992. We first regress three Q's based on CPI on various TFP and wage variables, and report the results in Table 9A. For comparison, we run the same set of regressions but using general price deflators as the price indices for the same 5 countries and same time period. The results, shown in Table 9B, are similar to the results for 10 countries that were reported in Table 5, enabling us to attribute difference between Tables 9A and 9B to the difference in price indexes, rather than the choice of sample countries. Without controlling for the wage effect, a faster TFP growth in the tradable sector did not have a statistically significant effect on the real exchange rate. The HBS effect on QN and NP/HB effect on QT worked in the opposite direction and cancelled out each other. When wage effects are controlled for, the depreciating effect through QT tends to dominate the appreciating effect through QN, and faster TFP growth in the tradable sector depreciates the real exchange rate with marginal statistical significance.

Coming back to Table 9A, we note that relative to the results based on deflators, the effect of tradables productivity differentials weakens, while the effect of nontradables productivity differentials strengthens. In the first panel of Table 9A, the effect of tradables productivity differential on QN exhibits a contrast from the results based on deflators. While the tradable productivity differential has a statistically significant positive effect on QN based on deflators, it has no statistically significant effect on QN based on CPIs. This weakening in the statistical accuracy of the tradable productivity differential is echoed in the effect of the relative productivity differential, reported in the third panel. On the other hand, the effect of nontradables

[12] The role of the retail sector can be larger if retail prices were used instead of general deflators.

productivity on QT strengthens for some specifications. In the results obtained after controlling for the wage effects, in the second panel, the effects of nontradable TFP differential on QT are more than twice as strong as those on the deflator-based measures.

This contrast suggests a few possibilities. First, the tradable CPI basket may include fewer domestically-produced tradables than the basket for the tradable general price deflator. Second, nontradable TFPs may play a much more important role in determining the price of the tradable imports than that of the tradable exports, if distribution costs account for a larger portion of consumer prices of imports than those of exports. Overall, the strengthening of the nontradables TFP effect in CPI regressions lends further support to the NP effect.

The use of CPI data makes it possible to test home bias, another important channel through with productivities influence QT, because home bias effects are best tested at the level of final demand. We proxy the degree of home bias by the average import share of the country's GDP over the 23 years from 1970 to 1992. We then explore the strength of the HB effect by including the interaction terms between the home-bias proxy and the tradable productivity differential in the regressions.

Table 10 shows the results. Mixed evidence emerges from the regression of the aggregate real exchange rate on the productivity differential, real wage differential and the interaction terms. The higher home bias a country has, the more its tradable productivity growth depreciates its aggregate real exchange rate. On a closer look, however, the evidence is not very strong. While the interaction term has the sign predicted by the theory in the QT regression, the coefficient is not statistically significant. In the QN regression, the interaction term is neither statistically significant nor signed in accordance with the theory. The low statistical significance could be largely due to the poor quality of import share as a measure of home bias, and we interpret the results here as suggesting a need for further exploration rather than providing definitive evidence in either direction.

VIII. Conclusion

Whether productivity growth leads to appreciation and depreciation the real exchange rate depends on the measure of productivity that is used. When labor productivity is used to measure productivity, the classical positive association between productivity and the real exchange rate shows up in the data. The higher is the tradable-sector productivity of a country, the more its real exchange rate appreciates. This appears to confirm the time-honored Harrod-Balassa-Samuelson (HBS) effect, but with a significant qualification. The positive effect on the real exchange rate works mostly through the tradables-based real exchange rate (QT) and weak relation to the relative price differential between traded and nontraded sectors (QN), contrary to the textbook version of the HBS effect. The statistically significant effect of productivity on the tradables-based real exchange rate (QT) could be interpreted as reflecting the presence of the nontradables component in tradables themselves, which would be consistent with both the HBS effect and nontradables-processing (NP) effect. However, the distinct lack of a statistically significant effect of productivity on the relative price differential (QN) seems to contradict the HBS effect—even broadly construed.

When total factor productivity (TFP) is used to measure productivity, the classical positive association between productivity and the real exchange rate dissipates. Rather, higher

productivity in the tradable sector, if any, tends to lead to depreciation of the real exchange rate, working through the tradables-based real exchange rate (QT) rather than through relative price differential (QN). This negative association between productivity and QT, coupled with the prominence of QT over QN as the conduit of productivity effect, is particularly difficult to reconcile with the HBS effect, even if the presence of nontradable components in QT is acknowledged. These findings suggest that the nontradables-processing (NP) effect needs to be taken more seriously.

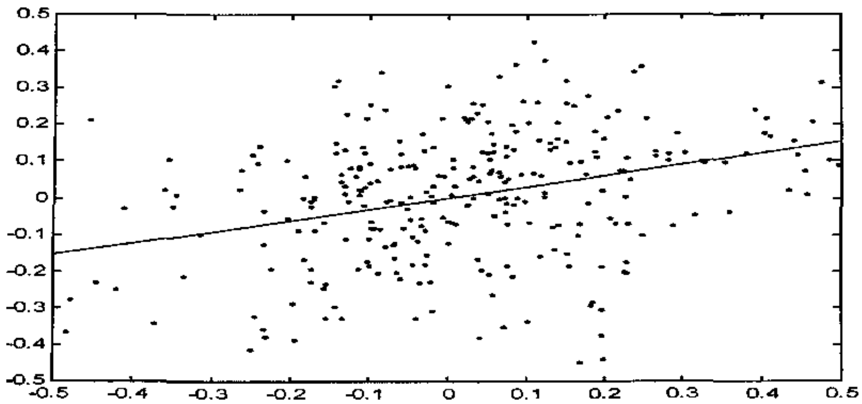
The predominant role played by the tradables-based real exchange rate (QT) as the conduit of the productivity effect on the real exchange rate also bodes well for the home bias (HB) effect in the real exchange rate. However, we only found limited evidence of the home bias effect, in contrast to ample indications of the nontradables-processing effect. Various results of this paper support, in the descending order of strength, the nontradables-processing effect, the Harrod-Balassa-Samuelson effect, and the home bias effect.

This, of course, is the reading of evidence obtained from the sample of about 10 OECD countries over the past three decades, and our findings need to be viewed in light of one important caveat. Among the OECD countries with comparable levels of productivity, the Harrod-Balassa-Samuelson (HBS) effect is likely to be dominated by various market imperfections that allow scope for strategic pricing decisions including the nontradables-processing (NP) effect. This possibility is reinforced by the positive intra-country correlation between relative productivity and relative prices, which is one premise of the HBS effect. In a sample that comprises a broader set of countries with larger productivity gaps among them—which was the original testing ground of the HBS effect—the HBS effect could easily dominate the nontradables-processing (NP) effect that operates through strategic pricing decisions of firms involved.

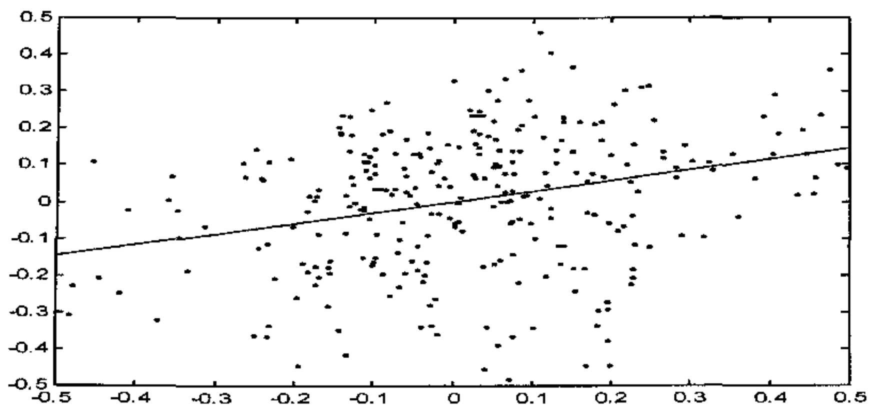
Having acknowledged the critical caveat, we can infer several lessons for future work on productivity and the exchange rate. First, related to the caveat, a fair test of the empirical relevance of the HBS effect would require a dataset that comprises a larger set of countries than has been used in recent panel or time-series studies. Second, considering the surprisingly virulent role of the tradables-based real exchange rate (QT) in transmitting the long-term real shock as well as the short-term nominal shock to the exchange rate, paying more attention to tradables-based real exchange rate (QT) is warranted when studying the effects of real shocks on exchange rates. Third, at least for the group of countries with comparable levels of productivity, strategic pricing decisions appear to loom large in the dynamics of the aggregate real exchange rate, going beyond the more microeconomic evidence uncovered in the existing literature on pricing to market. Fourth, and relatedly to the other lessons, the tradability of goods and services appears to be an important cause of market segmentation that makes strategic pricing decisions relevant over the long run.

Figure 1. The Effects of Relative Labor Productivity Differentials

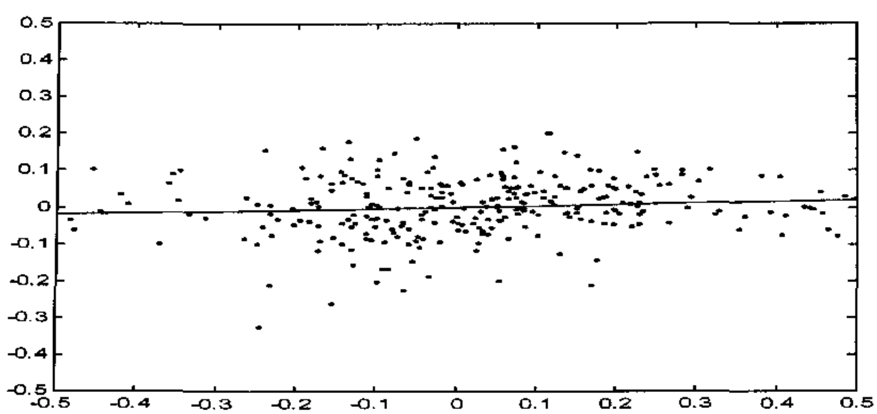
On Q's



On QT's



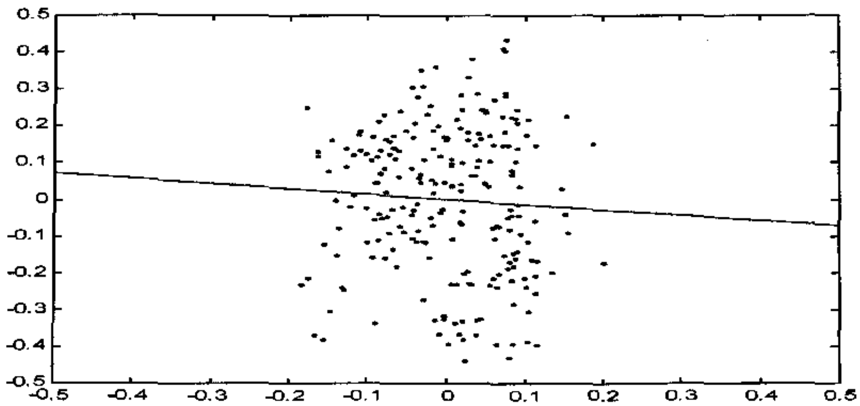
On QN's



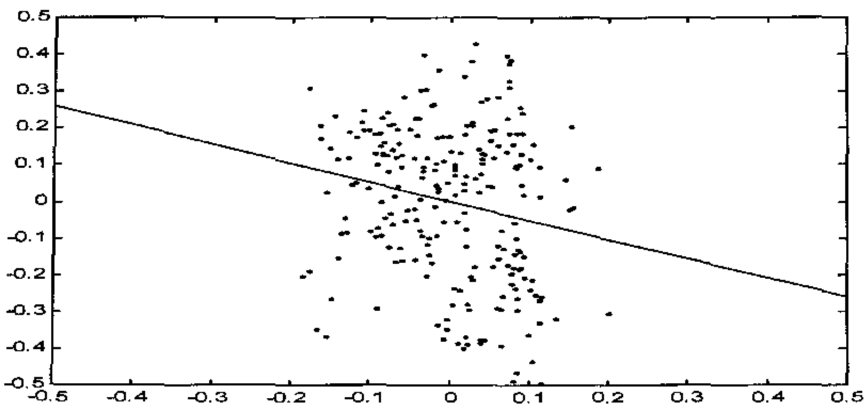
Source: Author's calculation based on STAN data

Figure 2. The Effects of Relative TFP Differentials.

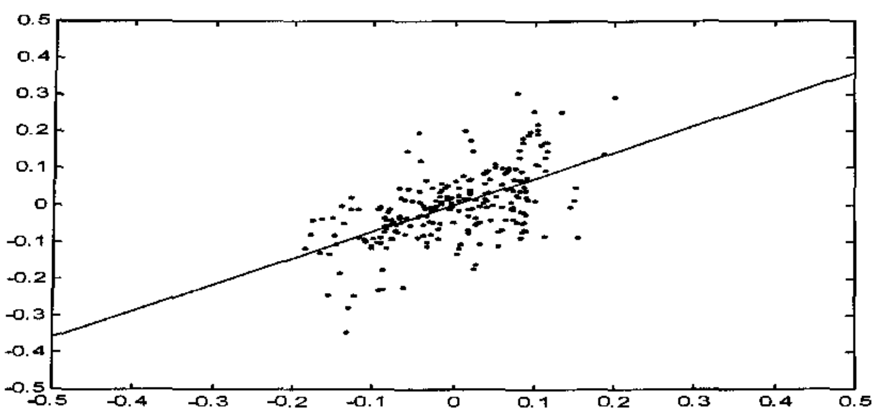
On Q's



On QT's

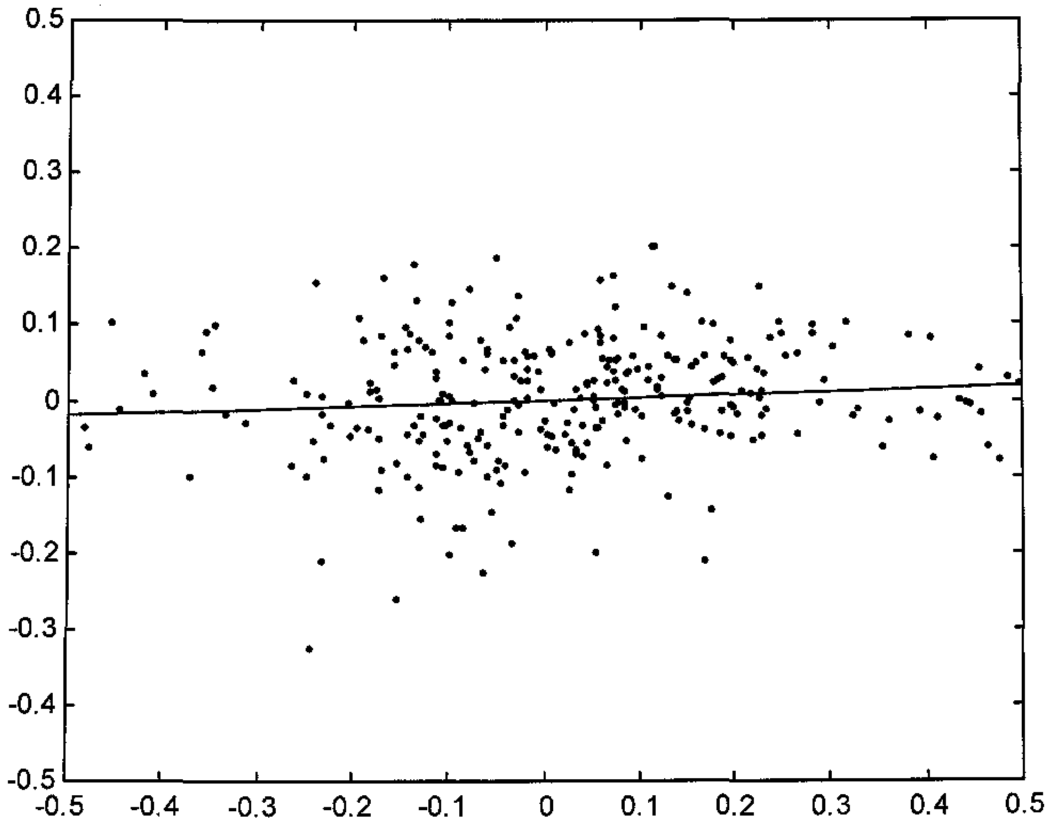


On QN's



Source: Author's calculation based on STAN data

Figure 3. Relative TFP Differential and Relative Labor Productivity Differential (1970-1992, 10 countries: log differences of relative TFP on the vertical axis and log differences of relative labor productivity on the horizontal axis)



Source: Author's calculation based on STAN data

Table 1. Unit Root Tests

1)	s+pt-pt*	-1.08
2)	(pt*-pn*)-(pt-pn)	-1.67
3)	s+p-p*	-1.61
4)	log(Real Wage)-log(Real Wage)*	-4.49
5)	log(TFP_T)-log(TFP_T)*	-0.81
6)	log(TFP_N)-log(TFP_N)*	-0.05
7)	relative productivity differential: 5)-6)	-0.49
8)	log(LP_T)-log(LP_T)*	-0.52
9)	log(LP_N)-log(LP_N)*	-4.24
10)	relative productivity differential: 8)-9)	-1.19
11)	log(MTFP_T)-log(MTFP_T)*	-0.76
12)	log(MTFP_N)-log(MTFP_N)*	-2.11
13)	relative productivity differential: 11)-12)	-0.96

Notes: Im-Pesaran-Shin (1995) ADF tests of the null of unit root-nonstationarity, with two lagged first-difference terms of residuals and no time trend.
(1)-(7): 1970-92, 10 countries including Belgium, Canada, Germany, Denmark, Finland, France, Italy, Japan, the Netherlands, and Sweden.
(8)-(10): 1970-97, 11 countries including Belgium, Canada, Germany, Denmark, Finland, France, United Kingdom, Italy, Japan, the Netherlands, and Sweden.
(11)-(13): 1970-96, 7 countries including Belgium, Canada, Finland, France, Italy, Japan, and the Netherlands.

Table 2. Effects of Total Factor Productivity on Internal Relative Prices

	pt-pn	pt-pn	pt-pn	pt-pn
log(TFP_T)	-0.84	-1.07		
	{-13.9}	{-10.04}		
log(TFP_N)	0.12	0.08		
	{0.63}	{0.54}		
log(Real Wage)		0.34		-0.03
		{2.85}		{-0.17}
log(TFP_T)-log(TFP_N)			-0.84	-0.77
			{-9.91}	{-5.17}
Diagnostics:				
Maximum lead	1	1	1	1
Maximum lag	1	1	1	1
ADF (Kao, 1999) cointegration test	-3.37	-3.51	-2.25	-2.27
Cross-section dimension	11	11	11	11
Time-series dimension	20	20	20	20

Sources: Based on Total Factor Productivity (1970-92) obtained from ISDB for Belgium, Canada, Germany, Denmark, Finland, France, Italy, Japan, Netherlands, Sweden, United Kingdom, United States

Notes: Country fixed effects are included
{t-ratio in parenthesis}

Table 3. Effects of Labor Productivity on Internal Relative Prices

	pt-pn	pt-pn	pt-pn	pt-pn
log(TFP_T)	-0.29	-0.05		
	{-4.48}	{-0.72}		
log(TFP_N)	0.52	0.08		
	{3.28}	{0.52}		
log(Real Wage)		-0.75		-0.72
		{-3.98}		{-4.03}
log(TFP_T)-log(TFP_N)			-0.31	-0.05
			{-5.02}	{-0.64}
Diagnostics:				
Maximum lead	1	1	1	1
Maximum lag	1	1	1	1
ADF (Kao, 1999) cointegration test	-1.38	-2.14	-1.15	-2.14
Cross-section dimension	12	12	12	12
Time-series dimension	25	25	25	25

Sources: Based on Labor Productivity (1970-97) for Belgium, Canada, Germany, Denmark, Finland, France, the United Kingdom, Itay, Japan, the Netherlands, Sweden, and the United States.

Notes: Country fixed effects are included
{t-ratio in parenthesis}
ADF statistic for the third column corresponds to probability 0.12, offering weak evidence of cointegration.

Table 4. Effects of Labor Productivity

	Panel I			Panel II		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
log(LP_T)-log(LP_T)*	0.242	-0.007	0.235	0.037	-0.073	-0.018
	{2.65}	{-0.14}	{2.95}	{0.45}	{-1.33}	{-0.272}
log(LP_N)-log(LP_N)*	-0.369	0.006	-0.283	-0.078	0.137	0.109
	{-1.88}	{0.05}	{-1.64}	{-0.47}	{1.23}	{0.802}
log(Real Wage)-log(Real Wage)*				1.004	0.258	1.143
				{5.07}	{1.94}	{7.06}
Diagnostics:						
Maximum lead	1	1	1	1	1	1
Maximum lag	1	1	1	1	1	1
ADF (Kao, 1999) cointegration test	-4.92	-1.90	-5.71	-4.75	-1.79	-5.63
Cross-section dimension:	11	11	11	11	11	11
Time-series dimension:	25	25	25	25	25	25

	Panel III			Panel IV		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
relative productivity differential	0.27	0.01	0.28	0.03	-0.05	0.01
	{3.43}	{0.17}	{4.13}	{0.35}	{-1.00}	{0.21}
log(Real Wage)-log(Real Wage)*				1.07	0.16	1.12
				{6.45}	{1.38}	{8.06}
Diagnostics:						
Maximum lead	1.00	1.00	1.00	1.00	1.00	1.00
Maximum lag	1.00	1.00	1.00	1.00	1.00	1.00
ADF (Kao, 1999) cointegration test	-5.05	-2.14	-5.92	-4.74	-1.78	-5.58
Cross-section dimension:	11	11	11	11	11	11
Time-series dimension:	25	25	25	25	25	25

Sources: Based on Labor Productivity (1970-97) for Belgium, Canada, Germany, Denmark, Finland, France, the United Kingdom, Italy, Japan, the Netherlands, and Sweden.

Notes: Country fixed effects included
{t-ratio in parenthesis}

Table 5A. Effects of Total Factor Productivity I

	Panel I			Panel II		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
log(TFP_T)-log(TFP_T)*	-0.70	0.98	-0.20	-1.74	1.09	-1.13
	{-1.86}	{5.95}	{-0.63}	{-5.74}	{7.12}	{-4.05}
log(TFP_N)-log(TFP_N)*	0.81	-0.39	0.54	-0.48	-0.17	-0.59
	{1.63}	{-1.79}	{1.29}	{-1.42}	{-1.02}	{-1.92}
log(Real Wage)-log(Real Wage)*				2.01	-0.36	1.75
				{8.43}	{-2.99}	{7.96}
Diagnostic information						
Maximum lead	1	1	1	1	1	1
Maximum lag	1	1	1	1	1	1
ADF (Kao, 1999) cointegration test	-3.57	-3.18	-3.91	-3.93	-3.19	-4.09
Cross-section dimension:	10	10	10	10	10	10
Time-series dimension:	20	20	20	20	20	20

	Panel III			Panel IV		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
relative productivity differential	-0.73	0.80	-0.30	-0.77	0.68	-0.38
	{-2.1}	{4.52}	{-1.04}	{-2.97}	{4.75}	{-1.69}
log(Real Wage)-log(Real Wage)*				1.16	-0.01	1.09
				{5.95}	{-0.09}	{6.44}
Diagnostic information						
Maximum lead	1	1	1	1	1	1
Maximum lag	1	1	1	1	1	1
ADF (Kao, 1999) cointegration test	-3.64	-2.92	-4.07	-3.34	-2.62	-3.62
Cross-section dimension:	10	10	10	10	10	10
Time-series dimension:	20	20	20	20	20	20

Sources: Based on Total Factor Productivity (1970-92) obtained from ISDB for Belgium, Canada, Germany, Denmark, Finland, France, Italy, Japan, the Netherlands, and Sweden.

Notes: Country fixed effects included
{t-ratio in parenthesis}

Table 5B. Effects of Total Factor Productivity II

	Panel I			Panel II		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
log(MTFP_T)-log(MTFP_T)*	-0.44	0.91	0.05	-1.45	0.90	-0.93
	{-0.76}	{5.70}	{0.11}	{-4.75}	{6.00}	{-3.46}
log(MTFP_N)-log(MTFP_N)*	0.57	-0.10	0.35	-0.16	-0.02	-0.31
	{0.98}	{-0.61}	{0.702}	{-0.58}	{-0.16}	{-1.32}
log(Real Wage)-log(Real Wage)*				1.87	-0.18	1.72
				{9.35}	{-1.85}	{9.78}
Diagnostics:						
Maximum lead	1	1	1	1	1	1
Maximum lag	1	1	1	1	1	1
ADF (Kao, 1999) cointegration test	-2.97	-3.14	-3.29	-3.54	-2.95	-3.84
Cross-section dimension:	7	7	7	7	7	7
Time-series dimension:	24	24	24	24	24	24

	Panel III			Panel IV		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
relative productivity differential	-0.42	0.39	-0.13	-0.63	0.39	-0.33
	{-0.97}	{2.20}	{-0.34}	{-2.61}	{2.81}	{-1.61}
log(Real Wage)-log(Real Wage)*				1.35	0.09	1.31
				{6.90}	{0.84}	{7.99}
Diagnostics:						
Maximum lead	1	1	1	1	1	1
Maximum lag	1	1	1	1	1	1
ADF (Kao, 1999) cointegration test	-3.01	-2.78	-3.39	-3.11	-2.35	-3.47
Cross-section dimension:	7	7	7	7	7	7
Time-series dimension:	24	24	24	24	24	24

Sources: Based on TFP calculated by authors (1970-96) for Belgium, Canada, Finland, France, Italy, Japan, and the Netherlands.

Notes: Country fixed effects included
{t-ratio in parenthesis}
Capital depreciation rate is assumed to be 5%

Table 6A. Effects of Two Productivities with Different Numeraire Currencies

	Labor Productivity			TFP		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
Relative to Japan	0.28	0.02	0.32	-1.01	0.06	-1.09
	{2.15}	{0.46}	{2.30}	{-3.74}	{0.45}	{-3.85}
ADF (Kao, 1999) cointegration test	-2.36	-2.31	-2.33	-2.29	-2.02	-1.71
Relative to Belgium	0.17	0.02	0.21	-0.46	0.83	0.14
	{1.60}	{0.21}	{2.45}	{-2.32}	{4.41}	{0.79}
ADF (Kao, 1999) cointegration test	-4.51	-2.69	-5.24	-3.72	-2.36	-4.22
Relative to Canada	-0.05	0.12	-0.02	-0.57	0.44	-0.43
	{-0.49}	{2.99}	{-0.27}	{-2.61}	{5.06}	{-2.21}
ADF (Kao, 1999) cointegration test	-4.30	-1.82	-4.77	-3.57	-2.90	-4.36
Relative to France	0.27	-0.01	0.29	-0.70	0.48	-0.46
	{4.42}	{-0.09}	{5.08}	{-1.27}	{3.49}	{-0.88}
ADF (Kao, 1999) cointegration test	-5.07	-2.21	-5.30	-3.25	-2.97	-3.40

Sources: Refer to notes for Table 4 and Table 5 for the information on the sample. The regressions correspond to panel III of Tables 4 and 5.

Table 6B. Labor Productivity and TFP, 1970–92

	(1)	(2)	(3)	(4)	(5)
Belgium	1.00	0.29	0.95	0.60	0.92
Canada	0.74	0.32	0.64	-0.52	0.07
Germany	-0.96	-0.79	-0.27	-0.92	0.48
Denmark	0.99	-0.16	0.85	-0.52	0.35
Finland	0.55	-0.53	-0.09	-0.59	-0.01
France	-0.61	-0.78	-0.90	-0.76	0.16
Italy	1.00	0.20	0.90	-0.26	0.82
Japan	0.99	0.98	0.84	0.91	0.95
Netherland	-0.97	-0.80	-0.47	-0.88	0.66
Sweden	-0.92	-0.87	-0.57	-0.96	-0.27
United States	0.95	-0.71			

	(6)	(7)	(8)	(9)	(10)
Belgium	0.98	0.01	0.68	-0.91	0.73
Canada	0.30	-0.82	-0.05	-0.91	-0.60
Denmark	0.92	-0.77	0.16	-0.91	-0.05
Finland	-0.34	-0.71	-0.64	-0.78	-0.32
France	-0.77	-0.84	-0.91	-0.86	-0.67
Italy	0.75	-0.78	-0.62	-0.53	0.15
Japan	0.96	0.96	0.12	0.88	0.90
Netherlands	-0.96	-0.84	-0.50	-0.92	0.17
Sweden	-0.94	-0.88	-0.61	-0.97	0.09
United States	0.69	-0.94			

Notes:

(1) Corr(log(TFP_T), log(LP_T))
(2) Corr(log(TFP_N), log(LP_N)
(3) Corr(log(TFP_T)-log(TFP_T)*, log(LP_T)-log(LP_T)*)
(4) Corr(log(TFP_N)-log(TFP_N)*, log(LP_N)-log(LP_N)*)
(5) Corr(relative TFP differential, relative LP differential)
(6) Corr(log(TFP_T),log(K/L_T))
(7) Corr(log(TFP_N),log(K/L_N)
(8) Corr(log(TFP_T)-log(TFP_T)*, log(K/L_T)-log(K/L_T)*)
(9) Corr(log(TFP_N)-log(TFP_N)*, log(K/L_N)-log(K/L_N)*)
(10) Corr(relative TFP differential, relative K/L differential)

Table 7. Effect of Retail Productivity on Internal Relative Prices

	pt-pn	pt-pn	pt-pn	pt-pn
log(Tfp_T)			-0.87	-0.98
			{-12.37}	{-9.09}
log(Tfp_N-RET)			0.26	0.10
			{1.51}	{0.62}
log(Tfp_RET)	-0.64	-0.08	0.10	0.01
	{-2.39}	{-0.33}	{0.79}	{0.08}
log(Real Wage)		-0.71		0.25
		{-4.54}		{1.76}
Maximum lead	1	1	1	1
Maximum lag	1	1	1	1
ADF (Kao, 1999) cointegration test	-0.69	-1.80	-2.77	-2.76
Cross-section dimension	9	9	9	9
Time-series dimension	20	20	20	20

Sources: 1970-92 data for Belgium, Canada, Germany, Denmark, Finland, France, Italy, the Netherlands, and Sweden.

Notes: Country fixed effects included
{t-ratio in parenthesis}
ADF statistic indicates the absence of cointegrating relationship.

Table 8. Effect of Retail TFP

	Panel I			Panel II		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
log(TFP_T)-log(TFP_T)*	-0.21	0.58	0.03	-1.02	0.68	-0.66
	{-1.06}	{6.76}	{0.14}	{-4.90}	{6.15}	{-3.40}
log(TFP_N-RET)-log(TFP_N-RET)*	-0.02	-0.15	-0.18	-0.98	-0.04	-1.03
	{-0.06}	{-1.11}	{-0.62}	{-3.68}	{-0.27}	{-4.15}
log(TFP_RET)-log(TFP_RET)*	0.18	-0.13	-0.04	-0.23	-0.09	-0.41
	{0.63}	{-1.07}	{-0.17}	{-1.09}	{-0.81}	{-2.07}
log(Real Wage)-log(Real Wage)*				1.82	-0.24	1.58
				{6.38}	{-1.55}	{5.92}
Maximum lead	1	1	1	1	1	1
Maximum lag	1	1	1	1	1	1
ADF (Kao, 1999) cointegration test	-4.04	-2.61	-5.27	-3.07	-2.76	-4.16
Cross-section dimension:	8	8	8	8	8	8
Time-series dimension:	20	20	20	20	20	20

Sources: 1970-92 data for Belgium, Germany, Denmark, Finland, France, Italy, the Netherlands, and Sweden.

Notes: Country fixed effects included
{t-ratio in parenthesis}

Table 9A. TFP Effects on CPI-Based Exchange Rates

	Panel I			Panel II		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
log(TFP_T)-log(TFP_T)*	0.20	-0.15	0.14	-1.35	0.68	-1.05
	{0.48}	{-0.38}	{0.38}	{-4.90}	{1.89}	{-3.84}
log(TFP_N)-log(TFP_N)*	0.10	-1.01	-0.35	-0.83	-0.58	-1.09
	{0.18}	{-1.86}	{-0.69}	{-3.01}	{-1.61}	{-3.98}
log(Real Wage)-log(Real Wage)*				1.72	-0.55	1.44
				{9.45}	{-2.36}	{8.01}
Maximum lead	1	1	1	1	1	1
Maximum lag	1	1	1	1	1	1
ADF (Kao, 1999) cointegration test	-2.5	-0.65	-3.02	-3.34	-1.01	-3.37
Cross-section dimension:	5	5	5	5	5	5
Time-series dimension:	20	20	20	20	20	20

	Panel III			Panel IV		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
relative tradable productivity differential	0.22	0.30	0.35	-0.20	0.64	0.09
	{0.55}	{0.81}	{0.90}	{-0.84}	{2.68}	{0.36}
log(Real Wage)-log(Real Wage)*				1.10	-0.50	0.85
				{6.12}	{-2.77}	{4.76}
Maximum lead	1	1	1	1	1	1
Maximum lag	1	1	1	1	1	1
ADF (Kao, 1999) cointegration test	-2.54	-0.93	-3.00	-2.68	-1.06	-2.82
Cross-section dimension:	5	5	5	5	5	5
Time-series dimension:	20	20	20	20	20	20

Sources: 1970-92 data for Canada, Germany, France, Italy, and Japan

Notes: Country fixed effects included
{t-ratio in parenthesis}
Cointegration is not supported (even at 10 percent) in middle columns of each panel.

Table 9B. TFP Effects: Comparator Regressions

	Panel I			Panel II		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
			2			
log(TFP_T)-log(TFP_T)*	0.03	0.68	0.31	-1.45	0.83	-1.04
	{0.06}	{4.46}	{0.64}	{-3.02}	{4.18}	{-2.47}
log(TFP_N)-log(TFP_N)*	0.51	-0.50	0.28	-0.39	-0.44	-0.55
	{0.69}	{-2.48}	{0.44}	{-0.80}	{-2.22}	{-1.31}
log(Real Wage)-log(Real Wage)*				1.82	-0.22	1.64
				{5.75}	{-1.66}	{5.95}
Maximum lead	1	1	1	1	1	1
Maximum lag	1	1	1	1	1	1
ADF (Kao, 1999) cointegration test	-2.13	-2.67	-2.27	-2.54	-2.53	-2.60
Cross-section dimension:	5	5	5	5	5	5
Time-series dimension:	20	20	20	20	20	20

	Panel III			Panel IV		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
relative tradable productivity differential	-0.03	0.58	0.20	-0.50	0.61	-0.23
	{-0.07}	{3.84}	{0.47}	{-1.52}	{4.40}	{-0.81}
log(Real Wage)-log(Real Wage)*				1.28	-0.12	1.17
				{5.20}	{-1.12}	{5.52}
Maximum lead	1	1	1	1	1	1
Maximum lag	1	1	1	1	1	1
ADF (Kao, 1999) cointegration test	-2.13	-2.85	-2.33	-2.34	-2.44	-2.39
Cross-section dimension:	5	5	5	5	5	5
Time-series dimension:	20	20	20	20	20	20

Sources: 1970-92 data for Canada, Germany, France, Italy, and Japan

Notes: Country fixed effects included
{t-ratio in parenthesis}

Table 10. Home Bias Effect

	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
log(TFP_T)-log(TFP_T)*	-3.34	-1.27	-3.77
	{-2.10}	{-0.66}	{-2.46}
log(TFP_N)-log(TFP_N)*	-1.07	-0.74	-1.40
	{-3.33}	{-1.90}	{-4.51}
log(Real Wage)-log(Real Wage)*	1.91	-0.40	1.70
	{8.46}	{-1.45}	{7.80}
HB*(log(TFP_T)-log(TFP_T)*)	-5.57	-5.58	-7.64
	{-1.24}	{-1.03}	{-1.77}
Maximum lead	1	1	1
Maximum lag	1	1	1
ADF (Kao, 1999) cointegration test	-3.34	-1.14	-3.41
Cross-section dimension:	5	5	5
Time-series dimension:	20	20	20

Sources: 1970-92 data for Belgium, Germany, Denmark, Finland, France, Italy, Netherlands, and Sweden

Notes: Country fixed effects included
{t-ratio in parenthesis}

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