KRANNERT SCHOOL OF MANAGEMENT

Purdue University
West Lafayette, Indiana

Real Exchange Rate Fluctuations, Wage Stickiness and Tradability

By

Yothin Jinjarak
Kanda Naknoi

Paper No. 1255
Date: September, 2010

Institute for Research in the Behavioral, Economic, and Management Sciences

Real Exchange Rate Fluctuations, Wage Stickiness and Tradability

Yothin Jinjarak*, *University of London*

Kanda Naknoi†, *Purdue University*

This draft: September 2010

First draft: April 2009

Abstract

This study proposes a new measure of tradability and examines its relationship with volatility of the sector-specific real exchange rate (RER). We derive degree of tradability from a model in which final goods are produced from labor, capital and intermediate inputs. With free capital mobility, the share of labor in value added measures degree of nontradability. Then the RER is driven by changes in relative wage and those in seller's markup. The contribution of relative wage into RER variance is predicted to be increasing in nontradability. We provide evidence for our theory using U.S.-Canada monthly RERs and U.S.-Germany quarterly RERs.

JEL codes: F41, F42

Keywords: real exchange rate; wage stickiness; tradability

---

*Department of Financial and Management Studies, SOAS, University of London, London WC1H 0XG, UK; yj5@soas.ac.uk

†Department of Economics, Purdue University, West Lafayette, IN 47907, USA; knaknoi@purdue.edu.
We thank Yin-Wong Cheung, Mario Crucini, David Hummels, Chong Xiang and participants in Purdue Brownbag seminar, the 2009 APEA Meeting, the 2009 SERC Conference and the 2010 Midwest Macro Meeting for comments.

1 Introduction

Recent literature on the real exchange rate (RER) has documented the importance of degree of tradability of goods as a determinant of short-run movements of RERs. The literature measures tradability in various ways as follows. Betts and Kehoe (2006) measures it by the size of trade relative to output and found that RER volatility of industrialized countries is decreasing in tradability. In Burstein, Neve and Rebelo (2003) and Burstein, Eichenbaum and Rebelo (2005), tradability is determined by distribution costs. They show that the presence of nontraded distribution costs increases the movements of RER following exchange-rate-based stabilization. Crucini, Telmer and Zachariadis (2005) also found that the share of nontraded intermediate inputs can explain cross-sectional variance of European RERs. Ghironi and Melitz (2005) and Naknoi (2008) define tradability as the endogenous set of traded goods and illustrate that the short-run adjustment in tradability offers an explanation for the variance decomposition of RERs documented in Engel (1999) and Mendoza (2000).

This study proposes an alternative measure of tradability and examines its influence on volatility of RERs, based on the idea that tradability of goods is determined by tradability of inputs, as in Burstein et al. (2003), Burstein et al. (2005) and Crucini et al. (2005). However, unlike these studies our focus is not the cost of nontraded intermediate inputs, but rather the cost of labor in the entire process of production. Our approach is motivated by the conventional wisdom that nontraded goods are labor intensive. However, the literature has not incorporated the cost of labor and labor intensity into the concept of tradability. We bring in the role of labor cost and labor intensity in the following ways.

First, we outline a two-country partial-equilibrium model with free capital mobility. The model features cross-industry interdependence in the production structure as in the input-output table. To be specific, final goods are produced from sector-specific labor, homogeneous capital and nontraded intermediate goods. At the same time, intermediate goods are also produced from sector-specific labor, homogeneous capital and different nontraded intermediates. This structure of production implies that all final goods embed immobile labor, therefore all final goods contain nontraded inputs, as argued by Jones and Sanyal (1982). We assume that the wholesalers and retailers in both countries have monopoly power and charge markups. Then we decompose the movements of bilateral sector-specific RERs into two components, namely the change in sector-specific relative wage and the change in sector-specific relative markup.

Next, we show that this decomposition is an industry analog of the decomposition in Engel (1999) and Mendoza (2000). Specifically, the change in relative wage in our decomposition is equivalent to their bilateral difference in the relative price of nontraded to traded goods or nontraded RER. At the same time, our change in relative markup is equivalent to their deviations from the law of one price for traded goods or traded RER. In their decomposition, the share of services in total consumption expenditure measures the share of nontraded goods in unit cost. The comparable parameter in our decomposition is the share of labor in value added, thus we argue that the share of labor in value added can measure nontradability of goods. Our approach does not arbitrarily classify final goods into traded or nontraded ones, but we attempt to disaggregate final goods into traded and nontraded fractions according to mobility of inputs. This is the first theoretical contribution of our study.

Our second theoretical contribution is that we demonstrate that our measure of nontradability is increasing in the cost share of labor at each stage of production, and increasing in the share of nontraded intermediate inputs. Since labor is required to produce all intermediate inputs, a rise in the share of nontraded intermediate inputs increases the share of labor in total cost and also value added. This finding implies that our model highlights the role of labor cost without contradicting the previous studies that emphasizes the role of nontraded intermediate inputs (Burstein et al., 2003; Burstein et al., 2005; and Crucini et al., 2005).

Our last theoretical contribution is that we show that contribution of changes in relative wage into RER variance is increasing in degree of nontradability. Intuitively, relative price of labor-intensive goods is influenced by changes in labor cost more than relative price of capital-intensive goods. The other implication is that frictions in labor market play an important role in the determination of volatility of relative price of goods.

Our model does not offer a prediction about degree of nontradability and RER variance. The reason is that our theory does not incorporate labor-intensity into price-setting and wage-setting decisions. Thus, we do not have theoretical predictions about how nontradability is related to variance of relative wage, variance of relative markup and their covariance.

In the empirical part we decompose variance of sector-specific RERs, using monthly data of 36 industries in the U.S. and Canada from January 1991 to January 2009, and quarterly data of 31 industries in the U.S. and Germany from the first quarter in 1995 and the fourth quarter in 2006. We calculate the share of labor in value added from the U.S. input-output table. The dataset has series of sector-specific prices, sector-specific wages and exchange rates, hence we can calculate changes in relative prices and relative wage over various time horizons. Changes in relative markup or bilateral difference in markup adjustment is obtained as the residuals. We measure changes over the time horizons from 1 month to 24 months for the U.S.-Canada industry pairs, and from 1 quarter to 8 quarters for the U.S.-Germany industry pairs.

We document five new empirical findings as follows. First, based on the U.S. input-output table, the calculated degree of nontradability ranges from 14 percent to 66 percent. Its median, average and standard deviation are 57 percent, 53 percent and 13 percent, respectively. Degree of nontradability of 25 out of 36 industries is higher than 50 percent. Hence, most goods in our dataset are nontradable. The cross-sectional correlation of nontradability with the cost share of labor and that with the labor cost embedded in intermediate input cost are 67 percent and 45 percent, respectively. These positive correlations confirm the first prediction of our model.

Second, we found that in the short run relative wage is positively correlated with RER in all industries. The correlation between relative wage and RER exceeds 50 percent for 1/3 of U.S.-Canada industry pairs, and 3 quarters of U.S.-Germany industry pairs. On average, relative wage is as volatile as relative price in the short run. Over long horizons, volatility of relative wage is 70-80 percent of volatility of relative price. However, volatility of relative wage is less disperse across sectors than that of relative price. Such distribution of volatility suggests that relative price and relative wage are driven by sector-specific shocks. Therefore, heterogeneity of degree of wage stickiness is an important determinant of movements of sector-specific RERs.

Third, we found that the contribution of changes in sector-specific relative wage into variance of sector-specific RERs varies from 0 percent to 64 percent. When the horizon is extended up to 24 months, the contribution is as high as 70 percent in an industry. For all horizons, the contribution is higher than 50 percent in 6 out of 36 industries for U.S.-Canada pairs, and 12 out of 31 industries for U.S.-Germany pairs. This evidence indicates that the RER in a number of industries is driven by its nontraded component, in accordance with the documented pattern of correlation between relative wage and RER. This finding highlights the importance of frictions in labor market, which has not been extensively studied in the literature on RER.

Fourth, the cross-sectional correlation between the contribution of relative wage into RER variance and degree of nontradability is found to be as high as 90 percent. This strongly positive correlation is predicted by our theory and it is robust to the horizon of changes. Like the second finding, this finding underscores the importance of labor market frictions.

Our final finding is about the cross-sectional correlation between RER and degree of nontradability. The correlation is found to be negative. It varies from -0.52 to -0.39 for the U.S.-Canada pairs, depending on the horizon of changes. For the U.S.-Germany pairs, the correlation is between -0.56 and -0.50. In other words, RER of labor-intensive goods is found to be less volatile than the RER of capital-intensive goods. Although our theory does not offer an explanation for this correlation pattern, our finding implies that degree of nontradability and labor intensity may influence the price-setting decision.

Our work is related to the literature on the border effect on RER volatility. Specifically, our findings suggest that the effect of price stickiness documented by Engel and Rogers (1996) could partially be driven by wage stickiness as a result of large labor market frictions preventing labor from moving across sectors. This aspect of our work contributes to the growing literature that emphasizes importance of labor market frictions in open economies, such as Kehoe and Ruhl (2009) and Mendoza, Tesar and Gorodnichenko (2008). The difference in our work is that we highlight importance of sectoral heterogeneity of labor market frictions rather than aggregate frictions. Our study also offers an indirect evidence of wage stickiness and supplement the studies on wage stickiness in closed-economy framework (Castellanos et al., 2004; Kahn, 1997; Liu and Phaneuf, 2007; Taylor, 1999).

Section 2 outlines the model and provides the framework for the variance decomposition of sector-specific RERs. The description of data and empirical results are in Section 3. Section 4 concludes.

2 The Model

There are two open economies called Home and Foreign. There exists an identical set of two industries in the two countries. Let the subscript i index the industry, where $i = 1, 2$. There are two factors of production, namely sector-specific labor and homogeneous capital. We assume that capital is perfectly mobile across border, but labor is immobile across border and across sectors. We use the 2x2 structure for the purpose of exposition, and the model can be generalized to study a large number of industries.

We take a partial equilibrium approach, in which sector-specific wages and and nominal exchange rate are taken as given. This framework is sufficient for illustrating the effects of tradability of inputs on variance decomposition of RERs. Below we discuss the goods markets in the home country, and those in the foreign country are a mirror image.

2.1 Intermediate goods market

The production structure is motivated by the input-output table. To be precise, the intermediate good i is produced by not only sector-specific labor $L_i(t)$ and homogeneous capital $K(t)$ but also the intermediate good $j, j \neq i$. Let $X_i(t)$ denote output of the intermediate good i and $M_j(t)$ denote input of the intermediate good j. The monopolist wholesaler i has the following Cobb-Douglas technology:

$$X_i(t) = M_j(t)^{\delta_i} L_i(t)^{\alpha_i} K(t)^{1-\delta_i-\alpha_i},$$

where $0 < \delta_i < 1$ and $0 < \alpha_i < 1$. Likewise, the wholesaler j combines the intermediate good i with capital and sector-specific labor to produce the intermediate good j:

$$X_j(t) = M_i(t)^{\delta_j} L_j(t)^{\alpha_j} K(t)^{1-\delta_j-\alpha_j},$$

where $0 < \delta_j < 1$ and $0 < \alpha_j < 1$.

Assume no international trade in intermediate goods. Hence, the market clearing condition requires that supply by the wholesaler j equals demand for the intermediate j by the wholesaler i:

$$X_j(t) = M_j(t). \tag{1}$$

Substituting the market clearing condition above into the wholesaler i's production function yields the following value added at this stage of production:

$$X_i(t) = L(t)^{\gamma_i} K(t)^{1-\gamma_i}, \tag{2}$$

where $\gamma_i = (\alpha_i + \delta_i \alpha_j)/(1 - \delta_i \delta_j)$.

We assume free capital mobility across sectors and across border, hence the rental rate of capital $R(t)$ is common across sectors for all time. On the other hand, we assume that labor cannot move across border and across sectors. In other words, labor market frictions create a wedge in wages in different sectors and we denote sector-specific wage with $W_i(t)$. Wages are taken as given by the wholesalers. Since we assume that the wholesaler in every industry is a monopolist, we can write the wholesale price of the intermediate i as:

$$Px_i(t) = \phi_i(t) \frac{W_i(t)^{\gamma_i} R(t)^{1-\gamma_i}}{\gamma_i{}^{\gamma_i}(1-\gamma_i)^{1-\gamma_i}}, \tag{3}$$

where $\phi_i(t)$ is the wholesaler's markup. The markup depends on the curvature of demand schedule for each intermediate, which in turn depends on demand for the final good in each sector.

2.2 Final goods market

The monopolist retailer i produces the final good Y_i with a linear technology.

$$Y_i(t) = X_i(t) \tag{4}$$

The retailer then distributes the final good with markup pricing.

$$P_i(t) = \mu_i(t) Px_i(t), \tag{5}$$

where $P_i(t)$ is the consumer price and $\mu_i(t)$ is the retailer's markup. The retailer's markup depends on the curvature of demand schedule, which is determined by the consumers' utility function.

However, we do not specify the consumers' utility function in this model. This is because we are not interested in the allocation of final goods. Our interests are rather the effects of supply structure on the observed volatility of price of final goods. In particular, we focus on the role of degree of tradability or nontradability in each sector.

2.3 Degree of good-specific nontradability

Because all retailers produce final goods with the linear technology in (4), the parameter γ_i in (2) becomes the share of labor in value added in the final good i:

$$\gamma_i = \frac{\alpha_i + \delta_i \alpha_j}{1 - \delta_i \delta_j}. \tag{6}$$

The assumption that capital is freely mobile across border implies that γ_i also measures the share of immobile factor in value added in each sector. For this reason, we can interpret γ_i as the intrinsic degree of nontradability of the good i.

Without loss of generality, we can extend the model to study a large number of industries N, where $N > 2$. In this case, α_j in (6) is the share of labor in total cost of production of all intermediates $j, j \neq i$. Hence, the product $\delta_i \alpha_j$ reflects the cost share of labor embedded in intermediate inputs from all other industries. Likewise, δ_j in (6) is the share of intermediate goods in total cost of production of all intermediates $j, j \neq i$.

Degree of nontradability or γ_i has two important properties as follows.

Proposition 1

$$\frac{d\gamma_i}{d\alpha_i} > 0, \ \ and \ \frac{d\gamma_i}{d\alpha_j} > 0.$$

Proof. From (6), $d\gamma_i/d\alpha_i = (1 - \delta_i\delta_j)^{-1} > 0$, and $d\gamma_i/d\alpha_j = \delta_i(1 - \delta_i\delta_j)^{-1} > 0$. ■

The model intuitively predicts that degree of nontradability rises when the share of labor in total cost rises in *any* industry. The reason is that production of an intermediate good requires intermediate inputs from all other industries. Hence, an increase in labor cost in both the industry i and labor cost embedded in the intermediate input j can raise the share of labor in value added.

Proposition 2

$$\frac{d\gamma_i}{d\delta_i} > 0, \ \ and \ \frac{d\gamma_i}{d\delta_j} > 0.$$

Proof. From (6), $d\gamma_i/d\delta_i = (\alpha_j + \delta_j\alpha_i)/(1 - \delta_i\delta_j)^2 > 0$, and $d\gamma_i/d\delta_j = (\alpha_i + \delta_i\alpha_j)/(1 - \delta_i\delta_j)^2 > 0$. ■

The model predicts that degree of nontradability rises when the share of nontraded inputs in total cost rises in *any* industry. The reason is that production of intermediate inputs in any industry requires nontraded labor. This result indicates that our model is consistent with the finding in Burstein et al. (2003, 2005) and Crucini et al. (2005) that the share of nontraded intermediate inputs in total cost is a determinant of nontradedness.

2.4 Sector-specific real exchange rates

Define the sector-specific RER or $Q_i(t)$ as follows.

$$Q_i(t) = \frac{S(t)P_i^\star(t)}{P_i(t)},$$

where S_t is the units of home currency per unit of foreign currency, and the superscript $\star$ denotes foreign variables. Assume that technology and market structure in the foreign country are identical to those in the home country. Substituting the retail price in (5) and the wholesale price in (3) into the definition of sector-specific RER gives the following expression:

$$Q_i(t) = \left(\frac{\mu_i^\star(t)\phi_i^\star(t)}{\mu_i(t)\phi_i(t)}\right)\left(\frac{S(t)W_i^\star(t)}{W_i(t)}\right)^{\gamma_i}\left(\frac{S(t)R^\star(t)}{R(t)}\right)^{1-\gamma_i}$$

Let us define $H_i(t) = (\mu_i^\star(t)\phi_i^\star(t))/(\mu_i(t)\phi_i(t))$. $H_i(t)$ represents the foreign distribution markup in the sector i relative to the domestic distribution markup. Taking natural logarithm and first differencing the above equation gives the movement of sector-specific RER:

$$\Delta q_i(t) = \Delta h_i(t) + \gamma_i \Delta\omega_i(t) + (1-\gamma_i)\Delta\kappa(t), \tag{7}$$

where lowercase denotes natural logarithm, Δ is the first difference, $\omega_i(t) = s(t) + w_i^\star(t) - w_i(t)$ or the change in relative wage, and $\kappa(t) = s(t) + r^\star(t) - r(t)$ or deviations of the cost of capital across countries. Hence, movements of sector-specific RERs are driven by the bilateral difference in adjustments of distribution markups and the bilateral difference in adjustments of factor prices.

The adjustments in distribution markups depend on the preferences which pin down the price elasticity of demand. The adjustments in wages and rental rate of capital essentially depend on frictions in the labor market and frictions in the capital market. The assumption of free capital mobility implies that the law of one price holds in the international capital market:

$$\kappa(t) = s(t) + r^{\star}(t) - r(t) = 0 \tag{8}$$

For this reason, the RER depends on the adjustments in relative wage and relative markup:

$$\Delta q_i(t) = \gamma_i \Delta\omega_i(t) + \Delta h_i(t). \tag{9}$$

Alternatively, we can rewrite the RER in (9) using the law of one price for the capital market in (8):

$$\Delta q_i(t) = \gamma_i \left[(\Delta w_i^{\star}(t) - \Delta r^{\star}(t)) - (\Delta w_i(t) - \Delta r(t))\right] + \Delta h_i(t). \tag{10}$$

Hence, the sector-specific RER depreciation is the sum of bilateral difference in change of wage relative to cost of capital, multiplied by the share of labor in value added, and bilateral difference in change in markups. This decomposition is in fact an industry analog of the decomposition of variance of country-level RERs in Engel (1999), Mendoza (2000) and Naknoi (2008). In these studies, country-level RER depreciation ($\Delta q(t)$) is the sum of bilateral difference in inflation of nontraded-goods basket relative to inflation of traded-goods basket (nontraded RER depreciation or $\Delta q_N(t)$) multiplied by the expenditure share of nontraded goods (s_N), and deviations from the law of one price for traded-goods basket (traded RER depreciation or $\Delta q_T(t)$):

$$\Delta q(t) = s_N \Delta q_N(t) + (1 - s_N)\Delta q_T(T), \tag{11}$$

where

$$\begin{aligned}\Delta q_N(t) &= (\Delta p_N^\star(t) - \Delta p_T^\star(t)) - (\Delta p_N(t) - \Delta p_T(t)),\\ \Delta q_T(T) &= \Delta s(t) + \Delta p_T^\star(t) - \Delta p_T(t),\end{aligned}$$

$0 < s_N < 1$. $p_N(t)$ and $p_T(t)$ denote natural logarithm of price of nontraded-goods basket and that of traded-goods basket, respectively.

In light of this decomposition in the macro literature, we interpret fluctuations of price of immobile factor relative to those of mobile factor as the nontraded component of sector-specific RERs. Evidently, the importance of the nontraded component in sector-specific RER fluctuations is increasing in the share of labor in value added. For this reason, we argue that the share of labor in value added in each sector can measure intrinsic nontradability of each good. The traded component in sector-specific RERs in our study is driven by adjustments in seller's markup, as similar to the macro literature. The novel aspect of our decomposition is that it explicitly reflects the role of labor intensity.

2.5 Variance decomposition of sector-specific real exchange rates

Let σ_{wi} and σ_{hi} denote the standard deviation of $\Delta\omega_i(t)$ and $\Delta h_i(t)$, respectively. Also, let ρ_{whi} denote the correlation between $\Delta\omega_i(t)$ and $\Delta h_i(t)$. Hence,

$$var(\Delta q_t^i) = \gamma_i^2\sigma_{wi}^2 + 2\gamma_i\rho_{whi}\sigma_{wi}\sigma_{hi} + \sigma_{hi}^2 \tag{12}$$

From (9) and (12), the contribution of relative wage into RER variance is given by:

$$v_w^i = \frac{\gamma_i^2\sigma_{wi}^2 + \gamma_i\rho_{whi}\sigma_{wi}\sigma_{hi}}{\gamma_i^2\sigma_{wi}^2 + 2\gamma_i\rho_{whi}\sigma_{wi}\sigma_{hi} + \sigma_{hi}^2}, \tag{13}$$

Variance decomposition of RERs is influenced by degree of nontradability as follows.

Proposition 3

$$\frac{dv_w^i}{d\gamma_i} > 0.$$

Proof. From (13), $dv_w^i/d\gamma_i = (\gamma_i(1-\gamma_i)\sigma_{wi}^2\sigma_{hi}^2+(1-\gamma_i)\rho_{whi}\sigma_{wi}\sigma_{hi}^3)/(\gamma_i^2\sigma_{wi}^2+2\gamma_i\rho_{whi}\sigma_{wi}\sigma_{hi}+\sigma_{hi}^2)^2$. Since $0 < \gamma_i < 1, \sigma_{wi} > 0$ and $\sigma_{hi} > 0$, then $dv_w^i/d\gamma_i > 0$. ■

Our theory predicts that the contribution of relative wage into RER variance is increasing in nontradability, all else equal. This implies that for a given level of volatility of relative wage and relative markup, relative wage plays a more significant role in movements of relative price of labor-intensive goods than those of capital-intensive goods. Intuitively, prices of labor-intensive goods are largely influenced by conditions in domestic labor market. To the contrary, prices of capital-intensive goods are influenced by conditions in the goods market rather than conditions in the labor market.

The other insight from our theory is the relationship between nontradability and variance of sector-specific RERs. From (12),

$$\begin{aligned}\frac{d(var(\Delta q_t^i))}{d\gamma_i} &= 2\gamma_i\sigma_{wi}^2 + 2\rho_{whi}\sigma_{wi}\sigma_{hi} + 2\gamma_i\sigma_{wi}\sigma_{hi}\frac{d\rho_{whi}}{d\gamma_i} \\ &\quad +(2\gamma_i^2\sigma_{wi} + 2\gamma_i\rho_{whi}\sigma_{hi})\frac{d\sigma_{wi}}{d\gamma_i} + (2\sigma_{hi} + 2\gamma_i\rho_{whi}\sigma_{wi})\frac{d\sigma_{hi}}{d\gamma_i}. \qquad (14)\end{aligned}$$

Whether RER volatility is increasing in nontradability is inconclusive, because the model cannot predict the sign of ρ_{whi}, $d\rho_{whi}/d\gamma_i$, $d\sigma_{wi}/d\gamma_i$ and $d\sigma_{hi}/d\gamma_i$. To predict their sign, a general equilibrium model which endogenizes wage-setting and price-setting decisions is necessary. However, our partial equilibrium model is sufficient for demonstrating the role of labor cost in variance decomposition of sector-specific RER.

In the next section, we calculate the share of labor in value added as our measure of nontradability from the input-output table of the U.S. Then we investigate its relationship with variance decomposition of sector-specific RER.

3 The Empirics

3.1 Description of Data

Following the theoretical framework, we calculate a labor share in value added:

$$\gamma_i = \frac{\alpha_i + \delta_i \alpha_j}{1 - \delta_i \delta_j} \tag{15}$$

Data necessary for this calculation of γ_i are obtained as follows.

- α_i is a share of employee compensation in total input cost for sector i, where the total input cost is a sum of intermediate-input cost, employee compensation, production and imports taxes less subsidies, and gross operating surplus.
- α_j is an aggregate employee compensation for all other sectors $j \neq i$, divided by total input cost for all other sectors.
- δ_i is a share of intermediate-input cost in total input cost for sector i.
- δ_j is an aggregate intermediate-input cost for all other sectors $j \neq i$, divided by total input cost for all other sectors.

We use the 2002 input-output data from the U.S. Bureau of Economic Analysis (BEA) in the calculation of γ_i.[1] One might extend our theoretical model to accommodate a

[1] In the BEA Input-Output Tables, intermediate-input cost, employee compensation, production and imports taxes less subsidies, and gross operating surplus are T005, V001, V002, and V003, respectively.

time-dependent γ_i, utilizing the input-output tables from various years. Nonetheless, the real empirical challenge is to match, on a sector by sector basis, data for wages and prices across countries using the best quality and highest frequency series possible. After searching comprehensively, we arrive at two sets of sector pairs:

U.S.-Canada pairs 36 sector pairs using wages and *CPI* monthly series from 1991:M1 to 2009:M1. For both prices and wages, we obtain the data (non seasonally adjusted) from the U.S. Bureau of Labor Statistics (BLS) and Statistics Canada (CANSIM). The U.S.-Canada exchange rate series is a monthly average from CANSIM.

U.S.-Germany pairs 31 sector pairs using wages and *PPI* quarterly series from 1995:Q1 to 2006:Q4. For Germany, we obtain the data (non seasonally adjusted) from Statisches Bundesamt, Wiesbaden. Note that in the case of U.S.-Germany sector pairs, we use *PPI* for comparison purpose and in order to expand sector coverage; this is equivalent to imposing an assumption that the distribution margin charged by retailers in the U.S. is comparable to that charged in Germany for the corresponding sectors.

We calculate markup adjustments as:

$$\Delta h_i(t) = \Delta q_i(t) - \gamma_i \Delta \omega_i(t)$$

which, essentially, is a time series of residuals. A correlation, ρ_{whi}, between $\Delta\omega_i(t)$ and $\Delta h_i(t)$ is therefore negative by construction.

Some studies on relative price, such as Cheung and Fujii (2006), attempt to calculate the markup adjustment from the data on price and cost. Their approach can give different series of markup, depending on their assumption about the cost function and the cost of capital. Our approach assumes that the cost of capital is the same across sectors, therefore the changes in price that are not explained by wage adjustment reflect the changes in markup. This is not the case when the domestic capital market has financial frictions.

We assume away frictions in the domestic capital market for two reasons. One, we have no data on the cost of capital at the sector level. Two, in industrialized countries in which the capital market is geographically integrated, we expect the frictions to be quite small comparing to frictions in the labor market.

3.2 Results

3.2.1 Degree of nontradability

We report the calculated degree of nontradability (γ_i) and its components in Table 1. Column 1 displays the industry codes from the input-output table. We rank the industries by degree of nontradability in Column 2. Degree of nontradability varies from 14 percent (cigarettes and tobacco products) to 66 percent (recreation reading materials and commercial printing). We found that degree of nontradability of 25 out of 36 industries is high than 50 percent. Its median, average and standard deviation are 57 percent, 53 percent and 13 percent, respectively.

To understand the role of labor cost, we report the cost share of labor (α_i) and the cost share of labor embedded in intermediate inputs ($\delta_i \alpha_j$) in Columns 3 and 4 in Table 1. The cost share of labor varies from 4 percent to 38 percent, and the cost share of labor embedded in intermediate inputs varies from 8 to 29 percent. Their average over all industries is 19 percent and 20 percent, respectively. Their correlation with degree of nontradability is 0.67 and 0.45, respectively. These positive correlations confirm the prediction in Proposition 1.

When we compare the two cost shares in Table 1, we found that in 12 industries the cost share of labor is higher than the cost share of labor embedded in intermediate inputs. Also, in these 12 industries degree of nontradability is higher than 50 percent. Hence, labor cost in the final production is as important to nontradability as labor cost in the production of intermediate goods. This finding highlights the importance of labor cost in the entire process of production, which is the new aspect in our work.

In Crucini et al. (2005), the cost share of nontraded intermediate inputs is obtained from the U.K.'s input-output table and the following goods were classified as nontraded goods: utilities, construction, distribution, hotels, catering, railways, road transport, sea transport, air transport, transport services, telecommunications, banking, finance, insurance, business services, education, health and other services. They found that the cost share of nontraded inputs in 53 industries varies from 5 percent (tobacco) to 32 percent (forestry and fishing). Since they do not consider labor in the final good production as a type of nontraded input, it is reasonable that their measure is lower than ours. However, like Crucini et al. (2005) we also found that the tobacco industry has the lowest degree of nontradability.

3.2.2 Summary statistics of the real exchange rate and relative wage

Table 2 tabulates summary statistics of volatility of RER and relative wage, which is measured by standard deviation of changes in various horizons. We report the average of all industries in Columns 1 and 2. The dispersion or the standard deviation across all industries is in the last two columns.

For the U.S.-Canada pairs, month-to-month RER depreciation is roughly as volatile as relative wage adjustment. However, RER depreciation is much more volatile than relative wage adjustment in horizons longer than one month. This pattern of volatility raises the following question. Is nominal exchange rate the common cause driving both RER and relative wage in all industries, while nominal prices and nominal wages are completely sticky in one-month horizon? To answer this question, we compare the dispersion of RER and relative wage across industries in the last two columns.

Evidently, the dispersion across industries of RER is more than twice of that of relative wage for all horizons. This result indicates that nominal prices and nominal wages are not completely sticky even in one-month horizon, and the answer to the question in the previous paragraph is no. For this reason, sectoral heterogeneity of degree of price stickiness and wage stickiness plays a critical role in fluctuations of RER.

We found similar a pattern in volatility of RER depreciation and volatility of relative wage adjustment for the U.S.-Germany pairs. To be precise, volatility of relative wage adjustment is 80 percent of that of RER depreciation over all time horizons. Dispersion of volatility across industries of relative wage is also lower than that of RER depreciation.

One cause for the small dispersion of relative wage in both U.S.-Canada pairs and U.S.-Germany pairs is the mobility of unskilled labor, which is assumed away in our model. In practice, every sector employs both sector-specific skilled labor and unskilled labor. Since unskilled labor is homogeneous, this type of labor faces the same wage in all sectors. Hence, relative wage dispersion across sectors reflect only dispersion among wages of skilled labor. However, our study does not disaggregate labor into skilled and unskilled labor, because the input-output table does not give a breakdown of types of labor. Our assumption of labor immobility simply captures the notion that frictions in labor market are larger than frictions in capital market.

In Figure 1, we report the time-series correlation between movements of RER and those of relative wage:

$$Corr(\Delta q_i(t), \Delta \omega_i(t)).$$

The horizon of changes is one month for U.S.-Canada pairs (Panel A) and one quarter for U.S.-Germany pairs (Panel B). In the Figure, the industries are ranked from low to high correlation. It is clear that the correlation between RER and relative wage is positive for all industry pairs. Moreover, the correlation is higher than 50 percent for 1/3 of U.S.-Canada industry pairs and 3 quarters of U.S.-Germany industry pairs. Its median is 40 percent for U.S.-Canada pairs and 92 percent for U.S.-Germany pairs. When we extend the horizon of changes, the median correlation becomes even higher, as summarized in Table 3. In particular, over longer horizons the median correlation for U.S.-Canada pairs varies from 0.49 to 0.78. For U.S.-Germany pairs, the median correlation is higher than

0.90 for all horizons. Although the lowest correlation becomes negative when the horizon is longer, those negative correlations apply to only 2 industries.

Based on the high correlations in Figure 1 and Table 3, we conjecture that relative wage fluctuations likely account for a significant fraction of variance of RER. We confirm this conjecture in the next subsection.

3.2.3 Nontradability and RER variance decomposition

Figure 2 displays the contribution of relative wage into variance of RER depreciation and degree of nontradability. We display the result for the U.S.-Canada month-to-month RER depreciation in the top panel and that for the U.S.-Germany quarter-to-quarter RER depreciation in the bottom panel.

The contribution of relative wage ranges from 0 percent to 58 percent for the U.S.-Canada RERs, and 0 percent to 64 percent for the U.S.-Germany RERs. In Panel A, the contribution of relative wage exceeds 50 percent in 6 industries out of 36 industries. The corresponding number of such industries in Panel B is 12. This significant role of nontraded component of RER in driving volatility of sector-specific RERs is in contrast with the finding in studies on aggregate RERs, such as Engel (1999). To be precise, the literature has found that in aggregate the U.S.-Canada RER and the U.S.-Germany RER are largely driven by the relative price of traded goods. Such results implies that in aggregate the relative wage adjustment is much less important than markup adjustments. The difference between the literature and our work arises primarily from difference in the classification of goods.

To highlight the novel aspect of our classification system, we fit the scatter plots in Panels A and B with a simple regression and display the fitted line in each panel. The slope of fitted line is 0.79 in Panel A, and 1.11 in Panel B. In other words, a one-percent increase in degree of nontradability increases the contribution of relative wage in variance of RER by more than three quarters of one percent.

As a robustness check, we extend the horizon of changes and plot similar diagrams in Figures 3 and 4. Evidently, the variance decomposition pattern remains mostly unchanged. In almost all industries the contribution of relative wage remains the same, although the maximum contribution of relative wage is as high as 70 percent when we extend the horizon of changes of U.S-Canada to 24 months. For the U.S-Germany RERs, the contribution of relative wage into RER variance is largely insensitive to the horizon of changes.

An alternative interpretation of this pattern of variance decomposition is that relative wage is strongly correlated with RER in a number of industries. This interpretation is consistent with the pattern of correlation between RER and relative wage documented in the previous subsection. It is important to point that we do not need degree of nontradability in our calculation of correlation between RER and relative wage, unlike when we decompose RER variance. For this reason, the positive and high correlations between RER and relative wage in Figure 1 and Table 3 substantiate our claim that movements of relative wage can account for a sizable fraction of variance of RER in many industries.

Our study is not the first study that documented the importance of movements of cost and markup in changes in relative price of goods. The recent study of product-level price data from the U.S. and Canada by Gopinath, Gourinchas, Hsieh and Li (2010) found that the median contribution of costs to relative price variability ranges from 55 percent at the weekly horizon to 77 percent at the quarterly horizon. However, the cost measure in their study is the cost of tradable inputs rather than nontradable inputs as in our study. For this reason, changes in the costs in their study may not be labor cost.

Having established the importance of relative wage in RER variance, next we investigate the impact of nontradability on the RER variance decomposition. Specifically, we pool the U.S.-Canada pairs with U.S.-Germany pairs to estimate the following regression equation:

$$v_w^i = \beta_0 + \beta_1 \gamma_i + \epsilon_i,$$

where β_0 and β_1 are coefficients to be estimated. ϵ_i is the industry-specific error. Then we estimate this equation for various time horizons and report the results in Table 4. Column 1 reports the results of the full sample which includes all time horizons. Columns 2-5 correspond to 3-month (1-quarter), 6-month (2-quarter), 12-month (4-quarter) and 24-month (8-quarter) horizons, respectively. The estimate of β_1 is roughly 90 percent regardless of the time horizon, and it is statistically significant at 1-percent level. The adjusted R^2 varies from 39 percent to 47 percent. This range is not low given that our theory features only the supply side of sectoral heterogeneity. The size of the coefficient estimate implies that a one percent increase in nontradability increases the fraction of RER variance that relative wage accounts for by almost one percent.

3.2.4 Nontradability and RER volatility

Table 5 reports the cross-sectional correlation between nontradability and standard deviation of changes of the following variables: RER, relative wage and relative markup. The correlation between nontradability and standard deviation of RER depreciation is moderately negative in all horizons for both U.S.-Canada pairs and U.S.-Germany pairs. This negative correlation is driven by the negative correlation between nontradability and standard deviation of relative markup adjustment, as displayed in the last column. To the contrary, the correlation between nontradability and standard deviation of relative wage adjustment is weakly positive.

An implication of the correlation pattern in Table 5 is that relative markup of labor-intensive goods is less volatile than those of capital-intensive goods. This suggests that labor intensity may be an important factor for the price-setting decision. While the literature such as Burstein et al. (2003; 2005) have explored the impact of nontraded input cost on price setting, there are no studies that explicitly links price setting with labor intensity. Although our theory does not feature demand-side heterogeneity to explain price setting, this empirical finding provides a guide to better theory in the future.

Note that the negative correlation between nontradability and RER volatility contrasts with the result in Betts and Kehoe (2006). Specifically, they found a negative correlation between RER variance and tradability. However, they measure tradability by the size of trade relative to output, which depends also on the demand structure and trade costs. It is plausible that the export share of labor-intensive goods is larger than the export share of capital-intensive goods. For this reason, our finding does not necessarily contradict their result.

4 Concluding remarks

Our theory and empirical results demonstrate that supply-side heterogeneity can help us understand the sources of fluctuations of sector-specific RER, namely movements of labor costs and movements of seller's markup. Although our partial equilibrium approach does not attempt to explain price setting and wage setting, it allows us to highlight the effects of movements of labor cost on movements on relative price of goods. In particular, the share of labor in value added becomes the parameter that determines the fraction of nontraded input embedded in final goods and therefore measures degree of nontradability.

We found evidence that relative wage plays an important role in RER volatility for many industries, and the importance is increasing in degree of nontradability, as predicted by the model. This evidence implies that labor market frictions could be as important to the dynamics of relative price as goods market frictions. In addition, our study provides an indirect evidence for wage stickiness, which has been extensively studied in a closed-economy context. (See Castellanos et al. (2004), Kahn (1997), Liu and Phaneuf (2007) and Taylor (1999), for example.)

To the contrary, RER volatility is found to be negatively correlated with degree of nontradability. This finding is opposite from the conventional theory that argues that lack of arbitrage should results in high RER volatility. To understand why, we need to specify a general equilibrium model which takes into account price-setting decision. That is beyond the scope of this study.

An application of our measure of nontradability is to investigate its relationship with persistence of RERs. The effect of tradability on persistence of product-level RERs has been recently explored by Cheung and Fujii (2008) using Japan's data, but they rely on tradable-nontradable dichotomy in their classification of goods. Our larger set of degree of nontradability can largely improve their analysis.

One caveat is the assumption of perfect capital mobility. If there are financial frictions in international capital markets, our results will still hold as long as financial frictions are constant over time. But the assumption that capital is perfectly mobile across sectors is a strong assumption. This is because in the short run it is costly to adjust capital, thus capital-intensive goods may have high degree of nontradability if the adjustment cost is high. Incorporating frictions in domestic capital market into the measure of nontradability should be an important agenda for future research.

References

Betts, C. M. and T. J. Kehoe (2006). U.S. real exchange rate fluctuations and relative price fluctuations. *Journal of Monetary Economics 53*(7), 1297–1326.

Burstein, A., M. Eichenbaum, and S. Rebelo (2005). Large devaluations and the real exchange rate. *Journal of Political Economy 113*(4), 742–784.

Burstein, A., J. C. Neves, and S. Rebelo (2003). Distribution costs and real exchange rate dynamics during exchange-rate-based stabilizations. *Journal of Monetary Economics 50*(6), 1189–1214.

Castellanos, S. G., R. Garcia-Verdu, and D. S. Kaplan (2004). Nominal wage rigidities in mexico: Evidence from social security records. *Journal of Development Economics 75*(2), 507–533.

Cheung, Y.-W. and E. Fujii (2006). Cross-country relative price volatility effects of market structure. *Review of International Economics 14*(5), 836848.

Cheung, Y.-W. and E. Fujii (2008). Deviations from the law of one price in japan. *CESIFO Working Paper 2275.*

Crucini, M. J., C. I. Telmer, and M. Zachariadis (2005). Understanding European real exchange rates. *American Economic Review 95*(3), 724–738.

Engel, C. (1999). Accounting for U.S. real exchange rate changes. *Journal of Political Economy 107*(3), 507–538.

Engel, C. and J. H. Rogers (1996). How wide is the border? *American Economic Review 86*(5), 1112–25.

Ghironi, F. and M. J. Melitz (2005). International trade and macroeconomic dynamics with heterogeneous firms. *Quarterly Journal of Economics 120*(3), 865–915.

Gopinath, G., P.-O. Gourinchas, C.-T. Hsieh, and N. Li (2010). International prices, costs and markup differences. *American Economic Review (forthcoming).*

Kahn, S. (1997). Evidence of nominal wage stickiness from microdata. *American Economic Review 87*(5), 993–1008.

Kehoe, T. J. and K. J. Ruhl (2009). Sudden stops, sectoral reallocations, and the real exchange rate. *Journal of Development Economics 89*(2), 235–249.

Liu, Z. and L. Phaneuf (2007). Technology shocks and labor market dynamics: Some evidence and theory. *Journal of Monetary Economics 54*(8), 2534–2553.

Mendoza, E. G. (2000). On the stability of variance decompositions of the real exchange rate across exchange-rate regimes: Evidence from mexico and the united states. *NBER Working Papers 7768.*

Naknoi, K. (2008). Real exchange rate fluctuations, endogenous tradability and exchange rate regimes. *Journal of Monetary Economics 55*(3), 645–663.

Taylor, J. B. (1999). Staggered price and wage setting in macroeconomics. In J. B. Taylor and M. Woodford (Eds.), *Handbook of Macroeconomics*, pp. 1009–1050. Elsevier.

Table 1: Degree of nontradability (γ_i) and its components

Industry	(1) IO Code	(2) γ_i	(3) α_i	(4) $\delta_i\alpha_j$
Cigarettes	3122	0.14	0.05	0.08
Tobacco products	3122	0.14	0.05	0.08
Gasoline	2110	0.29	0.07	0.16
Household cleaning products	3256	0.37	0.11	0.18
Meat, poultry and fish	1120	0.43	0.06	0.23
Fruits and melons, vegetables and tree nuts	1110	0.44	0.12	0.20
Alcoholic beverages	3121	0.48	0.10	0.22
Alcoholic beverages away from home	3121	0.48	0.10	0.22
Nonalcoholic beverages and beverage materials	3121	0.48	0.10	0.22
Beverages and beverage materials	3121	0.48	0.10	0.22
Pulp, paper and allied products	3221	0.49	0.17	0.19
New and used motor vehicles	3361	0.52	0.09	0.25
Sports vehicles including bicycles	3361	0.52	0.09	0.25
Medical care commodities	3391	0.53	0.29	0.14
Petroleum and coal products manufacturing	3240	0.54	0.04	0.29
Motor vehicle maintenance and repair	8111	0.54	0.29	0.14
Appliances	3352	0.55	0.20	0.20
Footwear	3150	0.56	0.22	0.19
Textile products and apparel	3140	0.57	0.20	0.21
Dishes and flatware	3322	0.57	0.30	0.15
Nonmetallic mineral product manufacturing	3270	0.58	0.26	0.18
Food away from home	3110	0.59	0.14	0.25
Newsprint	3222	0.59	0.20	0.21
Primary nonferrous metals	331B	0.60	0.17	0.24
Chemicals and allied products	3251	0.61	0.14	0.25
Plastic products	3260	0.62	0.25	0.20
Rubber and rubber products	3260	0.62	0.25	0.20
Communication and related equipment	334A	0.62	0.20	0.23
Private transportation	4850	0.63	0.38	0.14
Public transportation	4850	0.63	0.38	0.14
Machinery and equipment, except electrical	3333	0.64	0.27	0.20
Fabricated structural metal products	331A	0.64	0.20	0.23
Hides, skins, leather and related products	3160	0.65	0.25	0.21
Transportation equipment	336A	0.65	0.23	0.22
Recreational reading materials	3230	0.66	0.33	0.17
Commercial printing	3230	0.66	0.33	0.17

Table 2: Summary statistics of volatility of sector-specific RER and sector-specific relative wage

	Average of all industries		Dispersion across all industries	
Horizon of changes	RER	Relative wage	RER	Relative wage
U.S.-Canada pairs				
1-month	0.33	0.34	0.23	0.09
3-month	0.62	0.55	0.37	0.14
6-month	0.93	0.76	0.50	0.19
12-month	1.22	0.85	0.66	0.16
24-month	1.62	1.11	0.87	0.26
U.S.-Germany pairs				
1-quarter	0.64	0.53	0.29	0.20
2-quarter	0.93	0.75	0.43	0.22
4-quarter	1.37	1.06	0.51	0.04
6-quarter	1.79	1.42	0.65	0.16
8-quarter	2.18	1.68	0.78	0.10

Note: Volatility measure is standard deviation of the first difference of log over various time horizons.

Table 3: Summary statistics of correlation between sector-specific RER and sector-specific relative wage

Horizon of changes	Minimum	Maximum	Median	Average
U.S.-Canada pairs				
1-month	0.08	0.70	0.40	0.42
3-month	0.13	0.80	0.49	0.53
6-month	0.12	0.87	0.62	0.62
12-month	0.10	0.87	0.66	0.66
24-month	-0.07	0.92	0.78	0.75
U.S.-Germany pairs				
1-quarter	0.12	0.98	0.92	0.77
2-quarter	0.02	0.99	0.93	0.79
4-quarter	-0.14	0.99	0.96	0.85
6-quarter	-0.28	0.99	0.94	0.83
8-quarter	-0.47	0.99	0.96	0.87

Note: The correlation is calculated using the first difference of log of RER and that of relative wage.

Table 4: Results of the cross-industry regression of contribution of relative wage into variance of sector-specific RER

	Horizon of changes				
	(1)	(2)	(3)	(4)	(5)
Explanatory variables	All horizons	3-month	6-month	12-month	24-month
Nontradability	0.91***	0.90***	0.93***	0.87***	0.95***
	(0.04)	(0.09)	(0.08)	(0.09)	(0.09)
Constant	-0.12***	-0.12***	-0.12***	-0.10***	-0.12***
	(0.02)	(0.05)	(0.04)	(0.04)	(0.04)
Sample size	335	67	67	67	67
Adjusted R^2	0.42	0.39	0.44	0.41	0.47
F-statistics	544***	96***	125***	104***	120***

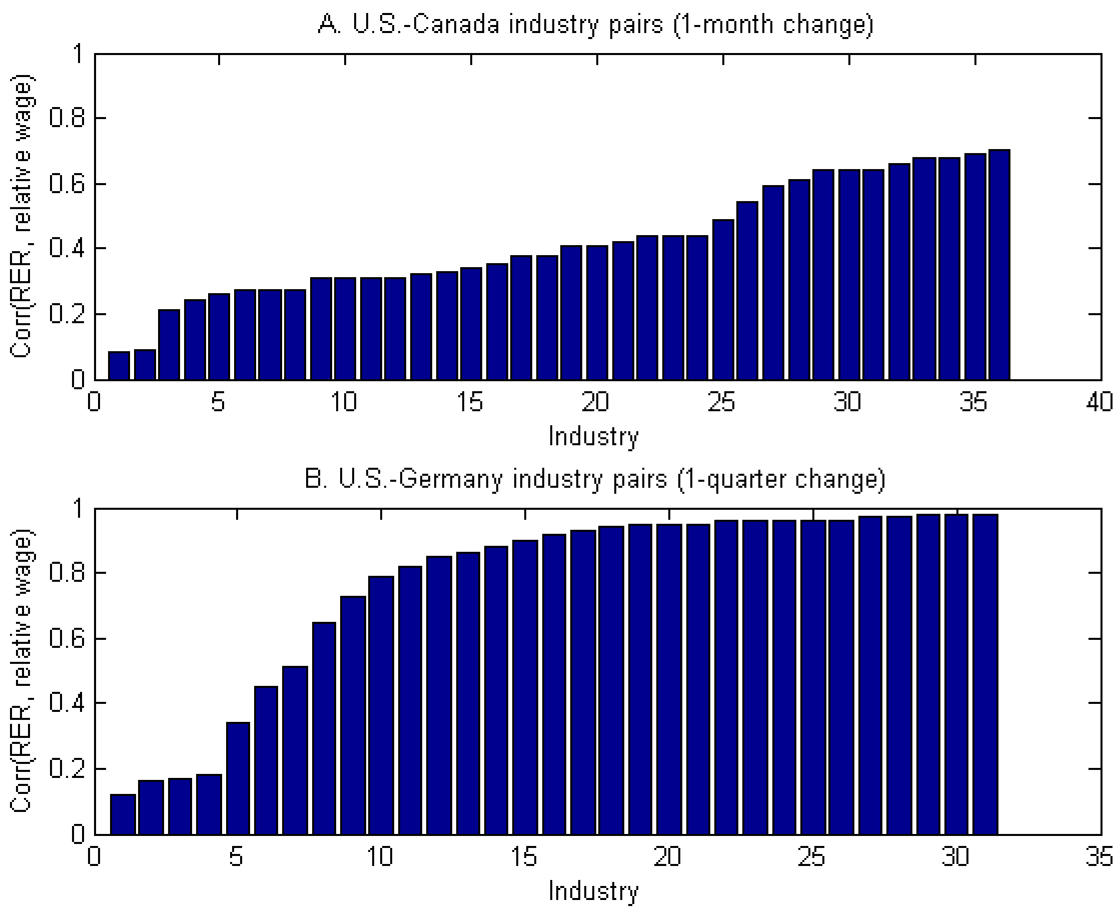
Notes:
1. Heteroskedasticity-robust standard errors are in the bracket.
2. *** denotes statistical significance at 1-percent level.

Table 5: Cross-sectional correlation of degree of nontradability with volatility of RER, volatility of relative wage and volatility of relative markup

Horizon of changes	RER	Relative wage	Relative markup
U.S.-Canada pairs			
1-month	-0.52	0.26	-0.42
3-month	-0.49	0.29	-0.41
6-month	-0.45	0.29	-0.38
12-month	-0.39	0.30	-0.39
24-month	-0.42	0.40	-0.45
U.S.-Germany pairs			
1-quarter	-0.56	0.17	-0.53
2-quarter	-0.54	0.17	-0.56
4-quarter	-0.55	0.08	-0.64
6-quarter	-0.54	0.13	-0.63
8-quarter	-0.50	-0.03	-0.63

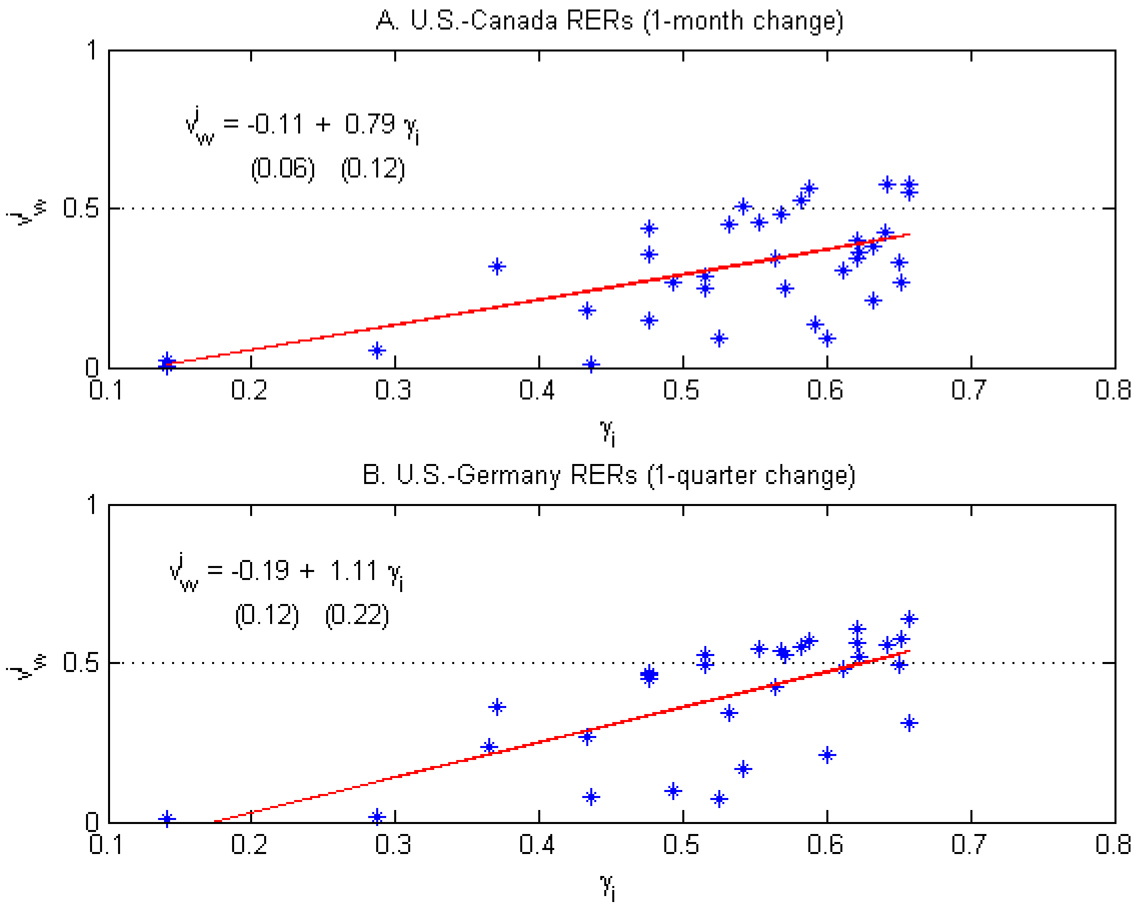
Note: Volatility measure is standard deviation of the first difference of log over various time horizons.

Figure 1: Correlation between sector-specific RER and relative wage



Note: The correlation is between the first difference of log of RER and the first difference of log of relative wage. The horizon of change is one month for U.S.-Canada pairs, and one quarter for U.S.-Germany pairs.

Figure 2: Degree of nontradability (γ_i) and contribution of relative wage into variance of sector-specific RER (v_w^i)



Note: The straight line fits the plots with the linear regression displayed in each panel. Numbers in the bracket are heteroskedasticity-robust standard errors.

Figure 3: Degree of nontradability (γ_i) and contribution of relative wage into variance of U.S.-Canada sector-specific RER (v_w^i)

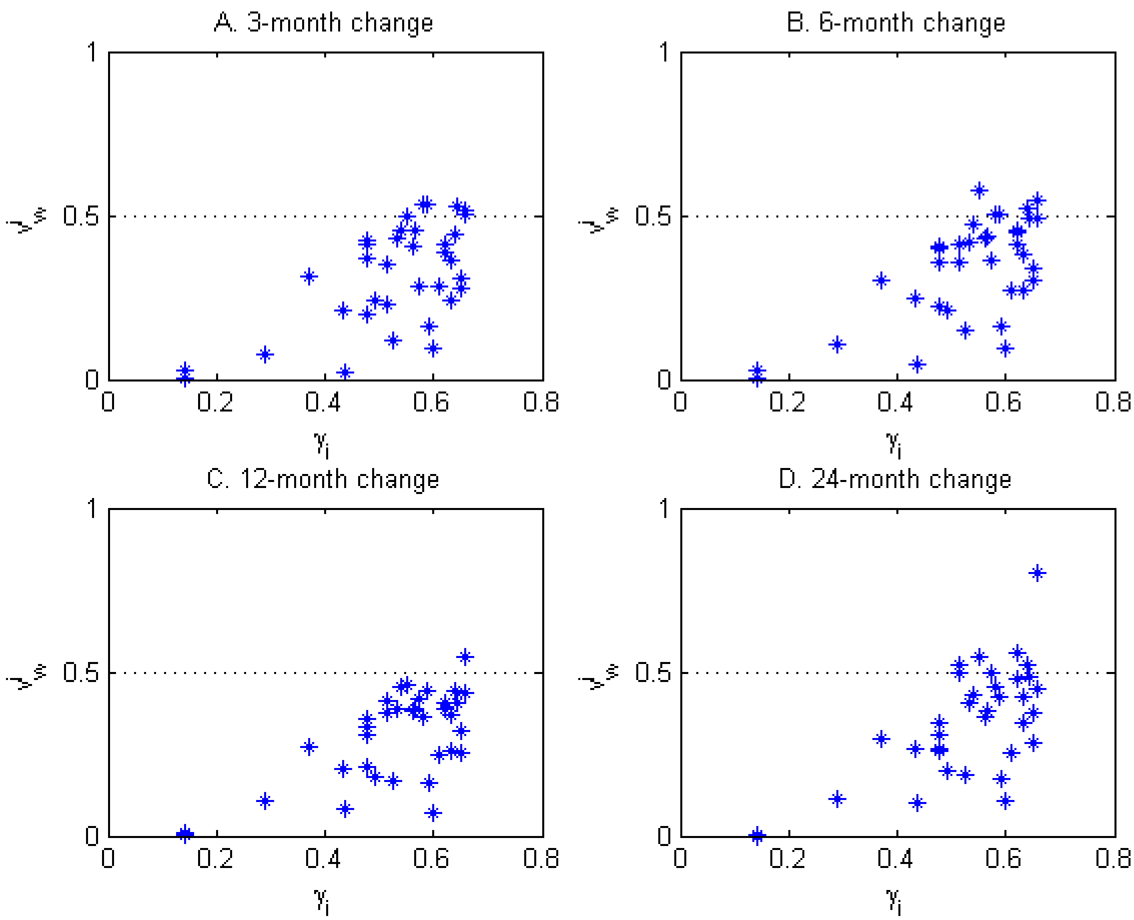


Figure 4: Degree of nontradability (γ_i) and contribution of relative wage into variance of U.S.-Germany sector-specific RER (v_w^i)