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# Understanding Real Exchange Rate Movements with Trade in Intermediate Products\*

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## Abstract

We suggest it may be “too easy” to attribute real exchange rate movements to law of one price deviations. We show that it is immaterial whether one uses seemingly traded goods, nontraded goods, or even just a single, unimportant consumer good, say beer. The ease of attributing the variation to any such deviations is explained using a model with intermediate goods trade. In the model, the stage of production determines the traded/nontraded distinction. We find empirical substantiation for the model: law of one price deviations lose explanatory power; and – defined appropriately in terms of intermediate goods – relative prices matter.

**JEL Classification:** F3 F4

**Keywords:** Real Exchange Rates, PPP, MSE decomposition

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# 1 Introduction

U.S. real exchange rates, by any measure, have fluctuated widely for decades. The extent of their variability is well documented, but an understanding of the source of the variability remains elusive; and understanding real exchange rates, in general, remains a daunting task. Most theoretical explanations of the behavior of real exchange rate changes fall into one of two categories.<sup>1</sup> The first category relates to the failure of the law of one price internationally. The second category reflects conditions that are fundamentally domestic and that result in changes in relative prices within a country. Despite solid theoretical foundations, empirical support for the importance of internal relative prices has thus far been weak. For example, Engel (1999), and many others after him, have decomposed the real exchange rate into two components designed to capture precisely these two approaches to understanding the real exchange rate's behavior. Most of the work in that vein has concluded quite strongly that deviations from the law of one price are empirically much more important than are the prices of traded goods relative to nontraded goods.

In this paper, we reinterpret such decompositions. Modifying the decompositions, we again compare the empirical importance of deviations from the law of one price with the importance of the relative prices of goods within countries. However, we find that the answer depends crucially on how we distinguish what is traded from what is not.

We first suggest that it is perhaps "too easy" to account for the real exchange rate fluctuations using deviations from the law of one price in consumer goods. We begin by looking carefully at the prices of a matched sample of individual Japanese and U.S. final goods and services, as well as at aggregate consumer prices in the two countries. We find that deviations from the law of one price for any single good (such as bottle of whiskey or a carton of eggs), which has only a tiny share in consumption, can account for a large share of the real exchange rate's variation. If the standard interpretation of this finding were correct, it would have far reaching implications. In particular, it would seem to matter

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<sup>1</sup>Empirically, measurement issues also have been important in explaining the observed exchange rate variability. For example, the product-aggregation bias described by Imbs, Mumtaz, Ravn, and Rey, 2005 (though its empirical importance was questioned by Chen and Engel, 2005), the temporal aggregation bias described by Taylor (2001), and the bias generated by non-compatible consumption baskets across countries all offer some reason why the real exchange rate might both differ from one and appear to be quite variable. For our empirical exercises, these measurement issues turn out to be unimportant.

little what happens to the price of any particular final good or set of goods relative to the prices of other final goods within countries. Moreover, we show that it is not just ‘traded’ goods (as noted in past studies) whose deviations in the law of one price can account for real exchange rate movements. Nontraded goods do just as well. For final goods, the traded/nontraded distinction is essentially irrelevant.

To explore the seeming irrelevance of the traded/nontraded distinction, we use a simple model of trade in intermediate products. The model reflects the work of Sanyal and Jones (1982) and of Burstein, Eichenbaum, and Rebelo (2005, 2006) among others. In this model, the traded/nontraded distinction manifests itself at the stage of production. Consequently, differences in tradeability across final goods play a much smaller role. Imports are traded, intermediate inputs into production; and final goods require a nontraded input. This framework implies that it is the price of imports relative to other goods in each country, not the relative prices of any subsets of final goods, that should matter for the real exchange rate.

We empirically examine this implication of the model, and we find support for it. Identifying the real exchange rate’s traded portion using the implicit import weight in the Consumer Price Index, we find that the relative traded/nontraded price does in fact account for the largest share of the real exchange rate’s variation. These findings contrast starkly with all earlier results of such decompositions among countries with flexible exchange rates; and, they provide fresh support for traditional models of the real exchange rate, models which rely on the distinction between the open and closed sectors of the economy.

## 2 Background: The Benchmark Decomposition

Some standard notation allows us to be more concrete about the two main approaches to explaining real exchange rate behavior and about their empirical counterparts. Let  $s$  denote the nominal exchange rate, expressed as domestic currency per unit of foreign currency, let  $p$  denote the aggregate price index, and let asterisks denote foreign variables. The real exchange rate is then:  $q = \frac{sp^*}{p}$ . To introduce the traded/nontraded distinction into this definition, we adopt the common heuristic that assumes the aggregate price index

is a geometric weighted average of the prices of traded and nontraded goods, denoted  $p_T$  and  $p_N$ . With  $\omega$  denoting the share of traded goods,<sup>2</sup> the aggregate price indices are:  $p = p_T^\omega p_N^{1-\omega}$  and  $p^* = p_T^{*\omega} p_N^{*1-\omega}$ . The real exchange rate now can be written in terms of the prices of traded and nontraded goods:

$$q = \frac{s p_T^{*\omega} p_N^{*1-\omega}}{p_T^\omega p_N^{1-\omega}}$$

Taking logs and rearranging a little gives an expression for the real exchange rate that dichotomizes it into the two terms that represent the two competing theoretical approaches:

$$(1) \quad \ln q = [\ln s + \ln p_T^* - \ln p_T] + (1 - \omega) \left[ \ln \frac{p_N^*}{p_T^*} - \ln \frac{p_N}{p_T} \right].$$

The term in the first set of square brackets is the deviation from the law of one price in traded goods, and the term in the second square brackets is the international difference in the price of nontraded goods relative to the price of traded goods. So, armed with domestic and foreign sub-price indices representing the traded and nontraded components underlying the overall price index, one can apportion observed movements in the overall real exchange rate to shares attributable to each of the two bracketed terms.

If observed fluctuations in the real exchange rate were best explained by the first term, then that would support those theories of real exchange rate behavior that rely on international barriers to trade, such as tariffs or transportation costs.<sup>3</sup> Alternatively, if the deviations were best explained by changes in the second term, then that would support theories that rely on differences in the domestic conditions of the individual countries. Such differences might arise, for example, from the Harrod-Balassa-Samuelson effect.<sup>4</sup>

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<sup>2</sup>Of course, the share,  $\omega$ , varies across countries. However, for the decompositions we study, this does not matter in practice. By construction, the weights in the decompositions cannot vary within the sample; so, they cannot account for fluctuations in the real exchange rate. So, for simplicity, we retain the notation that equates the domestic and foreign weights.

<sup>3</sup>While the law of one price can fail most obviously because of transportation costs and official trade barriers, it also can fail due to non-competitive market structures and other conditions that result in nominal price rigidities.

<sup>4</sup>The second term reflects exchange rate theories that most typically rely either on differential changes

Such results might also be interpreted as supporting some of the theories that rely on non-competitive market structures, but only to the extent that those theories have implications that are differentially important across traded and nontraded sectors.

The most important exemplar of this empirical approach is Engel (1999). What is startling about Engel's findings is how much of the real exchange rate's variability can be explained by the first term: deviations in the law of one price in traded goods account "for nearly 100 percent of the mean square error of the U.S. real exchange rate changes..." This finding has been substantiated for many other countries with floating exchange rates.<sup>5</sup> By and large, the prices of traded goods relative to nontraded goods have not seemed to matter much at all. It is this conclusion about relative prices - and what it means for the distinction between traded and nontraded goods - that we would like consider more closely.

### 3 Final Goods and Services

In this section, we provide two new decompositions using consumer goods price data from Japan and the United States. The results we present are illustrative, and they motivate the model and alternative empirical approach that follows.

First, we decompose the real exchange rate using individual goods. We find that deviations from the law of one price in any one of them can single-handedly account for a surprisingly large share of the real exchange rate's variation. Next, we swap the

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in productivity across the sectors of the economy, or on changes in the relative demands across sectors. The Harrod (1933) -Balassa (1964) -Samuelson (1964) proposition provides a potential explanation of even long-term deviations from purchasing power parity. The other explanations reflected by the second term are primarily shorter-term. Changes in preferences across the traded and nontraded sectors - whether due to changes in, say, consumption or government expenditures - will affect relative prices for as long as it takes for the factors of production to move across the sectors within a country. (Some of the new open economy models fit into this category as well.)

<sup>5</sup>Using a similar method, Betts and Kehoe (2001) examine 52 countries and find somewhat smaller, but still very large shares of the real exchange rate can be accounted for by deviations from the law of one price when producer prices are used. Mendoza (2005) also confirms Engel's findings for the U.S.-Mexico real exchange rate, except during periods when the peso was fixed to the dollar. Parsley (2007) using data from six south-east Asian countries, where intra-country relative productivity changes often are alleged to have occurred, finds results very similar to Engel's. Leading up to Engel's study, earlier work documented the relative stability of nontraded goods prices. See, for example, the early summary provided by Boucher Breuer (1994) or the later examples in differing contexts by Boucher Breuer and Lippert (1997) and by Ceglowski (2006).

roles of ostensibly traded and nontraded goods in Engel’s original decomposition. We find that it doesn’t matter whether we look at ostensibly traded or nontraded consumer goods. The traded and nontraded results are indistinguishable. For final goods, the traded/nontraded distinction appears to be irrelevant; and, every individual final good we examine appears to behave as if it is nontraded. The results of this section call into question the appropriateness of making a traded/nontraded distinction at the consumer level. Subsequent sections explore an alternative method for making that distinction.

### 3.1 Individual goods

To isolate the role of a single good, we note that we can write the domestic price index,  $p$ , in terms of the price of the  $i^{th}$  good,  $p_i$ , and the prices of all other goods,  $p_{-i}$ . We also can write the foreign price index,  $p^*$ , in terms of the corresponding foreign prices,  $p_i^*$  and  $p_{-i}^*$ . Denoting the weights in the price indices as  $\nu$  and  $(1 - \nu)$ , we have:<sup>6</sup>

$$p = p_i^\nu p_{-i}^{1-\nu}$$

$$p^* = p_i^{*\nu} p_{-i}^{*1-\nu}.$$

We can now write the real exchange rate in a way analogous to Equation (1) and decompose it into comparable constituents:

$$(2) \quad \ln q = (\ln s + \ln p_i^* - \ln p_i) + (1 - \nu) \left( \ln \frac{p_{-i}^*}{p_i^*} - \ln \frac{p_{-i}}{p_i} \right).$$

Here, the first term in the sum is the deviation from the law of one price in the  $i^{th}$  good. The second term is the international difference in its price relative to all other prices in the consumer basket. Note that rewriting the real exchange rate in this way does not change its original definition. Nor have the definitions of the domestic and foreign consumer price indices ( $p$  and  $p^*$ ) changed. However, having written the real exchange rate this way, we now are ready to gauge how much of the variation in the real exchange rate can be

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<sup>6</sup>As described above, the weights would in principle vary across countries. However, by construction, the weights cannot vary within the sample, so they cannot account for fluctuations in the real exchange rate. For expositional simplicity, we therefore retain the notation that equates the domestic and foreign weights.

attributed to the deviations from the law of one price in a single item, the first term.

We use data that include observations of prices of comparable individual Japanese and U.S. goods and services. Each of the goods and services was selected in order to have as close a match as possible between the two countries. The use of individual goods allows us to construct precise law of one price deviations. This minimizes problems associated with cross-country differences in CPI baskets. Additionally, the individual prices we study are collected at roughly the same point in time in both countries, which avoids a temporal bias often associated with CPI data.<sup>7</sup>

The source for the Japanese data is the Annual Report on the Retail Price Survey, published by the Statistics Bureau of the Management and Coordination Agency of the Government of Japan. The source for the U.S. data is the Cost of Living Index published by the American Chamber of Commerce Researchers Association. The data are quarterly, and they run from 1976 through 1997.<sup>8</sup>

Letting the subscript  $t$  denote the time period of each observation, we have the following identity in each period:

$$\ln q_t = (\ln s_t + \ln p_{i,t}^* - \ln p_{i,t}) + (1 - \nu) \left( \ln \frac{p_{-i,t}^*}{p_{i,t}^*} - \ln \frac{p_{-i,t}}{p_{i,t}} \right).$$

We are interested in the ability of each of the two components to account for the real exchange rate's variation, and our measure of variability is the real exchange rate's mean square error. Since there is no error term in this expression, the two components combined (along with their covariances, which are very small in our sample) must account for all of the variability in the real exchange rate in the sample.

Following Engel (1999), we focus on the mean squared error of changes in these variables. We calculate the  $k$ -period change in the real exchange rate,  $\ln q_t - \ln q_{t-k}$  for all of the horizons that the data allow.<sup>9</sup> We use the observations of the individual prices of

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<sup>7</sup>Taylor (2001) shows that averaging data collected at different points in time (a feature of CPI data) leads to biased estimates of real exchange rate persistence.

<sup>8</sup>More details are provided in Parsley and Wei (2001) and Parsley and Wei (1996). The data are available at: <http://www2.owen.vanderbilt.edu/david.parsley/research.html>

<sup>9</sup>Such an examination of a range of horizons is important since, in principle, the results might vary across horizons. For example, one might expect, *a priori*, that the deviations from the law of one price in traded goods might be important only at relatively short horizons, while the importance of such things as the Balassa-Harrod-Samuelson effect might be evident at longer horizons.



goods and services in the two countries to construct the corresponding law of one price deviations for each good or service at each horizon.<sup>10</sup> Now, we can calculate the fraction of the mean square error that can be attributed to changes in the deviation from the law of one price for each good or service.

The mean square error of the real exchange rate change is:  $MSE(\ln q_t - \ln q_{t-k}) = var(\ln q_t - \ln q_{t-k}) + [mean(\ln q_t - \ln q_{t-k})]^2$ , and the MSE of each of the two components is correspondingly measured. We follow Engel (1999) in calculating the mean change in the real exchange rate as:  $mean(\ln q_t - \ln q_{t-k}) = \frac{k}{\tau-1}(\ln q_\tau - \ln q_1)$ , where  $\tau$  is the sample length; and we calculate the mean changes in each of the two components correspondingly. For each good, we calculate the ratio:  $\frac{MSE(x_{t+k}-x_t)}{MSE(x_{t+k}-x_t)+MSE(y_{t+k}-y_t)}$ , where  $x$  is the real exchange rate's first component, the deviation in the law of one price in the individual good; and,  $y$  is its second component, the international difference in the price of the individual good relative to other goods. By focusing on this particular ratio, we are ignoring the correlations between the two components; however, the correlations are small, as mentioned above, and negative in our sample, so this simplification has no appreciable impact on the results.

Figure 1a illustrates how much of the mean square error of the real exchange rate change can be accounted for by deviations from the law of one price of a haircut, the classic example of a nontraded good. At nearly all horizons, haircuts appear to account for an astonishingly large share of all of the variability in real exchange rates. That is, despite the fact that the share of haircuts in the aggregate price index is very small, deviations in the law of one price of haircuts account for a large fraction of the variability of the real exchange rate. Moreover, this result does not abate even at very long horizons, when the changes in exchange rates and prices are measured at intervals of, say, over a decade (that is,  $k > 40$ ).

Figure 1b presents the results when the single good is eggs. Again, the individual price component, the first term, appears to account for a significant share of the real exchange

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<sup>10</sup>The change in the second term is then, of course, the difference between the change in the real exchange rate and the change in the deviation from the law of one price. That is, the expression for the real exchange rate is an identity, and the deviation from the law of one price is:  $(\ln s_t + \ln p_{i,t}^* - \ln p_{i,t}) - (\ln s_{t-k} + \ln p_{i,t-k}^* - \ln p_{i,t-k})$ ; so, the international difference in the relative prices is:  $(\ln q_t - \ln q_{t-k}) - [(\ln s_t + \ln p_{i,t}^* - \ln p_{i,t}) - (\ln s_{t-k} + \ln p_{i,t-k}^* - \ln p_{i,t-k})]$ .

rate's MSE, though it accounts for somewhat less than in the case of haircuts. Deviations from the law of one price of eggs can be said to account for at least half - and often a much larger fraction - of the fluctuation in the aggregate real exchange rate. Again, the deviations from the law of one price are important even at horizons well in excess of ten years.

We have repeated this exercise for the prices of the 26 other individual goods and services, all the items available to us. Table 1 summarizes the findings. For virtually all of the goods and services, and at all horizons that the data allow, deviations from the law of one price in a single good or service account for substantial shares of the real exchange rate's variation.

### 3.2 Nontraded goods within the aggregate CPI

This section demonstrates the ability of deviations from the law of one price in nontraded goods to account for the real exchange rate's movements. This new decomposition ultimately leads us to conclude that the empirical distinction between traded and nontraded goods, at least for consumer goods, is misplaced.<sup>11</sup>

To isolate the role of nontraded goods, we return to the conventional expressions of aggregate consumer price indices as composites of traded and nontraded goods,  $p = p_T^\omega p_N^{1-\omega}$  and  $p^* = p_T^{*\omega} p_N^{*1-\omega}$ .<sup>12</sup> Then, we rewrite the price indices in a way that isolates the deviations from the law of one price in nontraded goods, instead of traded goods.

$$(3) \quad \ln q = (\ln s + \ln p_N^* - \ln p_N) + \omega \left( \ln \frac{p_T^*}{p_N^*} - \ln \frac{p_T}{p_N} \right).$$

Here, the first term in the decomposition is the deviation from the law of one price in nontraded goods. Now, we can assess how well changes in this component can account for real exchange rate changes.

We use monthly data on nominal exchange rates and consumer prices for the United

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<sup>11</sup>Based on high correlations between real exchange rates and both relative traded goods prices, and relative nontraded goods prices, Obstfeld and Rogoff (2000), and Obstfeld (2001) reach a similar conclusion.

<sup>12</sup>Here, we use the same traded and nontraded categories used by Engel (1999).

States and Japan from January, 1970 to May, 1997 to construct traded and nontraded prices, as in Engel (1999).<sup>13</sup> As before, we have an identity in each period,  $t$ :

$$\ln q_t = (\ln s_t + \ln p_{N,t}^* - \ln p_{N,t}) + \omega \left( \ln \frac{p_{T,t}^*}{p_{N,t}^*} - \ln \frac{p_{T,t}}{p_{N,t}} \right).$$

Figure 2a gives the results of this decomposition along with the results using Engel's original decomposition, and Figure 2b gives the difference between the two. Again, we focus on the fraction of the mean square error of the change in the real exchange rate that can be accounted for by each of the two components. That is, we calculate the ratio:

$\frac{MSE(x_{t+k}-x_t)}{MSE(x_{t+k}-x_t)+MSE(y_{t+k}-y_t)}$ , where  $x$  is the real exchange rate's first component, now the deviation in the law of one price in nontraded goods; and,  $y$  is the residual component.<sup>14</sup>

We examine the decomposition at all of the horizons that the data allow.

As the top figure shows, the newly defined first term now accounts for the nearly all of the real exchange rate's fluctuations. As the bottom figure shows, the difference between the two decompositions is extremely small. It hardly matters whether one examines deviations in the law of one price in traded goods or in nontraded goods. The ability of law of one price deviations to account for real exchange rate fluctuations has nothing to do with the consumer goods' putative tradeability, *per se*. Instead it appears to be equally relevant for either bundle of consumer goods, traded or not.

In combination with existing empirical results, these findings might at first blush seem to suggest that the ability of law of one price deviations to account for real exchange rates is merely an artifact of volatile nominal exchange rates. After all, no matter how we construct the deviations from the law of one price, it is in that component – and in that component only – that the nominal exchange rate appears.<sup>15</sup> Yet, this is too facile an interpretation. Highly volatile nominal exchange rates cannot be the full story. Most

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<sup>13</sup>The data for these decompositions were obtained from Charles Engel's web site.

<sup>14</sup>As before, the correlations between the two components are small enough that they have no appreciable impact on the results.

<sup>15</sup>We also decomposed the real exchange rate into the nominal exchange rate, on one hand, and the difference in overall price levels, on the other. While this yields nonstationary components, it is nevertheless interesting to note that the nominal exchange rate, by itself, accounts for over 85 percent of the variation in the real exchange rate in our sample. Boucher Breuer and Ganguly (2007) similarly find that for both developing and industrialized countries, the nominal exchange rate accounts for a much larger share than do differences in overall price levels.

obviously, the result also requires that the prices of goods and services do not move with the exchange rate enough for the law of one prices to hold for consumer goods.<sup>16</sup> A complete explanation must address why, regardless of tradeability, consumer goods prices are detached from the nominal exchange rate.

## 4 A Simple Model with “Intermediate Products”

In this section, we provide a very simple model to capture the idea that the distinction between traded and nontraded goods may be relatively unimportant at the consumer level. The model is extremely pared down, yet it reflects the two key features of the data as they show up in the exchange rate decompositions described above. First, the prices of consumer goods do not move with the nominal exchange rate enough for the law of one price to hold for consumer goods. Second, the relative price of traded and nontraded consumer goods is correspondingly unrelated to the exchange rate. This simple model also has one additional, important empirical implication that we examine in the subsequent section. Specifically, in this model, the law of one price holds for raw imports (i.e., intermediate products); so the model implies that international differences in the relative price of imports - in contrast to such differences in the relative price of traded and nontraded final goods - should be able to account for a much larger share of fluctuations in the real exchange rate.

This work is in the spirit of Sanyal and Jones (1982), who developed one of the early models that made consumer goods, even in an open economy, fundamentally nontraded goods. In their model, “all consumer goods are nontradeables, differing from one another in the proportions in which they require inputs of traded middle [intermediate] products as opposed to local resources.” Our work also follows Frankel (1984), who points out that Sanyal and Jones’s approach implies a particular insensitivity of the consumer price index to the exchange rate. The simple model presented here is formally closest to the more recent work of Corsetti and Dedola (2005), of Burstein, Eichenbaum, and Rebelo

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<sup>16</sup>So, sticky prices – *hand in hand* with volatile exchange rates – are a candidate explanation; and we implicitly explore this possibility below. However, (like Obstfeld and Rogoff, 2000a), we find this argument lacking. As we show below, it is only final goods prices, not prices in general, that are sticky in the sense of being insulated from exchange rate changes.

(2005), and of Goldberg and Campa (2006), who, like Sanyal and Jones, combine imported intermediate goods with a domestic good to produce final goods.<sup>17</sup> In Corsetti and Dedola (2005) and Burstein, Eichenbaum, and Rebelo (2005), the two inputs are combined in fixed proportions, and distribution is the local good. Both these papers provide general equilibrium models, and the results that we present here are consistent with those models. However, for simplicity, we present a partial equilibrium model, implicitly taking the nominal exchange rate as exogenous. Behind their use of fixed proportions is a Leontief production function, which we make explicit here.

The key piece of the model is that final goods and services require at least some of a local resource, along with an intermediate input that may be imported. The local resource may reflect actual shelf space, transportation, or any other distribution and marketing inputs that are required to transform a raw import into a final good or service. The imports that arrive at the dock are simply treated as inputs into the production of final goods and services, or as an output requiring no local resource. This idea can be represented explicitly with a Leontief production function. In that case, the production of a final good or service,  $j$ , is described as follows:

$$(4) \quad y_j = \min\left\{\frac{x_j}{\alpha_j}, \frac{m_j}{\beta_j}\right\}$$

Here,  $y_j$  denotes the production of the  $j^{\text{th}}$  good;  $x_j$  and  $m_j$  denote the inputs to production: the local input and the imported intermediate product; and,  $\alpha_j$  and  $\beta_j$  are the weights of the two inputs in production. Letting  $w$  and  $p_m$  denote the prices of the local input and the imported intermediate product, free entry and profit maximization in this final goods sector imply that,  $p_j$ , the price of the  $j^{\text{th}}$  good is:

$$(5) \quad p_j = w\alpha_j + p_m\beta_j$$

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<sup>17</sup>See also: Devereux, Engel, and Tille (1999), Obstfeld (2001), Burstein, Neves, and Rebelo (2003), and MacDonald and Ricci (2005).

Likewise, with identical foreign technology, and letting asterisks denote the corresponding foreign variables, we have:

$$(6) \quad p_j^* = w^* \alpha_j + p_m^* \beta_j$$

In the production of the intermediate good, we have assumed that no local goods are used, so production is trivial. So, letting  $\beta_m = 1$ , we have:  $y_m = x_m$ . Domestic producers of the final goods and services can purchase either the domestically-made input at price  $p_m$  or the foreign made input at price  $sp_m^*$ . So, the two prices must be equal, and the law of one price holds in this sector:  $p_m = sp_m^*$ .

Letting  $p_m^*$  be determined exogenously, we now can explore the exchange rate's influence on the prices of a final good or service. The elasticity of the price of the  $j^{th}$  good or service with respect to the exchange rate is:

$$\varepsilon_{p_j s} = \beta_j \frac{p_m}{p_j}.$$

Notice that in this simple model, the exchange rate influences the price of the final good or service only through the role of the raw import: the greater the importance of the raw import, as measured by  $\beta_j$ , the greater the exchange rate elasticity. For goods where the local input is much more important than imports so that  $\beta_j$  is very small, the price is relatively insensitive to a nominal exchange rate change. That is, when  $\beta_j$  is very small, the price does not change commensurately with the exchange rate; so, the law of one price will not hold. A change in the nominal exchange rate then results in a corresponding change in the real exchange rate. In terms of real exchange rate decompositions, deviations from the law of one price will account for most of the real exchange rate's fluctuations.

At the opposite extreme is good m, the raw import, which requires no local input. For this good,  $\beta_j = 1$ , so  $\varepsilon_{p_j s} = 1$ . In this case, deviations from the law of one price for that good cannot possibly explain variations in the real exchange rate. When such a good is isolated in the real exchange rate decompositions, deviations from the law of one price will not account for the real exchange rate's fluctuations; instead, only international

differences in the price of imports relative to other goods will matter.

The implications for overall consumer prices can be seen most easily by noting that imports can form a subset of the consumer price index. Using a standard construction of the consumer price index,  $p = \sum_{j=1}^n \omega_j p_j$ , we can substitute for  $p_j$  using equations 5 and 6. This gives:  $p = \sum_{j=1}^n \omega_j (w\alpha_j + p_m\beta_j)$ , or

$$p = \sum_{j=1}^n \omega_j \beta_j p_m + \sum_{j=1}^n \omega_j \alpha_j w$$

The first term in this expression represents the portion of the consumer price index that reflects the role of imports, while the second term reflects the part that does not.

Trade in intermediate products thus offers a candidate explanation for the puzzling results from the real exchange rate decompositions, both our results and those of earlier studies. In addition, it suggests a new testable implication for such decompositions: for imports, it is the price relative to other goods – not the deviation from the law of one price – that should best account for changes in the real exchange rate. In the next section, we construct the empirical real exchange rate decompositions using imports. As described below, the results contrast with all of the decompositions that use final goods and services. Deviations from the law of one price no longer account for the bulk of the real exchange rate’s fluctuations.

## 5 Imports

To isolate the empirical role of imports, we note that the aggregate price index can be written in terms of the prices of imports and the prices of all other goods. That is, in principle, we can express the domestic and foreign prices indices as follows:<sup>18</sup>

$$p = p_m^\delta p_{-m}^{1-\delta}$$

$$p^* = p_m^{*\delta} p_{-m}^{*1-\delta},$$

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<sup>18</sup>While actual consumer price indices are not constructed using the observations of import prices, imports are nevertheless indirect constituents of the consumer price index. We construct the exact decompositions empirically; and, the import price weights in the consumption basket are then implicit.

where  $p_m$  and  $p_m^*$  are the prices of imports;  $p_{-m}$  and  $p_{-m}^*$  are the prices of all other goods; and  $\delta$  and  $(1 - \delta)$  are the weights on these prices that are implied by the behavior of the aggregate price index.<sup>19</sup>

Using these price expressions, we can once again decompose the real exchange rate into its two familiar parts:

$$(7) \quad \ln q = (\ln s + \ln p_m^* - \ln p_m) + (1 - \delta) \left( \ln \frac{p_{-m}^*}{p_m^*} - \ln \frac{p_{-m}}{p_m} \right).$$

The first term in this equation is the deviation from the law of one price in imports. The second term is the international difference in the price of imports relative to its complement in the consumer price index. Notice that, while each component now reflects the role of imports, the real exchange rate,  $q$ , is constructed as usual from the two countries' consumer price indices.

We examine the decomposition using quarterly observations of import price indices from 1989 through 2005. The data are taken from DataStream, which gets its U.S. import price data from the Bureau of Labor Statistics and its Japanese data from the Bank of Japan. As before, we have an identity in every period,  $t$ :<sup>20</sup>

$$\ln q_t = (\ln s_t + \ln p_{m,t}^* - \ln p_{m,t}) + (1 - \delta) \left( \ln \frac{p_{-m,t}^*}{p_{m,t}^*} - \ln \frac{p_{-m,t}}{p_{m,t}} \right).$$

We again calculate the fraction of the mean square error of the change in the real exchange rate that can be accounted for by changes in each of the two components.<sup>21</sup>

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<sup>19</sup>All price indices in this type of work are – to a greater or lesser extent – subject to the criticism that their composition varies across countries. This is a potential problem with consumer price indices; and it is no less of a potential problem for import price indices. Whether the composition of imports bundles or the composition of consumption bundles varies more is likely to depend on such things as whether factor endowments or preferences differ more across the countries. The problem is much less severe in empirical work (as in this paper) that uses changes in the price indices, rather than their levels. The first differences are less problematic since the composition of imports is likely to change only slowly relative to the volatility of the real exchange rate.

<sup>20</sup>The change in the second term is again simply the difference between the change in the real exchange rate and the change in the deviation from the law of one price. That is, the expression for the exchange rate is an identity, and the deviation from the law of one price is:  $(\ln s_t + \ln p_{m,t}^* - \ln p_{m,t}) - (\ln s_{t-k} + \ln p_{m,t-k}^* - \ln p_{m,t-k})$ ; so, the international difference in the relative prices is:  $(\ln q_t - \ln q_{t-k}) - [(\ln s_t + \ln p_{m,t}^* - \ln p_{m,t}) - (\ln s_{t-k} + \ln p_{m,t-k}^* - \ln p_{m,t-k})]$ .

<sup>21</sup>That is, we calculate the ratio:  $\frac{MSE(x_{t+k} - x_t)}{MSE(x_{t+k} - x_t) + MSE(y_{t+k} - y_t)}$ , where  $x$  is the real exchange rate's first



The results of this decomposition are presented in Figure 3. The figure shows the fraction of the real exchange rate's variability that can be accounted for by the variability of deviations in the law of one price in imports. International differences in the price of imports relative to other goods account for the rest.<sup>22</sup> The share accounted for by law of one price deviations is shown for all of the horizons that the data allow. The share is highest, but still very low in comparison with final goods, for the first few quarters; it then falls even further and remains even lower for most horizons.<sup>23</sup> Specifically, at horizons of only a few quarters, changes in the deviation from the law of one price in imports account for less than forty percent of the changes in the real exchange rate. As the horizon lengthens, deviations from the law of one price in imports generally account for less than twenty percent of the overall variation in the real exchange rate. We also decomposed the real exchange rate using Japanese and U.S. import price data from the OECD for the period 1975-2003; and, we find similar results: deviations from the law of one price again account for less than twenty percent at most horizons. We are grateful to José Campa and Linda Goldberg, for providing us with these data, which are used in Campa and Goldberg (2005). Correspondingly, at these horizons, roughly eighty percent of the variation instead can be accounted for by differences in the two countries' internal prices of imports relative to other goods. That is, the preponderance of real exchange rate movements can be explained by changes in domestic relative prices, the second term, not by international deviations from the law of one price, the first term.

These results contrast starkly with all of our results using final consumer goods prices, as well as with the results of many others who have constructed the decompositions. While, as the figure shows, the share of the real exchange rate's variation attributable to deviations in the law of one price in imports is generally less than twenty percent, the

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component, now the deviation in the law of one price in imports; and,  $y$  is its second component, the international difference in the price of imports relative to its complement in the consumer price index. The correlations between the two components are once again small enough that they have no appreciable impact on the results; so, the share attributable to the second component is essentially:  $1 - \frac{MSE(x_{t+k} - x_t)}{MSE(x_{t+k} - x_t) + MSE(y_{t+k} - y_t)}$ .

<sup>22</sup>As mentioned above, the comovements between changes in the two components are small; hence we ignore them in the reported decompositions. However, for completeness, we also computed the decompositions attributing half the (small) comovements to each term. This, of course, has no meaningful effect on the results.

<sup>23</sup>The share rises only when the horizon exceeds ten years, at which point the number of observations, of course, dwindles.

share is much higher for individual final goods. Averaging across all individual goods and horizons reported in Table 1, the share is about sixty-five percent, or more than three times as large. Deviations in the law of one price in imports also account for much less than the minimum average share for any single good at the shortest horizon: at about forty-six percent, the mean share for orange juice is the lowest.<sup>24</sup> Of course, the import results in figure 3 are for aggregate import prices, while Table 1 presents the results for individual goods. However, the aggregate comparisons are even more striking. For aggregate final goods prices – whether we look at Engel’s traded goods component, or at our own nontraded goods component – deviations from the law of one price account for nearly one hundred percent of the real exchange rate’s variability. Correspondingly, for aggregate consumer goods, changes in the relative prices of traded to nontraded final goods within countries hardly seems to matter at all. In contrast, our results show that deviations in the law of one price of imports account for only a small share of the exchange rate’s variation; while, prices of imports relative to other goods in each country are important in accounting for real exchange rate behavior.

To summarize, the model we adopt implies that all final goods embody both traded and nontraded constituents. So, real exchange rate decompositions using only final goods cannot quite disentangle what is traded from what is not; they consequently attribute too much of the real exchange rate’s variation to deviations from the law of one price in traded goods. For the purposes of real exchange rate decompositions, we therefore identify traded goods as those goods that actually have been traded internationally, that is: imports. Empirically, we find that deviations from the law of one price in imports account for a much smaller share of the real exchange rate’s variation than can be accounted for by the analogous deviations in any set of consumer goods prices, whether seemingly traded or not. The deviations also account for a smaller share of the exchange rate’s variation than can be accounted for by comparable deviations for any of the individual final goods and services that we have examined. In contrast with earlier results, the results using import prices indicate that relative price changes within countries may play an important role in

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<sup>24</sup>For a direct comparison with Table 1, the fraction of the mean squared error attributable to deviations in the law of one price in imports is: 29 percent, 12 percent, 19 percent, 18 percent, and 42 percent, at horizons of 5, 20, 25, 35, and 50 quarters, respectively.

real exchange rate determination. Based on these results, we cannot dismiss explanations of the real exchange rate that rely on such things as differential productivity changes, or changes in relative demands across the traded and nontraded sectors of the economy. When the traded/nontraded distinction is applied using intermediate products, rather than across only finished goods, then the distinction matters greatly for understanding real exchange rate behavior.

## 6 Conclusions

By construction, *all* real exchange rate fluctuations always can be accounted for exclusively by deviations from the law of one price. After all, the real exchange rate is simply the cost of a bundle of goods in one country in terms of a comparable bundle in a second country. So, if the law of one price held for all categories of goods, then the real exchange rate would not fluctuate. In the face of real exchange rate variability, the real questions are: what groups of goods and services account for most of the deviations, and for what groups are the deviations small? By answering both of these questions, we also learn which relative prices fluctuate internationally.

It is well known that the prices of consumer goods and services do not move with the nominal exchange rate. Hence, deviations from the law of one price account for most of the fluctuations in the real exchange rate. We find this to be true for seemingly traded and nontraded goods alike. Measured deviations from the law of one price are also large for all of the individual goods and services that we examine; and the deviations from the law of one price for even these individual goods typically account for a substantial share of the real exchange rate's variation. Correspondingly, international differences in the relative prices of traded to nontraded consumer goods vary little with the nominal exchange rate. In terms of the behavior of the real exchange rate, the distinction between traded and nontraded consumer goods matters little.

A simple model with intermediate imports and local inputs illustrates a possible explanation: traded goods (imports) are only a very small piece of what goes into the production of consumer goods and services. A purely domestic input - one that is not substitutable for imports - matters more. This distinction - between trade in final consumer goods and

trade in intermediate products - implies that the picture should be very different for the raw imports themselves, and indeed we find that it is. Deviations from the law of one price in imports account for a much smaller share of the real exchange rate's fluctuations. Unlike the prices of consumer items, the prices of imports as a whole do tend to move with the nominal exchange rate. So, international differences in import prices relative to other goods' prices account for much more of the real exchange rate's variation. The distinction between imports and consumer goods is an empirically important one for the behavior of the real exchange rate.

In contrast to many earlier findings using such decompositions, our results rekindle support for those theories of the real exchange rate that rely on compositional issues. The idea that there is a traded sector that is different from a nontraded sector reemerges as an empirically important one. What is more, the nontraded sector is huge. Relative to imports that are clearly traded, both the nontraded and the so-called traded parts of the consumption bundle behave as if they are nontraded goods.

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Table 1: Share of real exchange rate variation attributable to deviations from the law of one price in individual goods

Good or Service	Horizon, $k$ , in quarters						
	5	20	25	35	50	65	80
<i>Steak</i>	0.5879	0.6447	0.6575	0.6164	0.5895	0.3768	0.4630
<i>Ground Beef</i>	0.5907	0.6361	0.6424	0.5838	0.5372	0.4883	0.4925
<i>Chicken</i>	0.5805	0.6932	0.6414	0.7060	0.7798	0.7476	0.6978
<i>Bacon</i>	0.5677	0.6603	0.6045	0.6240	0.7115	0.5427	n.a.
<i>Milk</i>	0.7610	0.7976	0.8156	0.8283	0.7853	0.7839	0.5541
<i>Parmesan Cheese</i>	0.7627	0.8214	0.8321	0.8952	n.a.	n.a.	n.a.
<i>Eggs</i>	0.5102	0.7151	0.6539	0.6821	0.6083	0.6055	0.5001
<i>Lettuce</i>	0.4937	0.5361	0.5259	0.5630	0.5568	0.5162	0.4769
<i>Potatoes</i>	0.5674	0.6395	0.6690	0.7003	0.6451	0.5854	0.5345
<i>Tomatoes</i>	0.5449	0.6974	0.6138	0.6479	0.6285	0.5656	0.4891
<i>Bananas</i>	0.4920	0.6235	0.6066	0.7114	0.7070	0.5821	0.4850
<i>Margarine</i>	0.5855	0.6039	0.6097	0.6826	0.7069	0.6619	0.7190
<i>Sugar</i>	0.6234	0.7414	0.7921	0.8303	0.7143	n.a.	n.a.
<i>Coffee</i>	0.5466	0.4276	0.4331	0.5458	0.5440	0.5501	0.5589
<i>Orange Juice</i>	0.4559	0.5010	0.5153	0.5239	0.5210	0.5045	0.6164
<i>Soft Drink</i>	0.4986	0.5402	0.5545	0.5535	0.5203	0.4858	0.4941
<i>Whiskey</i>	0.5483	0.4498	0.3830	0.4314	0.5188	n.a.	n.a.
<i>Wine</i>	0.5546	0.7643	0.6720	0.7460	n.a.	n.a.	n.a.
<i>Beer</i>	0.8370	0.9146	0.9010	0.9123	n.a.	n.a.	n.a.
<i>Facial Tissue</i>	0.5101	0.5410	0.5676	0.5786	0.5388	0.5306	0.4558
<i>Laundry Detergent</i>	0.6743	0.5540	0.4780	0.4524	0.3943	0.4438	0.2870
<i>Men's Slacks</i>	0.6170	0.7561	0.7715	0.7463	n.a.	n.a.	n.a.
<i>Man's Shirt</i>	0.7932	0.8947	0.9204	0.9606	n.a.	n.a.	n.a.
<i>Men's Briefs</i>	0.7412	0.8580	0.7992	0.8142	n.a.	n.a.	n.a.
<i>Shampoo</i>	0.5460	0.5147	0.5420	0.6049	n.a.	n.a.	n.a.
<i>Toothpaste</i>	0.6663	0.5778	0.5417	0.7468	n.a.	n.a.	n.a.
<i>Man's Haircut</i>	0.8604	0.8666	0.8580	0.8374	0.8391	0.7814	0.7792
<i>Appliance Repair</i>	0.7109	0.7812	0.8321	0.8334	0.8644	0.7097	0.5828

*Notes:* Deviations from the law of one price between Japan and the United States were computed using prices observe in Osaka and Houston. The sample period is from the 1976.1 to 1997.4. Missing values (*n.a.*) preclude the MSE decomposition from being computed for all goods at all horizons.



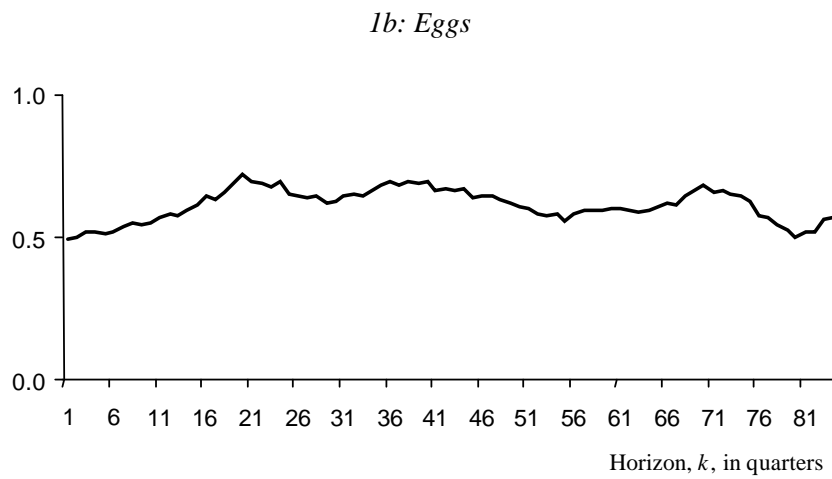
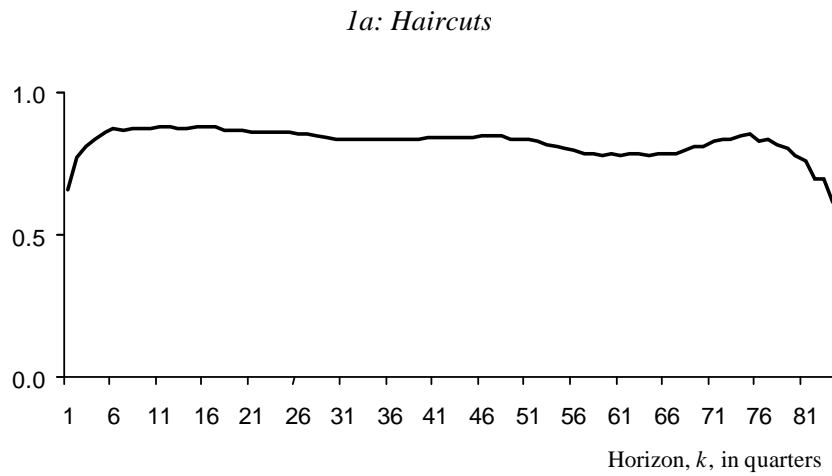
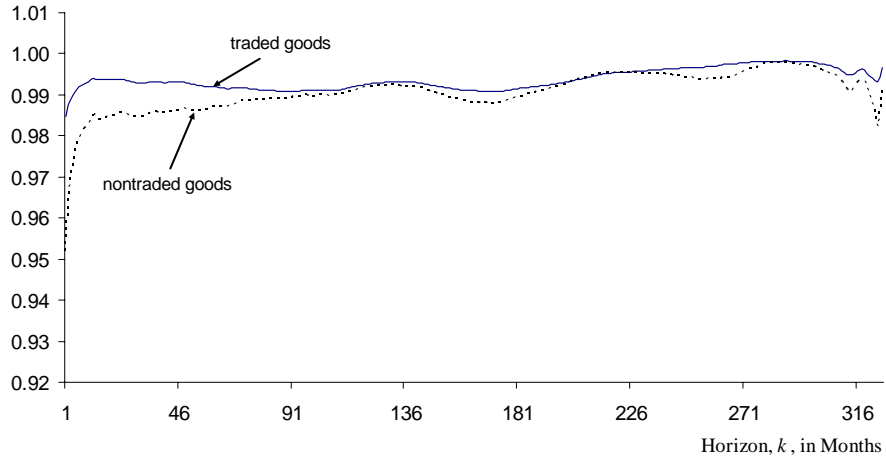


Figure 1: Share of real exchange rate variation attributable to law of one price deviations for individual goods

2a: Traded and nontraded final goods



2b: Decomposition difference

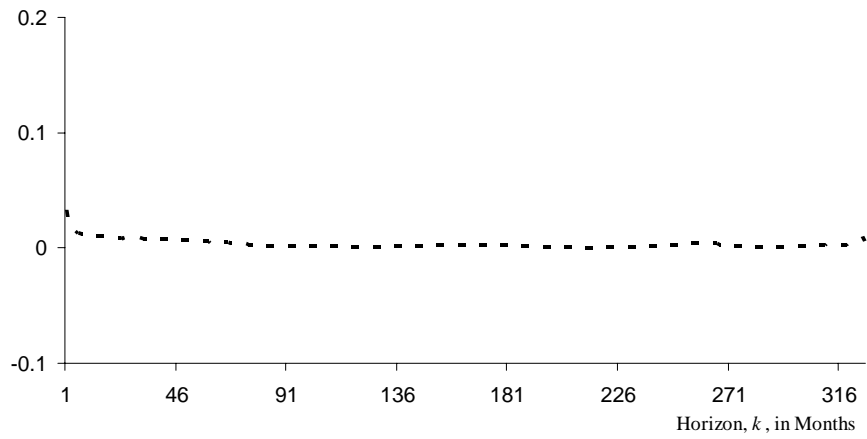


Figure 2: Share of real exchange rate variation attributable to law of one price deviations for aggregate consumer goods

### 3: Imports

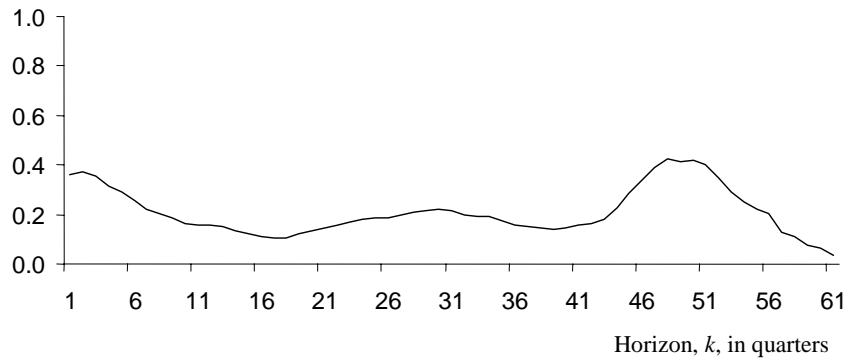


Figure 3: Share of real exchange rate variation attributable to law of one price deviations in imports