DOES PRODUCTIVITY GROWTH APPRECIATE THE REAL EXCHANGE RATE?

Jaewoo Lee and Man-Keung Tang*

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* Lee: Research Department, International Monetary Fund (jlee3@imf.org). Tang: Economics Department, Harvard University (mktang@post.harvard.edu). We benefited from comments and suggestions by Menzie Chinn, Joe Gagnon, Peter Isard, and Alessandro Rebucci, as well as seminar participants in the 2004 Summer European Econometric Society Meeting. Two anonymous referees offered insightful comments that greatly improved the paper. The authors are solely responsible for all errors and misinterpretations. This paper should not be reported as representing the views of the IMF, and the views expressed are those of the author and do not necessarily reflect the views of the IMF or IMF policy.

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Abstract

Revisiting the time-honored link between productivity growth and the real exchange rate, we find that higher labor productivity tends to appreciate the real exchange rate, consistent with the traditional view. Contrary to the traditional view, however, we find that the positive productivity effect is transmitted through the relative price between tradable goods, rather than through the relative price between tradables and nontradables. Moreover, higher total factor productivity is found to often depreciate the real exchange rate. These latter two pieces of evidence, combined with the conceptual strength of total factor productivity over labor productivity as a productivity measure, support the emerging view that limited tradability of goods and services gives a play to strategic pricing decision, and call for further refinement of the conventional view regarding the effect of productivity on the real exchange rate.

I. Introduction

While the effects of monetary and financial fundamentals on the exchange rate continue 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 in turn contributes 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 (tradables) productivity and the real exchange rate was formulated by Samuelson (1964) and Balassa (1964)—also traced back to Harrod (1939)—this celebrated Harrod-Balassa-Samuelson (HBS) effect has formed the cornerstone of the analysis of real exchange rate. Accordingly, the HBS effect has been examined in voluminous empirical literature. 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. In particular, De Gregorio 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 and the relative productivity, both measured 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 Pacific 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. A similar pattern was subsequently established more clearly in the study of major exchange rates by Engel (1999). This casts a shadow over an implicit presumption behind the HBS effect— namely, that purchasing power parity holds for tradables prices between countries. This finding was echoed in Canzoneri and others (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 undertaken by Chinn and Johnston (1999) and Fitzgerald (2003). They found little evidence of the presence of a long-term relationship between the real exchange rate and the productivity differential between countries.

From the theoretical viewpoint, 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 decisions than traditional open-macro models do, 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.[1]

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. We then explore the long-term relationship between productivity and the real exchange rate by employing a panel cointegration technique, which helps to 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 find that the two often-used measures of productivity, labor productivity and total factor productivity (TFP), have different effects on the exchange rate. 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. This distinction also helps to reconcile some of the apparently contradicting results in the literature. Within each measure of productivity, we confirm the results of the extant literature. When productivity is measured by labor productivity, the correlation between the exchange rate and the productivity differential remains positive. This is consistent with findings of the literature

[1] 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.

based on labor productivity, which comprise papers until the 1980s. 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 negative at times. This finding is consistent with the results of Chinn and Johnston (1999) who also used TFP.

While differing in many aspects, estimated effects of the two productivity measures both point to a common contrast to the traditional HBS effect. The traditional version of the HBS effect requires that the tradables prices abide by purchasing power parity, implying that the tradables-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.

Many of our results agree with other studies of the effect of productivity on the real exchange rate under imperfect competition, namely by Cheung, Chinn, and Fujii (1999); Fitzgerald (2003); and MacDonald and Ricci (2002). One contrast lies in that we use both the labor productivity and the TFP as measures of productivity, thereby clarifying the role that different measures of productivity played in generating the diverse results reported in the literature. We also pay particular attention to the role of nontradables component, which Corsetti and Dedola (2002) has shown to be capable of generating a wedge between international markets in combination with imperfect competition.

II. Real Exchange Rate Accounting

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

$$Q = \frac{EP*}{P} \qquad (1)$$

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*}).

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

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

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

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

For P and P*, α and $\alpha*$ are weights of tradables in each country. For P_T and P_T^*, β and $\beta*$ are weights of foreign-produced tradables in each country. Values of β's and $\beta*$'s, and their difference (β - $\beta*$) more specifically, reflect the extent of home bias. Relative weights on traded goods (α and $\alpha*$) are likely to be similar across countries that are similarly open to trade, while β and $\beta*$ can differ, for example, reflecting brand preferences within the same industry.[2]

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.

$$Q_T = \frac{EP_T^*}{P_T} \tag{3}$$

[2] We assume α and $\alpha*$ to be the same in the regressions reported in this paper; the empirical results are however similar even when we take explicit account of the difference between α and $\alpha*$.

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

This equation becomes, assuming $\alpha = \alpha^*$,

$$\left(Q_N\right)^{1/(1-\alpha)} = \frac{P_N^* / P_T^*}{P_N / P_T} \quad .$$

The traditional HBS effect applies when the home and foreign produced tradables are perfect substitutes, and thus the law of one price holds for tradables price aggregates ($Q_T = 1$). Under this "aggregate" law of one price, 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 law of one price does not hold for traded aggregates, productivity can affect the real exchange rate through both Q_T and Q_N, possibly weakening the HBS effect that works through Q_N. To discuss the possible channels through which productivity affects Q_T, we rewrite Q_T as follows.

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

There are two possible channels through which the law of one price fails to apply to traded aggregates and tradables-based real exchange rate differs 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, there can be difference both between prices of home and foreign tradables within a country ($P_T^{H*} \neq P_T^{F*}$) and in the weight of foreign goods in consumption basket across countries ($\beta \neq \beta^*$). 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 the two countries.[3]

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 the law of one price 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 aggregate version of the law of one price. 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

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

when long-run neutrality holds for the effect of nominal shocks.[4] This calls for a complementary approach that explores other causes of long-run deviation from the aggregate law of one price, 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.

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 effect, even if the law of one price holds product by product, QT may still be affected by tradables productivity so long as the world demand for home-produced tradables is not infinitely price-elastic. The nontradables processing 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

[4] 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.

component implies that the law of one price may not have to hold for each tradable product and QT may not be equal to one. Moreover, nontradables productivity will affect QT, creating a unique effect. These contrasts are summarized in the text table.

	Tradables Productivity	Nontradables productivity
Harrod-Balassa-Samuelson (HBS)	QN	QN
Home Bias	QN, QT	QN
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 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 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 tradables account for a bigger share in the home consumption basket than in the foreign consumption basket. Although the law of one price can hold for each tradable product, price movement of different products can differ following an asymmetric productivity shock. Subsequent changes in QT will reflect the difference in the composition of consumption basket between the home and foreign countries.

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 nontradables 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, tradables productivity and nontradables productivity will both influence QT. Subject to the firms' pricing decision, tradables productivity improvement at home tends to generate real depreciation, as the effect works through the terms-of-trade effect. 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, both imported and domestically produced.

Models that allow for the endogenous change in the range of available product varieties introduce still another complication in the relationship between productivity and the exchange rate. In a model with monopolistic competition and endogenous variety of products, Corsetti et. al (2005) show that the terms of trade declines and the real exchange rate depreciates, when productivity gains lower the manufacturing cost and increase the scale of production, with the variety of produced products narrowing in the process. In contrast, the terms of trade improves and the real exchange rate appreciates, when productivity gains reduce the cost of introducing new varieties and thus increase the number of product varieties produced.

Of course, predictions of these models depend on several modeling assumptions that have been adopted to analyze the consequence of price rigidities in various open macro settings, or the way product varieties are endogenously determined. Their empirical predictions regarding the effect of productivity on the real exchange rate thus need to be taken with a grain of salt.[5] In this paper, we 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 data on nominal exchange rates are taken from the *International Financial Statistics* of the IMF. The other data come from the International Sectoral Database (ISDB, 1998 edition) and the Structural Analysis Industrial Database (STAN) of the Organization for Economic Cooperation and Development (OECD). They contain sectoral data for OECD countries, of which we use data for 12 countries: Belgium, Canada, 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, 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 DeGregorio and others (1994), tradable sector comprises agriculture, manufacturing, mining and transport ; and nontradable sector comprises utilities, construction, retail, financial services and community services.

[5] Probably the most comprehensive model with price rigidity 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.

For productivity measures, we use both labor productivity and total factor productivity (TFP).[6] 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. We then aggregate the industry level productivities of four tradable industries and five nontradable industries, using each industry's employment share as weights.

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 countries. We start by computing 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. Regression results based on alternatively assumed depreciation rate of 3 or 8 percent are similar to those reported here.

[6] Refer to the appendix on details of data construction, for productivity measures and prices.

Our price measures are output-based deflators, and warrant a discussion.[7] While consumer price indices are the preferred measure, the disaggregate CPIs were available only for six countries—Canada, Germany, France, Italy, Japan, and the United States—thereby allowing us to construct 5 bilateral real exchange rates. While we use this data to affirm several findings of the paper, most of the empirical investigation relies on output-based deflators, for three reasons. First, the results offer a comparison with the literature that has used deflators in measuring the prices of traded and nontraded aggregates. Second, the use of deflators can be justified when the null hypothesis incorporates perfect competition in the international tradables market. Thus, the results offer a test of the combined null hypothesis of HBS effect and perfect competition in the international market. Of course, the distinction between consumer prices and deflators should be borne in mind when the evidence is compared with the alternative hypothesis. In particular, the home bias effect is made up of two components: the terms-of-trade effect induced by imperfectly competitive international market, and the composition effect due to difference in consumption basket. Admittedly only with consumer prices can we jointly examine both components; however, the use of deflator-based real exchange rate can still allow us to assess the importance of the first component – the terms-of-trade effect. This is not a trivial quest, as some models (e.g. Corsetti et al. (2005)) have shown that improvement in productivity does not produce a theoretically clear-cut effect on the terms of trade.

[7] This discussion was triggered by the comment of an anonymous referee, who pointed out that many papers on exchange rates have erroneously ignored the distinction between consumer prices and deflators.

Finally, for the five currencies with sector-level CPI data, CPI-based real exchange rates (relative to the U.S.) are found to be cointegrated with deflator-based real exchange rates, with the unitary cointegrating vector (Table 2). Our finding of unitary cointegrating vector between the two real exchange rates offers an empirical resolution of the conceptual jump that has not been brought out in the literature. However, this resolution is empirical and tentative, and warrants further investigation using disaggregate data from a larger number of countries.

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 the price or productivity ratios between tradable and nontradable sectors, and use "differential" to refer to inter-country differences in any variable. For example, 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 tradables and nontradables 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, and relative productivity 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.[8]

$$\log Q_{Tit} = \beta_{0i} + \beta_1 \left(\log Z^*_{Tt} - \log Z_{Tit}\right) + \beta_2 \left(\log Z^*_{Nt} - \log Z_{Nit}\right) + \varepsilon_{it} \qquad (6)$$

In this equation, the tradables-based real exchange rate is regressed on the productivity differential in the tradable sector ($\log Z^*_T - \log Z_{Ti}$), and the productivity differential in the nontradable sector ($\log Z^*_N - \log Z_{Ni}$). 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.

$$\log Q_{Tit} = \beta_{0i} + \beta_1 \left[\left(\log Z^*_{Tt} - \log Z^*_{Nt}\right) - \left(\log Z_{Tit} - \log Z_{Nit}\right)\right] + \varepsilon_{it} \qquad (7)$$

[8] In the working paper version of this paper, we also examined a specification that included real wages, as a robustness check if nothing else. The effect of labor productivity was found to be subsumed into the wage channel in accordance with the standard theory, but the effect of TFP was qualified only marginally by the inclusion of real wages. The working paper is available at *http://www.imf.org/external/pubs/ft/wp/2003/wp03154.pdf*.

We vary dependent variables among three Q's and independent variables between labor productivity and TFP.

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).[9] Cointegrating relationship was estimated by the panel version of dynamic OLS (DOLS) in line with Kao and Chiang (2000) and Mark and Sul (2001).[10] The specific combination of dependent and independent variables changes with each specification, but all regressions are of the following format, where independent variable $\mathbf{Z}_{it}$ refers to the vector that comprises productivity variables as discussed in equations (6) and (7).

$$Q_{it} = \beta_{0i} + \beta_1 \mathbf{Z}_{it} + \sum_{k=-m}^{m} \beta_2 \Delta \mathbf{Z}_{it+k} + \varepsilon_{it} \qquad (8)$$

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

[9] The series that looks least nonstationary is the differential in nontradable labor productivities and the differential in real wage.

[10] The existence of cointegrating relationship was also confirmed by country-by-country regressions. We rely on panel estimates for statistical inference on the coefficients.

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. RESULTS

A. Qs and Productivity Differential

To investigate if and how real exchange rates are correlated with cross-country differentials in sectoral or relative productivity, we estimate regressions of type (6) and (7) for Q, QT, and QN. Equations of type (6) are:

$$\log Q_{it} = \beta_{0i} + \beta_1 \left(\log Z^*_{Tt} - \log Z_{Tit}\right) + \beta_2 \left(\log Z^*_{Nt} - \log Z_{Nit}\right) + \varepsilon_{it} \qquad (6A)$$

$$\log Q_{Tit} = \beta_{0i} + \beta_1 \left(\log Z^*_{Tt} - \log Z_{Tit}\right) + \beta_2 \left(\log Z^*_{Nt} - \log Z_{Nit}\right) + \varepsilon_{it} \qquad (6B)$$

$$\log Q_{Nit} = \beta_{0i} + \beta_1 \left(\log Z^*_{Tt} - \log Z_{Tit}\right) + \beta_2 \left(\log Z^*_{Nt} - \log Z_{Nit}\right) + \varepsilon_{it} \qquad (6C)$$

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 nonzero. If non-HBS effects (home bias and nontradables processing effects) are at work, slope coefficients in QT regressions are expected to differ from zero. Similar zero restrictions should apply to equations of type (7), where the regressors are relative productivity differentials.

We find that the relationship between real exchange rates and productivity differentials varies with the measure of productivity. The basis of this finding can be gleaned from Figures 1 and 2. In the three panels of Figure 1 that plot relative labor productivity differentials 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. In Figure 2 which plots three Q's and relative TFP differentials (for 10 countries from 1970 to 1992), relative TFP differentials appear to be somewhat negatively correlated with Q and QT, in contrast to Figure 1. For QN, relative TFP differentials appear to be strongly positively correlated with QN.

This contrast emerges more starkly in econometric estimates. Table 3 reports estimated effects of relative labor productivity differentials. In the upper panel, coefficient estimates for equation (6) do not provide much support for the HBS effect. Boding well for non-HBS effects, however, productivity differentials have no statistically significant effect on QN, while they have statistically significant effects on QT. For both Q and QT, higher tradables labor productivity leads to real appreciation, while higher nontradables productivity leads to real depreciation.[11] Moreover, the coefficient estimates on tradables and nontradables productivities are opposite in

[11] The apparently surprising positive effect of tradable labor productivity on QT might be attributed to what Corsetti et. al (2005) describes as productivity gains related to R&D activities and capability of product innovation.

sign and similar in magnitude. In particular, the statistically significant effect of nontradables productivity differential on QT indicates the presence of nontradables processing effect.[12] The effect of relative productivity differentials, reported in the lower panel, corroborates the results reported in the upper panel.

Next, the effects of TFP differentials are reported in Table 4, based on OECD data for 10 countries during 1970–1992 period. In the upper panels of the table, we find evidence supportive of the HBS effect in the QN regression, in contrast to Table 3 which is based on labor productivity. A faster increase in home tradables productivity leads to an appreciation in QN, while a faster increase in home nontradables productivity leads to a depreciation. As another contrast to Table 3, the effects of TFP differentials on QT are opposite in sign to those of labor productivity differentials. In Table 4, faster tradables TFP improvement leads to a real depreciation in QT, while nontradables TFP improvement leads to a real appreciation in QT, suggesting non-HBS effects.

In Table 4, the combined effect of productivity on the aggregate real exchange rate, Q, is not statistically significant, as conflicting effects on the two components (QT and QN) cancel out each other. Estimated effects of relative productivity differentials, shown in the lower panel, are consistent with results from the upper panel. An increase in the relative productivity differential appreciates QN, depreciates QT if any, and has no statistically significant effect on Q.

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[12] Nontradables processing effect captured here reflects the strategic pricing decision owing to the wedges induced by the presence of nontraded inputs (much like Corsetti and Dedola (2002) argument), rather than the composition effect that can hardly be captured by the price deflators based on value-added measures.

Finally, we repeat regressions behind the lower panels of Tables 3 and 4, namely regressions of three Q's on 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 an accidental outcome of having used the U.S. dollar as the numeraire currency. Table 5 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 differs from that of TFP. With the exception of Q's relative to Canada, labor productivity appreciates QT, has weak effect on QN, and appreciates Q. With Canada as the numeraire country, the statistically strong positive effect on QN is swept up by the statistically insignificant effect on QT, thereby resulting in no statistically significant effect of labor productivity on Q. The effects of TFP on QT and QN are also similar to those in Table 4, except that its effect on QN is not statistically significant when Japan is 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 either has no statistically significant effect or depreciates it, while labor productivity appreciates it.

We read the results, including the contrast between the two productivity measures, as providing a useful stepping stone for the study of the effect of productivity on real exchange rates. As we discussed in the introductory section, the literature itself has produced apparently contradicting results. While earlier studies based on labor productivities often produced evidence in favor of the HBS effect, more recent studies based on TFP have provided evidence against it. But this is essentially the result that we get using data from the same set of countries, and the contrast turns out to reflect the inherent difference between two measures of productivity used (more on this in the next section). Hence, our results envelope the major patterns identified in the literature.

B. Labor Productivity and TFP

The constrasting results just documented beckon us to compare directly the two measures of productivity. The literature on productivity and the real exchange rate, including tests of the HBS effect, has used both labor productivity and TFP as measures of productivity. Although conceptual difference between the 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, we have just seen that labor productivity and TFP often have different effects on the real exchange rate in the long run.

Assuming a Cobb-Douglas production function, we can derive the expression that links the two measures of productivity and their differentials across countries.

$$\log(Y/L) = \log(A) + \gamma \log(K/L) \tag{11}$$

$$\begin{aligned} &\log(Y/L) - \log(Y/L)^{*} \\ &= \left[\log(A) - \log(A)^{*}\right] + \left[(\gamma - \gamma^{*})\log(K/L) + \gamma^{*}\left(\log(K/L) - \log(K/L)^{*}\right)\right] \end{aligned} \tag{12}$$

Within each country (equation (11)), the two measures of productivity differential will move together unless capital-labor ratios are negatively correlated with TFP growth. Across countries (equation(12)), the 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.[13]

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

Column (1) of Table 6 shows the correlation between the log of tradables TFP and the log of tradables 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 tradables 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.

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

The positive correlation is even weaker for nontradables. Column (2) shows the correlation between the log of nontradables TFP and the log of nontradables 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 nontradables TFP differential and the nontradables 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 nontradables productivities are more positively correlated than within-country nontradables 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 the 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 reported in the lower panel of Table 6. The correlation between the tradables TFP differential and the tradables capital-labor ratio differential (column (8)) is negative for 6 of the 9 countries. And with the exception of Belgium, none of the countries shows a correlation higher than 0.2. Similarly, column (9) shows that the correlation between nontradables TFP differential and nontradables capital-labor ratio differential is negative for all countries except Japan.

These comparisons suggest 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. The measured differential in labor productivity would be a combined measure of TFP differential and investment-dynamics differential. Moreover, to the extent that investment responds to market conditions, demand shocks are likely to simultaneously affect both the real exchange rates and investment (thus labor productivity), implying that the measure of labor productivity is susceptible to endogeneity concerns. As a result, for the appraisal of theories on productivity and the real exchange rate—especially those that focus on QT—the TFP differential would be the more primitive and preferred measure of productivity, being free from the influence of the possibly endogenous variations in investment both over time and across countries.

Having provided an empirical synthesis of the findings in the literature, our results on sectoral real exchange rates call for a strong qualification to the unbridled HBS effect. For each productivity measure, there is some evidence that supports the HBS effect. However, the supportive evidence is undermined by a contradicting evidence that is obtained under the same productivity measure. Moreover, between the two sets of results using different productivity measures, the one based on the more theoretically satisfactory measure – TFP – provides less supportive evidence.

As we have just shown, labor productivity differential is found to appreciate the real exchange rate, apparently providing support for the HBS effect. At the same time, the positive association works through QT rather than QN, thereby invalidating the HBS effect narrowly interpreted: Under the narrow HBS effect, productivity is expected to have stronger effect on QN than on QT; however, the opposite is true in the data.

When we turn to TFP, the differentials in TFP are found to appreciate QN, consistent with the prediction of the HBS effect. But then again, TFP differentials are found to have no statistically significant effect on the real exchange rate (Q), and to depreciate QT if any. If only the HBS effect were at work, TFP differentials would not have depreciated QT, and would also have appreciated the real exchange rate (Q).

Even in cases which appear to support the HBS effect, a deeper investigation reveals that the actual channel beckons us to look harder at non-HBS effects, be it as an alternative or additional link between productivity and the real exchange rate. Moreover, the results based on TFP—a preferred measure of productivity not influenced by investment dynamics—show that tradables productivity tends to depreciate the real exchange rates between tradables and between aggregates. This casts a very strong doubt on the traditional version of HBS effect.

Finally, besides casting doubt on the HBS effect, our results indicate that non-HBS effects work largely through QT. 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 nominal shocks, QT appears to be also a key transmitter of real (productivity) shocks in the long run.

VI. Conclusion

Whether productivity growth leads to appreciation or depreciation of the real exchange rate depends on the measure of productivity 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 positive effect, however, works mostly through the tradables-based real exchange rate (QT)—and not through the relative price differential between traded and nontraded sectors (QN)—contrary to the textbook version of the Harrod-Balassa-Samuelson (HBS) effect.

When total factor productivity (TFP) is used to measure productivity, the classical positive association between productivity and the real exchange rate dissipates. 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 effect needs to be taken more seriously.

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 make room for strategic pricing decisions, including the nontradables-processing 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 effect that operates through strategic pricing decisions of firms involved.

Having acknowledged the critical caveat, we can infer some lessons for future work on productivity and the exchange rate. First, 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. Next, 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. This happens to coincide with the directions taken by some of the emerging theoretical literature in international macroeconomics.

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Appendix : Data Construction

This appendix discusses how we aggregate industry-level data to construct the price, labor productivity and TFP indexes for the tradable and nontradable sectors. Following DeGregorio, Giovannini and Wolf (1994), at 2-digit ISIC level, the 4 tradable industries are agriculture, mining, manufacturing and transport; and the 5 nontradable industries are utilities, construction, retail, financial services and community services. Data are taken from the ISDB (1998) and STAN.

For the following, subscript *s* refers to industry, *i* country, *y* year, and superscript *h* denotes sector (tradable or nontradable).

- Price of tradables (nontradables) for country *i* in year *y*:

$$P_{i,y}^{h} = \exp\left[\sum_{s\in h} w_{s,i} \log(P_{s,i,y})\right], \quad h \in \{\text{Tradables, Nontradables}\}$$

where the country-specific weights are based on the size of value added of each industry averaged over 1970-1992. That is,

$w_{s,i} = \dfrac{\sum_{y'} VA_{s,i,y'}}{\sum_{y'}\sum_{s'\in h} VA_{s',i,y'}}$, y' from 1970 to 1992, and *VA* is value added measured at current prices.

Except in Table 5, where gross output-based deflators are used, all prices used are value added-based deflators.

$$P_{s,i,y} = \frac{VA_{s,i,y} / VAV_{s,i,y}}{VA_{s,i,1970} / VAV_{s,i,1970}} \text{ (value-added based), or}$$

$$\frac{GO_{s,i,y} / GOV_{s,i,y}}{GO_{s,i,1970} / GOV_{s,i,1970}} \text{ (gross-output based)}$$

where *VAV* is value added volume, *GO* is gross output measured at current prices and *GOV* is gross output volume.

- Labor productivity index of tradables (nontradables) for country *i* in year *y*:

$$LP_{i,y}^{h} = \exp\left[\sum_{s\in h} w_{s,i} \log(LP_{s,i,y})\right], \quad h \in \{\text{Tradables, Nontradables}\}$$

where $LP_{s,i,y} = \dfrac{VAV_{s,i,y} / EM_{s,i,y}}{VAV_{s,i,1970} / EM_{s,i,1970}}$. *VAV* is value-added volume and *EM* is total employment.

- TFP index of tradables (nontradables) for country *i* in year *y*:

$$TFP_{i,y}^{h} = \exp\left[\sum_{s\in h} w_{s,i} \log(TFP_{s,i,y})\right], \quad h \in \{\text{Tradables, Nontradables}\},$$

where between 1970 and 1992, $TFP_{s,i,y} = \dfrac{TFPISDB_{s,i,y}}{TFPISDB_{s,i,1970}}$. *TFPISDB* is the TFP figures published by the ISDB.

After 1992, industry level TFP figures are not reported in the database. We compute the TFP figures for each industry between 1993 and 1996, assuming simple Cobb-Douglas production functions with two inputs (labor and capital) and constant returns:
$VAV_{s,i,y} = TFP_{s,i,y}(EM_{s,i,y})^{\alpha_{s,i}}(K_{s,i,y})^{1-\alpha_{s,i}}$ where *EM* is total employment and *K* is capital. $\alpha_{s,i}$ is allowed to vary across both industries and countries. We use the labor share figures for the year when the ISDB TFP series ends to proxy for $\alpha_{s,i}$. The corresponding gross fixed capital formation figures are used to back out the initial capital stock. The extended TFP series between 1993 and 1996 is constructed with subsequent industry-level data on value-added volume, employment and gross fixed capital formation, with the assumption that capital stock depreciates at 5% per year.

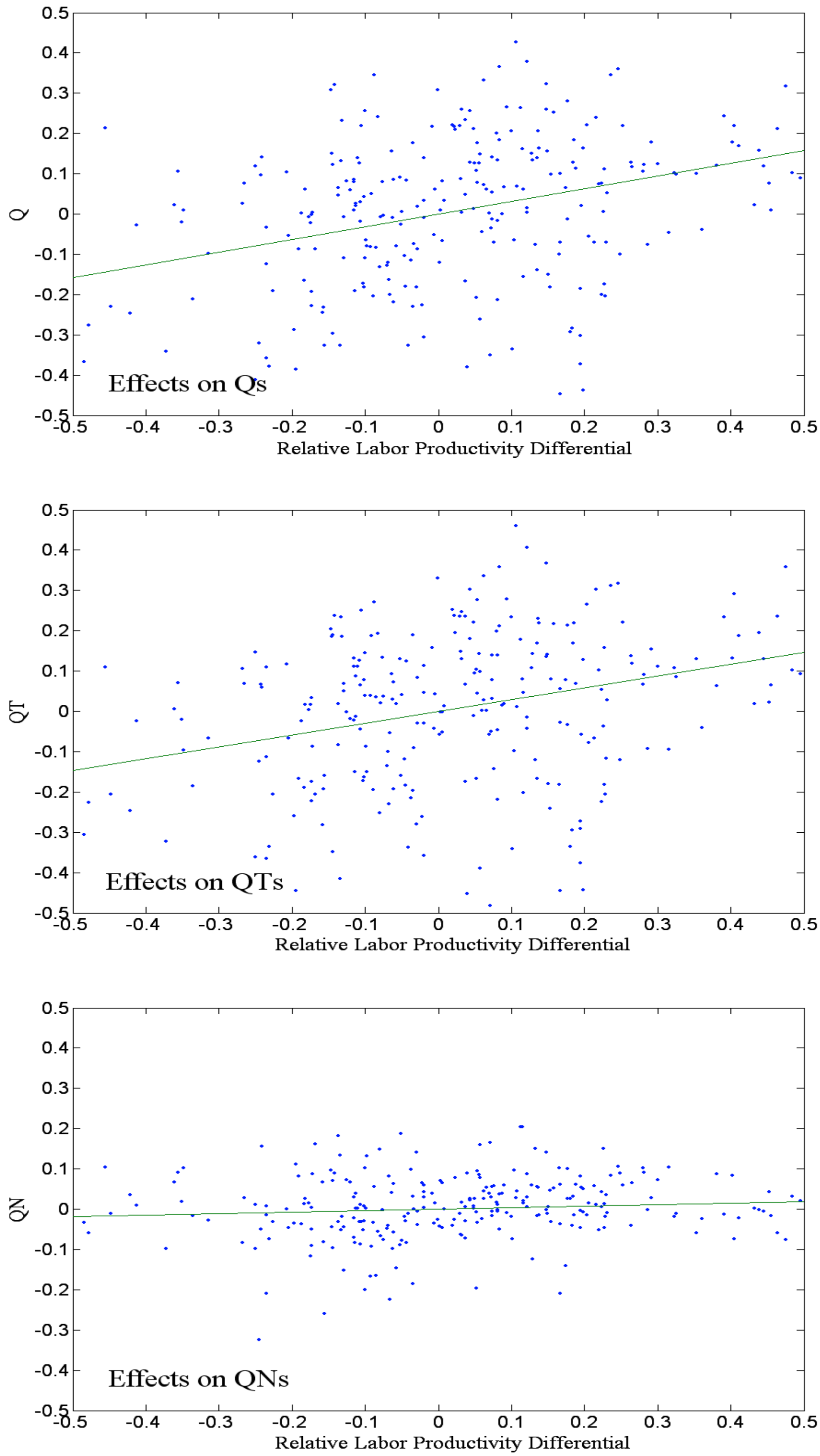

Figure 1. The Effects of Relative Labor Productivity Differentials.

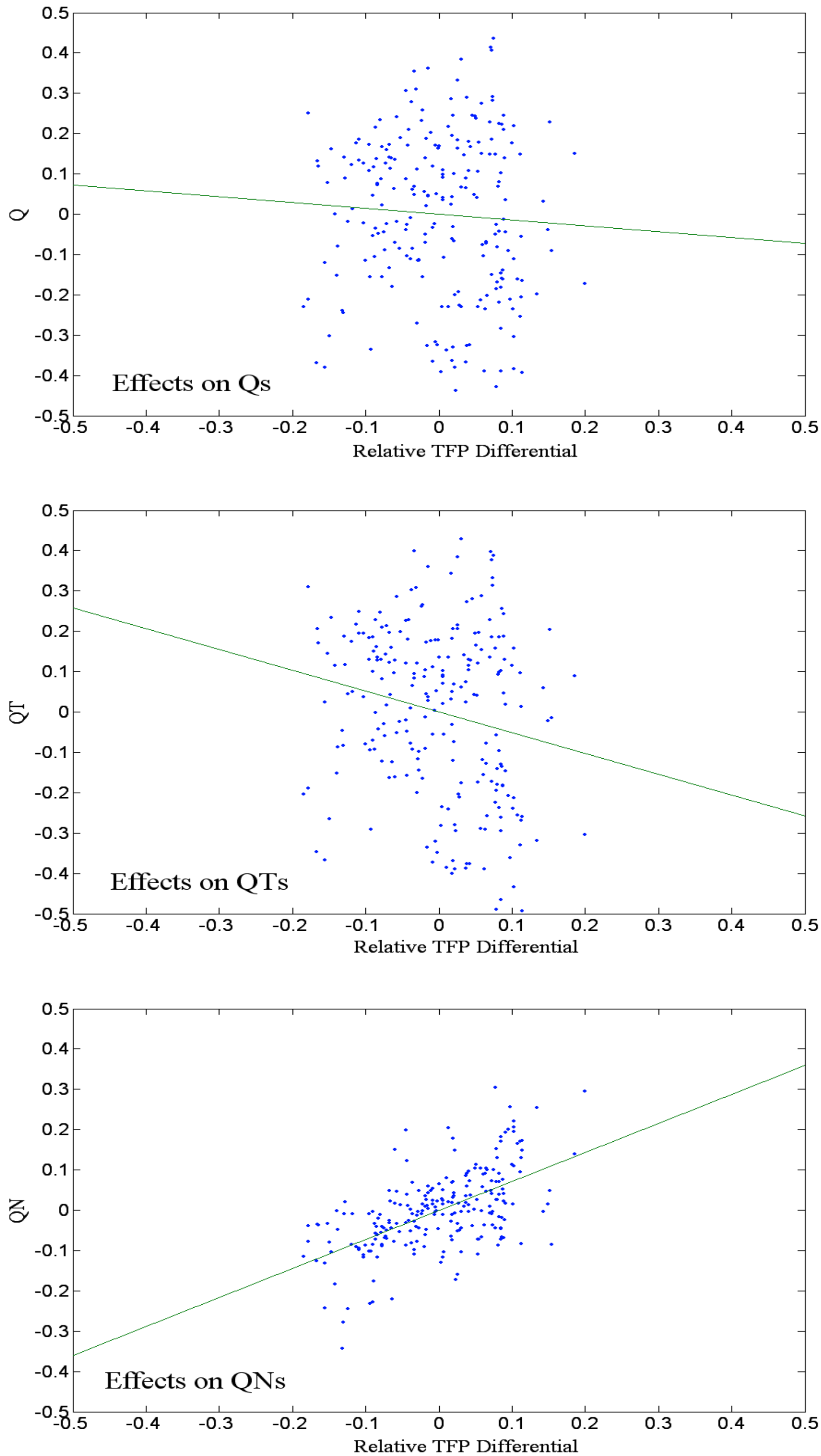

Figure 2. The Effects of Relative TFP Differentials.

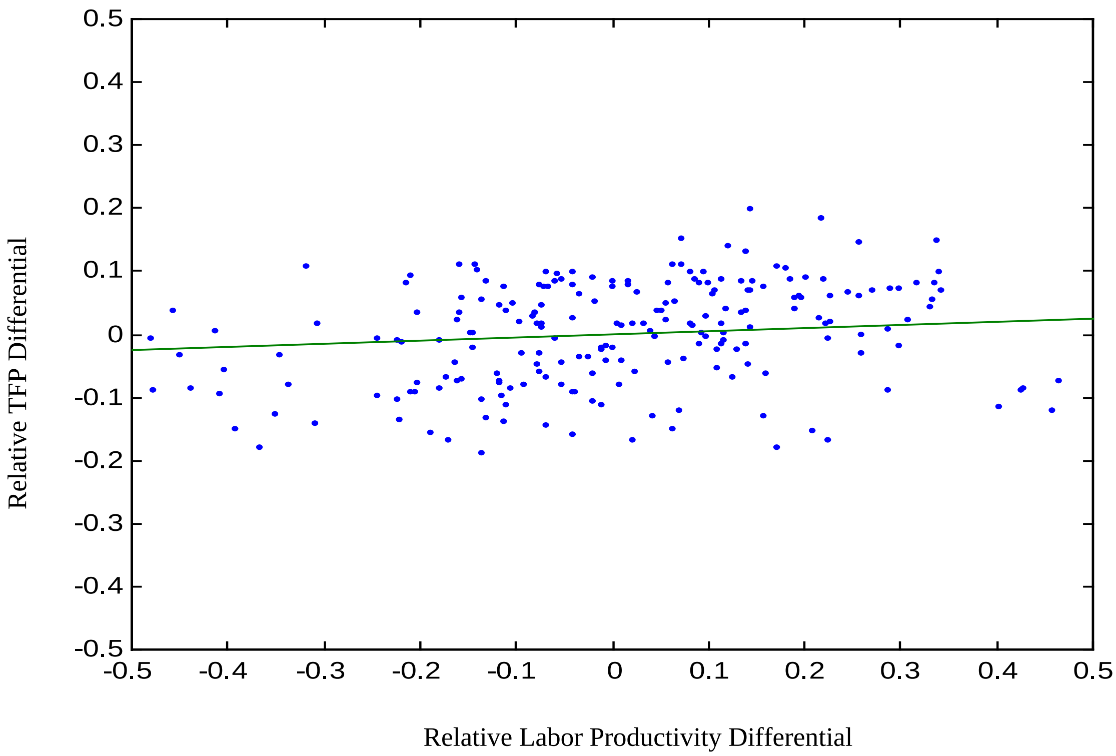

Figure 3. Relative TFP Differential and Relative Labor Productivity Differential.

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(TFP_T)-log(TFP_T)*	-0.81
5)	log(TFP_N)-log(TFP_N)*	-0.05
6)	relative productivity differential: 5)-6)	-0.49
7)	log(LP_T)-log(LP_T)*	-0.52
8)	log(LP_N)-log(LP_N)*	-4.24
9)	relative productivity differential: 8)-9)	-1.19
10)	log(MTFP_T)-log(MTFP_T)*	-0.76
11)	log(MTFP_N)-log(MTFP_N)*	-2.11
12)	relative productivity differential: 11)-12)	-0.96

Note:
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)-6): 1970-1992, 10 countries including BEL, CAN, DEU, DNK, FIN, FRA, ITA, JPN, NLD, SWE
7)-9): 1970-1997, 11 countries including BEL, CAN, DEU, DNK, FIN, FRA, GBR, ITA, JPN, NLD, SWE
10)-12): 1970-1996, 7 countries including BEL, CAN, FIN, FRA, ITA, JPN, NLD

Table 2. Relationship between Q's based on Different Deflators

	QT	QN
Coefficient Estimate	0.98	1.26
	{11.77}	{3.16}
t-ratio (null that coefficient = 1)	{-0.28}	{0.65}
Diagnostics:		
maximum lead	1	1
maximum lag	1	1
Cointegration test (Kao, 1999)		
cross-section dimension	5	5
time-series dimension	23	23

Cointegrating regression of CPI-based sectoral real exchange rates on
GDP deflator-based sectoral real exchange rates
1970-1995, Canada, Germany, France, Italy, Japan
Country fixed effects included
{t-ratio in parenthesis}

Table 3. Effects of Labor Productivity

	Panel I		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
log(LP_T)-log(LP_T)*	0.242	-0.007	0.235
	{2.65}	{-0.14}	{2.95}
log(LP_N)-log(LP_N)*	-0.369	0.006	-0.283
	{-1.88}	{0.05}	{-1.64}
Diagnostics:			
maximum lead	1	1	1
maximum lag	1	1	1
Cointegration test (Kao, 1999)	-4.92	-1.90	-5.71
Cross section dimension:	11	11	11
Time series dimension:	25	25	25

	Panel II		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
relative productivity differential	0.27	0.01	0.28
	{3.43}	{0.17}	{4.13}
Diagnostics:			
maximum lead	1.00	1.00	1.00
maximum lag	1.00	1.00	1.00
Cointegration test (Kao, 1999)	-5.05	-2.14	-5.92
Cross section dimension:	11	11	11
Time series dimension:	25	25	25

Based on Labor Productivity (1970-1997) for Belgium, Canada, Germany, Denmark, Finland, France, United Kingdom, Italy, Japan, Netherlands, Sweden
Country fixed effects included
{t-ratio in parenthesis}

Table 4. Effects of Total Factor Productivity

	Panel I		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
log(TFP_T)-log(TFP_T)*	-0.70	0.98	-0.20
	{-1.86}	{5.95}	{-0.63}
log(TFP_N)-log(TFP_N)*	0.81	-0.39	0.54
	{1.63}	{-1.79}	{1.29}
Diagnostic information			
maximum lead	1	1	1
maximum lag	1	1	1
Cointegration test (Kao, 1999)	-3.57	-3.18	-3.91
Cross section dimension:	10	10	10
Time series dimension:	20	20	20

	Panel II		
	s+pt-pt*	(pt*-pn*)-(pt-pn)	s+p-p*
relative productivity differential	-0.73	0.80	-0.30
	{-2.1}	{4.52}	{-1.04}
Diagnostic information			
maximum lead	1	1	1
maximum lag	1	1	1
Cointegration test (Kao, 1999)	-3.64	-2.92	-4.07
Cross section dimension:	10	10	10
Time series dimension:	20	20	20

Based on Total Factor Productivity (1970-1992) obtained from ISDB for Belgium, Canada, Germany, Denmark, Finland, France, Italy, Japan, Netherlands, Sweden

Country fixed effects included

{t-ratio in parenthesis}

Table 5. 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}
Cointegration test (Kao, 1999)	-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}
Cointegration test (Kao, 1999)	-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}
Cointegration test (Kao, 1999)	-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}
Cointegration test (Kao, 1999)	-5.07	-2.21	-5.30	-3.25	-2.97	-3.40

Refer to Table 4 and Table 5 for notes; The regressions correspond to panel II of Tables 4 and 5.

Table 6. Labor Productivity and TFP 1970–1992

	(1)	(2)	(3)	(4)	(5)
BEL	1.00	0.29	0.95	0.60	0.92
CAN	0.74	0.32	0.64	-0.52	0.07
DEU	-0.96	-0.79	-0.27	-0.92	0.48
DNK	0.99	-0.16	0.85	-0.52	0.35
FIN	0.55	-0.53	-0.09	-0.59	-0.01
FRA	-0.61	-0.78	-0.90	-0.76	0.16
ITA	1.00	0.20	0.90	-0.26	0.82
JPN	0.99	0.98	0.84	0.91	0.95
NLD	-0.97	-0.80	-0.47	-0.88	0.66
SWE	-0.92	-0.87	-0.57	-0.96	-0.27
USA	0.95	-0.71			

	(6)	(7)	(8)	(9)	(10)
BEL	0.98	0.01	0.68	-0.91	0.73
CAN	0.30	-0.82	-0.05	-0.91	-0.60
DNK	0.92	-0.77	0.16	-0.91	-0.05
FIN	-0.34	-0.71	-0.64	-0.78	-0.32
FRA	-0.77	-0.84	-0.91	-0.86	-0.67
ITA	0.75	-0.78	-0.62	-0.53	0.15
JPN	0.96	0.96	0.12	0.88	0.90
NLD	-0.96	-0.84	-0.50	-0.92	0.17
SWE	-0.94	-0.88	-0.61	-0.97	0.09
USA	0.69	-0.94			

Note:

(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)