Exchange Rate Regimes and Wage Comovements in a Dynamic Ricardian Model*

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Abstract

We construct a dynamic Ricardian model with a nominal exchange rate and trade costs. The model predicts that the nominal wages of the trading countries exhibit stronger positive comovements when the countries fix their bilateral exchange rates, while comovements of real wages are not affected by exchange rate regimes. Our numerical experiments suggest that a reduction in trade costs increases both nominal and real wage comovements, regardless of regimes. After downward nominal wage rigidity is introduced, the difference in nominal wage comovements under the fixed regime vs. the flexible regime decreases, while that for real wages increases. When we define a fixed exchange rate regime as membership in the European Monetary Union, panel regression results based on data from OECD countries from 1973 to 2012 are broadly consistent with the predictions of the model and numerical experiments.

JEL classification: F1, F3
Keywords: fixed exchange rate regime, currency union, trade, wage comovements

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1 Introduction

One stylized fact is that a fixed exchange rate can act as an anchor for prices for trading countries, i.e., prices in a country tend to comove positively with prices in its trading partners to which it pegs its currency (e.g., Edwards, 1993; Calvo and Vegh, 1994; Willett, 1998). Another stylized fact is that the cross-country correlation between price levels and wage levels is strongly positive (e.g., Crucini and Yilmazkuday, 2014), which indicates that wages can be approximately representative of prices. These two stylized facts suggest that under a fixed exchange rate regime, nominal wages should comove positively between trading countries. This possibility is important particularly for countries that peg their currency or join a currency union because their wages can be tightly linked to wages in their trading partners. In fact, McKinnon (2005, 2006) argues that it is nominal wage changes that would be the main vehicle of international adjustment under a fixed exchange rate.

Few studies, however, have theoretically or empirically investigated comovements of nominal wages. This is probably because typical trade models are real models and thus do not explicitly address the monetary aspects of trade such as nominal exchange rates and wages, although Dornbusch, Fischer and Samuelson (1977) and Ito and Ohyama (1985) note that it is possible to extend the discussion of the standard Ricardian model to include nominal variables. This paper now fills this void by developing and testing a dynamic stochastic Ricardian model with a nominal exchange rate and trade costs.

Our production structure extends the model of Ricardian trade with a continuum of goods developed by Dornbusch et al. (1977) to a dynamic stochastic model. We are similar to Eaton and Kortum (2002) in that we extend the model of Dornbusch et al. (1977), but we differ from them in that we model productivities in a different way. We specify the productivity distribution as a straight line, and it is stochastic over time. On the other hand, Eaton and Kortum (2002) specify it as the Frechet distribution, and it is not stochastic over time. We are also similar to Levchenko and Zhang (2011) in that we extend a Ricardian model to a dynamic model, but we differ from them in that our dynamic model focuses on labor as a factor of production, focuses on final goods, and incorporates exchange rates into the determination of specialization. Our preference structure is novel in the Ricardian model literature in that our utility function is a money-in-the-utility function. The monetary and financial sides of our model follow Chari, Kehoe and McGrattan (2002). To be specific, the introduction of money, the setup of an asset market and the determination of an equilibrium exchange rate in our model are similar to theirs.

We then use our model and numerical experiments to analyze how exchange rate regimes affect nominal wage comovements between the trading countries, measured by nominal wage correlations, as well as the effects of trade costs and downward nominal wage rigidity. The main predictions of our model are as follows. First, nominal wages comove strongly and positively between trading countries that peg their currencies. This prediction has implications on exchange rate policies. Under a fixed exchange rate regime, wage inflation in a foreign country can be accompanied by wage inflation in a home country. Under a flexible exchange rate regime, on the other hand, exchange rate changes can shut out the repercussions, through trade, of changes in nominal wages in a foreign country. Therefore, a peg acts as an anchor for nominal wages. Second, our numerical experiments suggest that a reduction in trade costs tends to increase nominal wage comovements under both the fixed and flexible exchange rate regimes. Third, when downward nominal wage rigidity is introduced into the numerical experiments, the comovements between home and foreign nominal wages decline slightly under both regimes, and the difference in nominal wage comovements under the fixed regime vs. the flexible regime decreases.

In addition to nominal wage comovements, we also analyze the comovements of real wages. In our model, the choice of exchange rate regime does not affect comovements of real wages due to the neutrality of money. Meanwhile, a reduction in trade costs tends to increase real wage comovements under both the fixed and flexible exchange rate regimes. When downward nominal wage rigidity is introduced, the comovements between home and foreign real wages decline slightly under both regimes, but the difference in real wage comovements under the fixed regime vs. the flexible regime increases.

We use a panel of 24 OECD countries from 1973 to 2012 to test the predictions of our model about nominal and real wage comovements. We perform empirical analysis at one-year and four-year frequencies under the premise that nominal wage rigidity is more likely in the short run. The regression results suggest that if a country and its main trade partner were in the EMU, then their nominal wages experienced significantly stronger comovements. The positive effects of the EMU on comovements are smaller in the short run than in the long run, although the difference is statistically insignificant. When we restrict the sample to EMU countries, we find some evidence that these countries experienced stronger positive nominal wage comovements compared to the pre-euro era. For the non-EMU countries, there is no evidence that non-currency-union pegs strengthened nominal wage comovements. Turning to real wage comovements, we find that country pairs with EMU membership had a more positive effect on real wage comovements in the short run than in the long run, although the effects were insignificant. Lastly, the regression results indicate that the trade intensity between two countries is positively correlated with the comovements of both nominal and real wages. These findings are broadly consistent with the predictions of our model and numerical analysis.

Our paper thus makes the following contributions. First, it adds to the literature on exchange rates and wages by highlighting the role of exchange rate regimes. While many studies analyze the relationship between real exchange rates and real wages (e.g., Goldberg and Tracy 2000; Campa and Goldberg 2001), by incorporating money and a nominal exchange rate into the Ricardian model, our paper examines the relationship between nominal exchange rates and both nominal and real wages. In particular, our paper reveals that the effects of trade on the nominal wage comovements between the trading countries are different under the fixed and flexible exchange rate regimes. To the best of our knowledge, our paper is the first to use a Ricardian model to analyze the relationship between exchange rates and wage comovements.

Second, our paper adds to the empirical evidence of nominal wage comovements by showing that nominal wages comove more positively between the trading countries under pegs. As far as we know, there are only three studies on the subject. The first, Budd, Konings and Slaughter (2005), highlights the comovements of nominal wages within a multinational firm through internal risk sharing. The second, Robertson (2000), highlights the comovements of nominal wages between the border region of Mexico and the U.S. and between the interior and border regions in Mexico. He provides evidence for these comovements, indicating that the wage impact of emigration is transmitted to the overall Mexican economy. The third, Lamo, Perez and Schuknecht (2008), highlights the comovements of nominal wages across sectors within a country. They show strong positive comovements of public and private sector nominal wages over business cycles since the 1960s in the euro area and a number of other OECD countries.[1] While these previous works focus on inter- and intra-country nominal wage comovements due to internal risk sharing within a multinational firm and emigration, we establish that trade and exchange rate regimes provide an alternative to FDI and migration as a cause of nominal wage comovements.

Third, our paper adds to the literature on the relationship between exchange rates

[1] Lamo et al. (2008) also study causal linkages between public and private sector wages, i.e., the public/private wage leadership. Their causality analysis suggests that although influences from the private sector appear on the whole to be stronger, there are direct and indirect feedback effects from a public wage setting in a number of countries as well. See the references in their paper for studies on wage leadership in a particular country (primarily Sweden and several others).

and macroeconomic real variables (e.g., Stockman, 1987; Baxter and Stockman, 1989; Flood and Rose, 1995; Obstfeld and Rogoff, 1995a; Stockman, 1998; Kollmann, 2001; Chari et al., 2002; Duarte, Restuccia and Waddle, 2007). While past studies have analyzed comovements between exchange rates and macroeconomic real variables such as output and consumption, our model focuses on comovements of real variables between trading countries and examines a possible effect of exchange rate regimes. We thus provide a different angle of the analysis of real comovements.

Fourth, our paper adds to the literature on the relationship between real exchange rates and the relative price of nontradable goods (Betts and Kehoe, 2006, 2008) by providing it with an alternative theoretical foundation. While past studies have derived this relationship from traditional real exchange rate theory, our paper derives it from a dynamic Ricardian model of trade with exchange rate. Our model indicates that different exchange rate regimes have different effects on this relationship, which can guide empirical work along the direction outlined in Betts and Kehoe (2008).

The rest of this paper is organized as follows. In Section 2, we construct a dynamic Ricardian model with a nominal exchange rate and trade costs and derive the predictions on wage comovements. We present supporting empirical evidence in Section 3. Section 4 concludes by offering a brief discussion of the results.

2 Theory

In this section, we construct a dynamic Ricardian model of trade with a nominal exchange rate and trade costs and thus address the monetary aspects of trade. As mentioned in the introduction, the setup of the model borrows from two main sources, first, the Ricardian models (Dornbusch et al., 1977; Eaton and Kortum, 2002; Levchenko and Zhang, 2011), and second, models of money and exchange rates (Chari et al., 2002). The model in our paper is highly stylized, but it allows us to obtain analytic solutions for the baseline version of the model, and clear insights about the effects of exchange rate regimes and trade on wage comovements.

2.1 Model setup

There are two countries, home and foreign. The variables associated with the home and foreign countries are indicated by superscripts H and F, respectively. Each country is capable of producing the same continuum of tradable goods. The goods are indexed by i, and $i \in [0,1]$. There exist iceberg trade costs τ, i.e., when a country ships $1+\tau$ unit of goods to the other country, only 1 unit arrives. Because of trade costs, some tradable varieties may not be traded in equilibrium. Each country also produces a nontradable good, z. As in typical Ricardian models, there is only one input factor, labor, and it is perfectly mobile across industries within a country but immobile across countries.[2] Thus, wages are the same across industries within a country but can be different across countries.

For country $j = H, F$, the period preference for the representative consumer is

$$U_t^j = \frac{\left(C_t^j\right)^{1-\zeta}}{1-\zeta} - \kappa \frac{\left(L_t^j\right)^{1+\gamma}}{1+\gamma} + \chi h\left(\frac{M_t^j}{P_t^j}\right),$$

where

$$C_t^j = \left[\left(\int_0^1 C_t^j(i)^{\frac{\eta-1}{\eta}}\, di\right)^{\frac{\eta}{\eta-1}\cdot\epsilon} \cdot C_t^j(z)^{1-\epsilon}\right],$$

[2] Because our focus is on labor, similar to Eaton and Kortum (2002), our model does not include capital, maintaining the model in a simple form. In Section 3.1, however, we will discuss migration and capital movements and include their controls in our regressions.

$\zeta, \kappa, \gamma, \chi$ and $\eta > 0$ and $0 < \epsilon < 1$. The period budget constraint is

$$\int_0^1 P_{jt}(i)\, C_t^j(i)\, di + P_t^j(z)\, C_t^j(z) + M_t^j + \sum_s q^j(s_{t+1})\, B^j(s_{t+1}) = W_t^j L_t^j + M_{t-1}^j + B_t^j + \Pi_t^j + T_t^j.$$

There is also a borrowing constraint

$$B^j(s_{t+1}) \geq -P_t^j \bar{b^j}.$$

Here, $C_t^j(i)$ denotes the consumption of tradable good i in country j, and $C_t^j(z)$ is the consumption of the nontradable good in country j. The parameter η governs the elasticity of substitution between tradable goods, and ϵ is the fraction of expenditure that goes to the tradable goods. The quantity L_t^j is labor supply. The variables M_t^j and P_t^j are money supply and the aggregate price level. The variables $P_{jt}(i)$,[3] $P_t^j(z)$, and W_t^j are the nominal price of tradable good i, the nominal price of nontradable good, and nominal wages, all denoted in the local currency. The variables $q^j(s_{t+1})$ and $B^j(s_{t+1})$ are the price and the quantity of a nominal bond that pays one unit of local currency in state s in period $t+1$, and zero otherwise. Lastly, Π_t^j and T_t^j are profits of firms and a nominal transfer from the government of country j. The constant $\bar{b^j}$ is the constraint on real borrowing. Our budget constraint is similar to that in the Chari et al. (2002) model, except that ours has the consumption of nontradable goods.

Given the prices $P_{jt}(i)$ and $P_t^j(z)$, the minimization of the cost of C_t^j yields the following unit cost of C_t^j, which we refer to as the price of C_t^j

$$P_t^j = \left[\epsilon^{-\epsilon}(1-\epsilon)^{\epsilon-1}\right] \left(\int_0^1 (P_{jt}(i))^{1-\eta}\, di\right)^{\frac{1}{1-\eta}\epsilon} \left(P_t^j(z)\right)^{1-\epsilon}.$$

[3] A tradable good i that the consumer buys can be a home or foreign good, so there is no superscript j for the variable $P_{jt}(i)$. Instead, we use the subscript j to indicate that it is the price that the consumer in country j actually pays.

Hence, the budget constraint can be written as

$$P_t^j C_t^j + M_t^j + \sum_s q^j\left(s_{t+1}\right) B^j\left(s_{t+1}\right) = W_t^j L_t^j + M_{t-1}^j + B_t^j + \Pi_t^j + T_t^j.$$

The production technology is

$$\begin{aligned} Y_t^j(i) &= A_t^j(i)\, L_t^j(i), \\ Y_t^j(z) &= A_t^j(z)\, L_t^j(z), \end{aligned}$$

where $A_t^j(i)$ and $A_t^j(z)$ are the stochastic productivities. Here, we do not impose any assumption on their stochastic processes because they are not needed for the derivation of Proposition 1. In Section 2.3, we will specify them for further analysis.

The market for each tradable good is perfectly competitive. The home producers of good i have to compete with foreign producers of the same good. Home and foreign consumers only buy from the producers with the lowest price. Consequently, the domestic prices posted by the home firms and foreign firms for good i in their respective local currencies are

$$\begin{aligned} P_t^H(i) &= W_t^H / A_t^H(i), \\ P_t^F(i) &= W_t^F / A_t^F(i), \end{aligned}$$

respectively, but the prevailing market prices that consumers in the home and foreign countries actually pay are now given by

$$\begin{aligned} P_{Ht}(i) &= min\left\{P_t^H(i), (1+\tau) P_t^F(i)\, e_t\right\}, \\ P_{Ft}(i) &= min\left\{(1+\tau) P_t^H(i) / e_t, P_t^F(i)\right\}, \end{aligned}$$

where e_t is the nominal exchange rate, defined as the price of foreign currency in the home currency.

We order the varieties i such that $A_t^H(i)/A_t^F(i)$ is decreasing in i. As in Dornbusch et al. (1977), we assume that $A_t^H(i)/A_t^F(i)$ is strictly decreasing in i. Thus, there exists a cutoff variety k_t^F such that for all $i \in [0, k_t^F)$, $P_t^H(i) < (1+\tau) P_t^F(i) e_t$ holds. Similar, there exists a cutoff variety $k_t^H < k_t^F$ such that for all $i \in (k_t^H, 1]$, $(1+\tau) P_t^H(i)/e_t > P_t^F(i)$ holds. Therefore, varieties in $[0, k_t^H)$ are produced only by the home country, while varieties in $(k_t^F, 1]$ are produced only by the foreign country. The varieties $i \in [k_t^H, k_t^F]$ are not traded due to the trade costs and are produced in both countries.

The market for nontradable goods is also perfectly competitive. Consequently, the local-currency prices for the nontradable goods are

$$P_t^j(z) = W_t^j / A_t^j(z).$$

As in Chari et al. (2002), money is introduced into the utility function. The money supplies in the two countries follow stochastic processes, to be specified in later subsections for different exchange rate regimes. In country $j = H, F$, any new money balance $M_t^j - M_{t-1}^j$ is distributed to households through lump-sum transfer. That is, $T_t^j = M_t^j - M_{t-1}^j$. As in Chari et al. (2002), the equilibrium exchange rate is determined by the first order condition

$$e_t = \frac{P_t^H \left(C_t^H\right)^\zeta}{P_t^F \left(C_t^F\right)^\zeta}\delta = \frac{\lambda_t^F}{\lambda_t^H}\delta, \tag{1}$$

where δ is a constant depending on the state of the economies in the initial period; the marginal utility in the home country relative to that in the foreign country in the initial period. The variables λ_t^H and λ_t^F are the marginal utility associated with the home and foreign nominal wealth, respectively. Unlike Chari et al. (2002), our focus is not on nominal price rigidity. Hence, we assume flexible prices.

At the beginning of each period, both money shocks and productivity shocks are observed by all players in the economy. Firms then post prices, consumers make purchase decisions, production occurs, and markets clear. Because our main interests are in the role of exchange rate regimes in anchoring nominal wages in the long run, for most of the paper we assume that all prices and wages are flexible. In the numerical experiments in later sections, we explore a version of the model with flexible prices but downward-rigid nominal wages.

The market clearing conditions are

$$\begin{aligned}
L_t^H &= \int_0^{k_t^F} L_t^H(i)\,di + L_t^H(z)\,, \\
L_t^F &= \int_{k_t^H}^1 L_t^F(i)\,di + L_t^F(z)\,, \\
Y_t^H(i) &= C_t^H(i) + C_t^F(i)(1+\tau) \quad \forall i < k_t^H, \\
Y_t^F(i) &= C_t^H(i)(1+\tau) + C_t^F(i) \quad \forall i > k_t^F, \\
Y_t^j(i) &= C_t^j(i) \quad \forall k_t^H \le i \le k_t^F, \\
Y_t^j(z) &= C_t^j(z)\,.
\end{aligned}$$

In addition, there is a balanced-trade condition

$$\int_0^{k_t^H} C_t^F(i)(1+\tau) P_t^H(i)\,di = \int_{k_t^F}^1 C_t^H(i)(1+\tau) P_t^F(i)\,e_t di.$$

2.2 Exchange rate regimes and the nominal wage comovements

We characterize the general relationship between the changes in home and foreign nominal wages in Proposition 1. We briefly outline the derivations here and leave the proof to the

Appendix. First, using the relationship between nominal prices and nominal wages implied by the technology and market structure, we can express the real exchange rate as a function of the nominal exchange rate, nominal wages, and productivities:

$$e_t \frac{P_t^F}{P_t^H} = \left(\frac{e_t W_t^F}{W_t^H} \right)^{1-\epsilon} \left(\frac{A_t^H(z)}{A_t^F(z)} \right)^{1-\epsilon} D_t, \tag{2}$$

where

$$D_t = \left[\frac{\int_0^{k_t^H} \left((1+\tau) P_t^H(i) \right)^{1-\eta} di + \int_{k_t^H}^{k_t^F} \left(P_t^F(i) e_t \right)^{1-\eta} di + \int_{k_t^F}^{1} \left(P_t^F(i) e_t \right)^{1-\eta} di}{\int_0^{k_t^H} \left(P_t^H(i) \right)^{1-\eta} di + \int_{k_t^H}^{k_t^F} \left(P_t^H(i) \right)^{1-\eta} di + \int_{k_t^F}^{1} \left((1+\tau) P_t^F(i) e_t \right)^{1-\eta} di} \right]^{\frac{1}{1-\eta}\epsilon}.$$

The term D_t can be viewed as the ratio of the price index for tradable goods in the foreign country to that in the home country. The presence of the term D_t is due to the trade costs τ. When τ is zero, $D_t = 1$.[4]

Next, the equilibrium exchange rate, stated in equation (1), links the real exchange rate to relative consumption

$$e_t \frac{P_t^F}{P_t^H} = \delta \left(\frac{C_t^H}{C_t^F} \right)^{\zeta}.$$

Because consumption is linked to labor supply via the labor market clearing conditions and labor supply is linked to nominal wages through the households' optimization problem, we can relate the real exchange rate to nominal wages and the nominal exchange rate:

$$e_t \frac{P_t^F}{P_t} = \left(\frac{W_t^H}{W_t^F e_t} \right)^{\frac{\zeta(1+\gamma)}{\gamma(1-\zeta)}} \delta^{1+\frac{\zeta(1+\gamma)}{\gamma(1-\zeta)}}. \tag{3}$$

Thus we can view equation (2) as the relationship between the real exchange rate

[4]Depending on the distribution of tradable productivities in the two countries, the relationship between D_t and τ can be complex. For instance, for positive values of τ, if distributions of tradable productivities in the two countries are mirror images to each other (i.e., $A_t^H(i) = A_t^F(1-i)$ for all i), then D_t is also 1.

and relative wage implied by technology, and equation (3) as the relationship between the real exchange rate and relative wage implied by preferences. Combining equations (2) and (3) to eliminate the real exchange rate, we can relate the changes in nominal wages to changes in technology.

Proposition 1. *The relationship between growth in home nominal wages and the foreign counterpart is*

$$\frac{W_t^H}{W_{t-1}^H} = \frac{W_t^F}{W_{t-1}^F}\frac{e_t}{e_{t-1}}\left(\frac{A_t^H(z)\,A_{t-1}^F(z)}{A_{t-1}^H(z)\,A_t^F(z)}\right)^{\frac{\gamma(1-\epsilon)(1-\zeta)}{\gamma(1-\epsilon)+\zeta(1+\gamma\epsilon)}}\left(\frac{D_t}{D_{t-1}}\right)^{\frac{\gamma(1-\zeta)}{\gamma(1-\epsilon)+\zeta(1+\gamma\epsilon)}}. \tag{4}$$

Based on Proposition 1, we can decompose the change in home nominal wages into changes in foreign nominal wages, nominal exchange rates, productivities of the nontradable good, and the relative price of tradable goods. Intuitively, if the nominal exchange rate is flexible, it is less likely that the change in home nominal wages must match the foreign counterpart. Hence, we expect comovements of nominal wages to be stronger under the fixed exchange rate regime. In particular, when $\zeta = 1$, i.e., the utility with respect to consumption has log form, then equation (4) is reduced to

$$\frac{W_t^H}{W_{t-1}^H} = \frac{W_t^F}{W_{t-1}^F}\frac{e_t}{e_{t-1}}.$$

In this case, nominal wages comove perfectly under a fixed exchange rate.

Next, we further specify our model by making explicit assumptions about the utility of the real balance and the stochastic processes governing money supplies and productivities. These assumptions serve two purposes. First, under them we explicitly show that nominal wage comovements are stronger under the fixed exchange rate regime. Second, the assumptions will guide our numerical experiments and regressions. Specifically, for $j = H, F$, we assume that

- (a) The utility of the real balance is $h\left(M_t^j/P_t^j\right) = ln\left(M_t^j/P_t^j\right)$.

- (b) The productivities are

$$A_t^j(i) = A^j(i)\, exp\left(a_t^j + \alpha_t^j\right),$$
$$A_t^j(z) = A^j(z)\, exp\left(a_t^j(z) + \alpha_t^j(z)\right),$$

where a_t^j and $a_t^j(z)$ are the deterministic trends of the productivities, and α_t^j and $\alpha_t^j(z)$ are the stochastic components. The stochastic components follow AR(1) processes

$$\alpha_t^j = \rho^j \alpha_{t-1}^j + u_t^j,$$
$$\alpha_t^j(z) = \rho^j(z)\, \alpha_{t-1}^j(z) + v_t^j,$$

where u_t^j and v_t^j are zero-mean shocks and they can be correlated.

Regarding the money supplies, we assume that

- (c1) when the exchange rate is flexible, the money supply of country j follows the stochastic processes

$$M_t^j = exp\left(\mu_t^j\right) M_{t-1}^j \left(1 + g^j\right),$$

where g^j is a constant, and μ_t^H and μ_t^F are zero-mean iid shocks with a common cdf $\Phi(\mu)$.

- (c2) if the exchange rate is fixed, the foreign money supplies follow the stochastic process

$$M_t^F = exp\left(\mu_t^F\right) M_{t-1}^F \left(1 + g^F\right),$$

where g^F is a constant, and μ_t^F is a zero-mean iid shock with the cdf $\Phi(\mu)$. The home country sets M_t^H to fix the exchange rate.

- (d) Both monetary shocks are independent of the productivity shocks.[5]

Based on the assumptions and the first order conditions with respect to labor supply and consumption, we can write the expression for the change in home nominal wages under the fixed exchange rate regime as

$$ln\left(\frac{W_t^H}{W_{t-1}^H}\right) = ln\left(1 + g^F\right) + \mu_t^F + d_t + f_t,$$

where d_t is a function of nontradable productivity shocks v_t^H and v_t^F, and f_t is a function of both tradable and nontradable productivity shocks $u_t^H,\ u_t^F,\ v_t^H$ and v_t^F.[6] Under the

[5] This assumption is common in the literature on macroeconomics, especially international macroeconomics (Hairault and Portier, 1993; Chari et al., 2002; Devereux and Sutherland, 2007). In the spirit of Friedman and Schwartz (1963) and Romer and Romer (1989), we regard monetary shocks as nominal disturbances independent of the real side of the economy and the policy response of the central banks to the real economy. Therefore, we believe that it is reasonable to assume such monetary shocks to be independent of shocks to the production processes.

[6] The functions d_t and f_t are, respectively defined by

$$exp[d_t\left(v_t^H, v_t^F\right)] = exp[\frac{\gamma(1-\epsilon)(1-\zeta)}{\gamma(1-\epsilon)+\zeta+\zeta\epsilon\gamma}\left(A_t^H(z) - A_{t-1}^H(z) - A_t^F(z) + A_{t-1}^F(z)\right)],$$

$$\begin{aligned} exp[f_t\left(u_t^H, u_t^F, v_t^H, v_t^F\right)] = {} & \frac{e_t}{e_{t-1}}\frac{D_t}{D_{t-1}}\left\{\left(\frac{W_{t-1}^H}{e_{t-1}}\right)^{1-\eta} exp[\frac{\gamma(1-\epsilon)(1-\zeta)(1-\eta)}{\gamma(1-\epsilon)+\zeta(1+\epsilon\gamma)}\left(A_t^H(z) - A_{t-1}^H(z) - A_t^F(z) + A_{t-1}^F(z)\right)]\times\right. \\ & \frac{D_t}{D_{t-1}} exp[(\eta-1)\left(a_t^H + \rho^H\alpha_{t-1}^H + u_t^H\right)]\int_0^{k_t^H}\left(\frac{A^H(i)}{1+\tau}\right)^{\eta-1} di + \\ & \left. exp[(\eta-1)\left(a_t^F + \rho^F\alpha_{t-1}^F + u_t^F\right)]\int_{k_t^H}^1\left(A^F(i)\right)^{\eta-1} di\right\}^{\frac{\epsilon\gamma(\zeta-1)}{(1-\eta)(\zeta+\gamma)}}\times \\ & [A^F(z)\, exp\left(a_t^F(z) + \rho^F(z)\,\alpha_{t-1}^F(z) + v_t^F\right)]^{\frac{\gamma(1-\epsilon)(1-\zeta)}{\zeta+\gamma}}\times \\ & \frac{\kappa^{\frac{\zeta}{\zeta+\gamma}}\left(M_{t-1}^F\right)^{\frac{\zeta(1+\gamma)}{\zeta+\gamma}}\left(C_{t-1}^F\right)^{\frac{\zeta\gamma(1-\zeta)}{\zeta+\gamma}}\left(P_{t-1}^F\right)^{\frac{\gamma(1-\zeta)}{\zeta+\gamma}}[\epsilon^{-\epsilon}(1-\epsilon)^{\epsilon-1}]^{\frac{\gamma(\zeta-1)}{\zeta+\gamma}}}{\left(\chi\psi^F\right)^{\frac{\zeta(1+\gamma)}{\zeta+\gamma}}}. \end{aligned}$$

.

flexible exchange rate regime, the change in home nominal wages is

$$ln\left(\frac{W_t^H}{W_{t-1}^H}\right) = ln\left(1+g^H\right) + \mu_t^H + d_t + f_t.$$

Similarly, we can write the change in foreign nominal wages as

$$ln\left(\frac{W_t^F}{W_{t-1}^F}\right) = ln\left(1+g^F\right) + \mu_t^F + f_t.$$

From the last three equations, it is obvious that when the exchange rate regime is fixed, the comovements between home and foreign wages are caused by both the identical monetary effects, $ln\left(1+g^F\right)+\mu_t^F$, and the correlation in the productivity effects, f_t. Under the flexible exchange rate regime, the monetary effects in the two countries are not correlated unless the monetary shocks are correlated. In this case, the comovements in wages will be weaker because the comovements are caused by only the correlation in productivity effects.

We now formalize these results regarding nominal wage comovements under different exchange rate regimes as Proposition 2, and leave the proof to the Appendix.

Proposition 2. *Under assumptions (a), (b) and (d), nominal wage comovements between the countries are more positive or less negative under the fixed exchange rate regime (assumption (c2)), compared to the flexible exchange rate regime (assumption (c1)). To be specific,*

$$corr^{FX}\left(ln\left(\frac{W_t^H}{W_{t-1}^H}\right), ln\left(\frac{W_t^F}{W_{t-1}^F}\right)\right) - corr^{FL}\left(ln\left(\frac{W_t^H}{W_{t-1}^H}\right), ln\left(\frac{W_t^F}{W_{t-1}^F}\right)\right) \geq 0,$$

where FX and FL denote the fixed and flexible exchange rate regimes, respectively. The strict equality holds only when monetary shocks μ_t^H and μ_t^F are perfectly correlated.

2.3 The effects of trade costs and downward nominal wage rigidity on nominal wage comovements

In this subsection, we examine how two additional factors, trade costs and downward nominal wage rigidity, may affect nominal wage comovements, and whether their effects interact with exchange rate regimes. Trade costs are important because we analyze nominal wage comovements between trading countries. Intuitively, if trade costs are reduced, more tradable goods will become traded, potentially leading to stronger alignment of nominal wages. Downward nominal wage rigidity is also important because it is deemed a salient feature of the labor markets in the Eurozone (Schmitt-Grohé and Uribe, 2013) and may restrict nominal wage comovements.

Because it is difficult to obtain analytic results related to trade costs and downward nominal wage rigidity in our model, we resort to numerical experiments. Similar to Proposition 2, we measure wage comovements as the correlation coefficient between wages. First, without introducing nominal wage rigidity, we calculate the correlation coefficient between nominal wages under both flexible and fixed exchange rate regimes for different values of the trade costs τ. We then repeat the calculations for a setup with flexible nominal prices and downward-rigid nominal wages.

The values of key parameters are obtained from the literature. To be precise, the constant relative risk aversion parameter (ζ) is 3 (Hubbard, Skinner and Zeldes, 1994), the disutility of labor parameter (γ) is 0.262 (Imai and Keane, 2004), the share of all tradable goods in total expenditures (ϵ) is 0.3 (Arkolakis and Ramanarayanan, 2009), the elasticity of substitution between tradable goods (η) is 1.5 (Backus, Kehoe and Kydland, 1994), the upper bound of trade costs τ is 0.6 (Xu, 2003), and the persistence in productivity shocks to tradable goods production (ρ^H and ρ^F) is both 0.95 (Kehoe and Perri, 2002).

As in Stockman and Tesar (1995), the covariance matrix of productivity shocks is specified as

$$V\left([u_t^H \quad v_t^H \quad u_t^F \quad v_t^F]'\right) = \frac{1}{100}\begin{pmatrix} 3.62 & 1.23 & 1.21 & 0.51 \\ 1.23 & 1.99 & 0.51 & 0.27 \\ 1.21 & 0.51 & 3.62 & 1.23 \\ 0.51 & 0.27 & 1.23 & 1.99 \end{pmatrix}.$$

We follow Chari et al. (2002) to set the size of home and foreign monetary shocks to be 0.023. We assume that the monetary shocks are independent of each other. Consistent with assumption (d), the monetary shocks are also independent of productivity shocks.

To study the effects of downward nominal wage rigidity, it is important to have frequent drops in nominal wages in the flexible wage equilibrium. We set the growth rate of money supplies in both countries (g^H and g^F) to be 0.02 such that nominal wages would drop in about half of the numerical experiments. To reduce computational time and improve numerical stability, we specify the baseline productivity for tradable goods as $A^H(i) = 2 - i$ and $A^F(i) = 1 + i$. Other parameters are normalized because they affect the levels but not the growth rates of nominal wages. We vary τ between 0 and 0.6 and the step size is 0.02. For each value of τ, we draw 400 sets of productivity and monetary shocks, and compute the correlations between nominal wages using the 400 pairs of calculated nominal wage growth rates in the two countries.

The purpose of our numerical experiments is to study the qualitative effects of trade costs and downward-rigid nominal wages. We do not seek to match any moments or statistics of the data.

First, for the case of no nominal wage rigidity, we plot the correlations between the home and foreign nominal wages for different values of trade costs τ in Figure 1. As we can see, a reduction in trade costs τ tends to increase the correlation between the home and foreign nominal wages under both the fixed and flexible exchange rate regimes. This implies a negative relationship between trade costs and nominal wage comovements regardless of the regime. Intuitively, when more trade is enabled by a decrease in trade costs, nominal wages in the two countries are more closely linked.

Next, we introduce downward nominal wage rigidity, a feature that is not included in the theoretical model because we have aimed to obtain analytic solutions. For each draw of shocks, we compute the equilibrium with flexible nominal prices and wages. If this flexible-wage equilibrium requires a decrease in nominal wage(s), we impose that the nominal wage(s) is equal to wage(s) in the last period and recalculate the equilibrium. The results of numerical experiments associated with downward nominal wage rigidity are plotted in Figure 2. Comparing Figure 1 and Figure 2, we can see that the rigidity reduces the correlations between nominal wages under both the flexible and fixed exchange rate regimes.

To see whether rigidity increases or reduces the effect of exchange rate regimes on nominal wage comovements, in Figure 3 we plot the differences in nominal wage correlations between the fixed and flexible regimes for the case of no rigidity and the case of downward nominal wage rigidity. Figure 3 suggests that when nominal wages are flexible, the positive effect of fixed exchange rate regimes on nominal wage comovements is stronger. Intuitively, nominal wage rigidity restricts the alignment of nominal wages driven by the monetary factor under the fixed exchange rate regime.

2.4 Comovements of real variables

So far we have focused on nominal wages, but it is also interesting to analyze real wages and other real variables. In fact, our model is closely related to past studies that have analyzed comovements between exchange rates and macroeconomic real variables such as output and consumption (e.g., Stockman, 1987; Baxter and Stockman, 1989; Flood and Rose, 1995; Obstfeld and Rogoff, 1995a; Stockman, 1998; Kollmann, 2001; Chari et al., 2002; Duarte et al., 2007). However, our model differs from the past studies in that it analyzes comovements of real variables of trading partners under different exchange rate regimes. We summarize the findings regarding exchange rate regimes and comovements of real variables in the following proposition, and again leave the proof to the Appendix.

Proposition 3. *Suppose that nominal prices and wages are flexible. Thus, (1) the exchange rate regime does not affect real wage comovements, and (2) the exchange rate regime does not affect the pattern of trade, real exchange rate, real consumption comovements, labor comovements, or real output comovements.*

Intuitively, these results for real variables are expected because without imperfections such as price rigidity and wage rigidity, money does not affect real allocations. However, our model tells more about real comovements. As shown in the Appendix, it indicates that differences in productivity growth of nontradable goods between two countries affect the degree of real comovements.

As in Subsection 2.3, we carry out numerical experiments to study the effect of trade costs and downward nominal wage rigidity. Figure 4 and Figure 5 are the real wage counterparts for Figure 1 and Figure 2, respectively. For both the case without rigidity and the case with downward nominal wage rigidity, a reduction in trade costs tends to increase real wage comovements under both exchange rate regimes. In Figure 6, we compare the differences in correlations of real wages between the fixed and flexible regimes, for the case of no rigidity and the case of downward nominal wage rigidity. Unlike the results for nominal wage comovements, under downward nominal wage rigidity, the relative effects of the fixed exchange rate regime on real wage comovements are larger, albeit the differences in correlations are small in magnitude.

Intuitively, when both nominal prices and wages are flexible in the long run, changes in money supply affect nominal prices and wages in similar ways, leaving the real wages unaffected by monetary factors. However, in the short run, if nominal wages are less flexible than prices, then changes in the money supply will affect real wages. When two countries peg their exchange rate, money supplies will have similar effects on real wages in the two countries, leading to real wage comovements in the short run. However, a full investigation of the role of wage rigidity is beyond the scope of this paper.

3 Empirical Evidence

To test our theory, we empirically examine the comovements between the wage growth rates of a country and its trade partner and how the wage comovements may be affected by exchange rate regimes, trade costs, and downward nominal wage rigidity.

3.1 Regression specification

We derive the regression specifications from our theory. Proposition 1 and the assumptions about productivity processes imply that

$$\begin{aligned} ln\left(\frac{W_t^H}{W_{t-1}^H}\right) = ln\left(\frac{W_t^F}{W_{t-1}^F}\right) + ln\left(\frac{e_t}{e_{t-1}}\right) + \frac{\gamma\left(1-\epsilon\right)\left(1-\zeta\right)}{\gamma\left(1-\epsilon\right)+\zeta\left(1+\gamma\epsilon\right)} \cdot \left(\Delta a_t^H\left(z\right) - \Delta a_t^F\left(z\right)\right) + \\ \frac{\gamma\left(1-\epsilon\right)\left(1-\zeta\right)}{\gamma\left(1-\epsilon\right)+\zeta\left(1+\gamma\epsilon\right)} \cdot \left(\rho^H\left(z\right)\alpha_{t-1}^H\left(z\right) - \rho^F\left(z\right)\alpha_{t-1}^F\left(z\right)\right) \\ + \frac{\gamma\left(1-\zeta\right)}{\gamma\left(1-\epsilon\right)+\zeta\left(1+\gamma\epsilon\right)} ln\left(\frac{D_t}{D_{t-1}}\right) + \frac{\gamma\left(1-\epsilon\right)\left(1-\zeta\right)}{\gamma\left(1-\epsilon\right)+\zeta\left(1+\gamma\epsilon\right)} \cdot \left(v_t^H - v_t^F\right). \end{aligned} \tag{5}$$

The last equation suggests a linear regression of home nominal wage growth on foreign nominal wage growth, the change in the nominal exchange rate, the trend and cyclical components of productivities, and the price index of tradable goods.

To test the prediction of Proposition 2 that the nominal wage comovements will be stronger under the fixed exchange rate regime, we include the interaction term between the fixed exchange rate regime and foreign nominal wage growth in the following estimation equation. Because our numerical experiments suggest that the trade costs are negatively correlated with nominal wage comovements regardless of exchange rate regimes, we add trade intensity, a variable inversely related to τ, to the regression and interact it with the changes in foreign nominal wages. In addition to trade and exchange rates, migration and capital movements can also affect wage comovements.[7] Hence, we add these two variables and their interactions with foreign nominal wage growth to the regression.

Thus our regression specification is

$$
\begin{aligned}
ln\left(\frac{W_{jt}^{H}}{W_{jt-1}^{H}}\right) = {} & \beta_0 + \beta_1 \cdot ln\left(\frac{W_{jt}^{F}}{W_{jt-1}^{F}}\right) + \beta_2 \cdot ln\left(\frac{W_{jt}^{F}}{W_{jt-1}^{F}}\right) \cdot peg_{jt} + \beta_3 \cdot peg_{jt} \\
& + \beta_4 \cdot ln\left(\frac{W_{jt}^{F}}{W_{jt-1}^{F}}\right) \cdot trade_{jt} + \beta_5 \cdot trade_{jt} + \beta_6 \cdot ln\left(\frac{W_{jt}^{F}}{W_{jt-1}^{F}}\right) \cdot FDI_{jt} + \beta_7 \cdot FDI_{jt} \\
& + \beta_8 \cdot ln\left(\frac{W_{jt}^{F}}{W_{jt-1}^{F}}\right) \cdot migration_{jt} + \beta_9 \cdot migration_{jt} + \beta_{10} \cdot ln\left(\frac{e_{jt}}{e_{jt-1}}\right) \\
& + \beta_{11} \cdot \left(\Delta a_{jt}^{H}(z) - \Delta a_{jt}^{F}(z)\right) + \beta_{12} \cdot \alpha_{jt-1}^{H}(z) + \beta_{13} \cdot \alpha_{jt-1}^{F}(z) \\
& + \beta_{14} \cdot ln\left(\frac{D_{jt}}{D_{jt-1}}\right) + \epsilon_{jt}, \qquad (6)
\end{aligned}
$$

where W_{jt}^{H} is the nominal wage index of country j, W_{jt}^{F} is the nominal wage index for the main economic partner of country j, and e_{jt} is the nominal exchange rate between country j and its main economic partner. The variables FDI_{jt} and $migration_{jt}$ are measures of

[7] There is a vast literature on trade and migration. Dornbusch et al. (1977) and Trefler (1997), for example, analyze the effects of immigration in a model of Ricardian trade with a continuum of goods. Note that Trefler (1997) provides an informal analysis using a 3-good version of Dornbusch et al. (1977). They consider a change in relative size as immigration. Thus, nominal wages in the host country fall to produce goods with relatively low productivity that were not previously produced in the host country. Likewise, nominal wages in the home country rise to shut down goods with relatively low productivity that were previously produced in the home country. Thus immigration causes nominal wages to fall in the host country but to rise in the home country, changing the range of goods produced in each country. It can also be shown that real wages fall in the host country but rise in the home country. Migration can thus cause the (negative) comovements of both nominal and real wages.

There is also a sizable literature on trade and capital movements. For example, a well-known argument concerns trade vs. capital movements in the H-O model. Consider the Dixit and Norman (1980) integrated world equilibrium in an integrated economy in which goods and factors are free to move across countries. Thus, trade in goods can achieve this integrated world equilibrium without factor movements across countries. Alternatively, capital movements can also achieve it without trade in goods (or labor mobility across countries). Thus capital movements are substitutes for trade in goods. In either case, after trade or capital movements, factor prices become equalized across countries. That is, nominal wages go up in one country but go down in the other country. It can also be shown by the Stolper-Samuelson argument that real wages go up in one country but go down in the other country. Thus capital movements can provide an alternative to trade as a cause of (negative) comovements of both nominal and real wages.

bilateral FDI and migration, respectively. The indicator variable peg_{jt} is equal to 1 if a country j pegs its exchange rate to its base country, and it is equal to 0 otherwise. The variable $(\Delta a_{jt}^{H}(z) - \Delta a_{jt}^{F}(z))$ is the difference in changes in the trends of nontradable-sector labor productivities between the two countries, and $\alpha_{jt-1}^{H}(z)$ and $\alpha_{jt-1}^{F}(z)$ are lag levels of cyclical productivities. In actual regressions, we also include country fixed effects. The quantity ϵ_{it} is the error term that contains the productivity shock term $v_{jt}^{H} - v_{jt}^{F}$ and other disturbances.

Our intention is to use the regression analysis to estimate the partial correlation between home and foreign nominal wage growth rates under different exchange rate regimes. We do not intend to identify the causality between nominal wages because they are equilibrium objects. In particular, our main interest is in the parameter β_2, which measures the additional nominal wage comovements experienced by countries with a fixed exchange rate regime relative to those with a flexible regime. Proposition 2 is substantiated if $\beta_2 > 0$.

Proposition 3 predicts that the exchange rate regime does not affect real wage comovements. To test this prediction, we estimate an equation that is identical to equation (6) except that we replace nominal wages with real wages. If the coefficient on the interaction between the peg variable and foreign real wage growth, β_2, is statistically insignificant, then the prediction of Proposition 3 with regard to real wage comovements is supported.

Our numerical experiments suggest that a reduction in trade costs increases both nominal and real wage comovements. Given that trade intensity is usually negatively associated with trade costs, we expect the coefficient on the interaction between trade intensity and foreign wage growth, β_4, to be positive.

Meanwhile, in our numerical experiments downward nominal wage rigidity reduces the nominal wage comovements under the fixed exchange rate regime, relative to the flexible regime, but it increases the effect of the fixed exchange rate regime on real wage comovements. To test these predictions, we run regressions with variables defined over 1-

year and 4-year periods, respectively, under the premise that nominal wage rigidity is more likely to be present in the annual data. Based on the results of numerical experiments, we expect that in regressions with nominal wage growth β_2 is positive and significant in both annual and quadrennial regressions, and that it is smaller in the annual regressions. In regressions with real wage growth, we expect that β_2 is more positive in the annual regressions than in the quadrennial regressions.

Lastly, because our specification incorporates trends in productivity, the wage co-movements that we examine empirically are the cyclical fluctuations in wages around trends.

3.2 Data

Our regression analysis uses nominal wage data from the OECD Library (www.oecd-ilibrary.org), which provides detailed wage information of OECD countries starting from 1973. Nominal wages are measured by the index for nominal hourly earnings in manufacturing sectors. Our choice of nominal wage measurement, identical to that in Levchenko and Zhang (2011), is consistent with the theory that requires a country-specific measure for nominal wages.

Our definition of peg is based on Ilzetzki, Reinhart and Rogoff (2011) who draw on national sources, and secondary sources, such as the Picks Black Market Yearbook and International Financial Statistics (IFS), to classify exchange rate regimes into six types. In the order of increasing flexibility, the categories are (1) no separate legal tender, pre-announced peg or currency board arrangement, pre-announced horizontal band that is narrower than or equal to +/-2%, and de facto peg; (2) pre-announced crawling peg, pre-announced crawling band that is narrower than or equal to +/-2%, de facto crawling peg, and de facto crawling band that is narrower than or equal to +/-2%; (3) pre-announced crawling band that is wider than or equal to +/-2%, de facto crawling band that is narrower than or equal to +/-5%, moving band that is narrower than or equal to +/-2%, and managed floating; (4) freely floating; (5) freely falling; and (6) dual market in which parallel market data are missing. We define a peg as regimes of type (1) or type (2), and define the other four types of regimes as flexible.

In our model, we implicitly assume that the exchange rate peg is credible. In practice, however, non-currency-union pegs often lack credibility compared to the currency union (Obstfeld and Rogoff, 1995b).[8] Historically, countries had been known to break their pegs and devalue when the prices of their products were not competitive internationally. If economic agents expect such devaluations, then there are smaller incentives to align nominal wages to the base country. In contrast, being in a currency union constitutes a credible exchange rate peg to other union members as the same currency is used by all countries in the union and it is costly to exit the union. It is thus possible that these two types of pegs have different effects on wage comovements. Therefore, in many regressions, we redefine the peg regime to be the currency union and interact the currency union indicator with the foreign wage growth. In such regressions, the reference group includes countries that adopt a flexible exchange rate regime and countries that engage in non-currency-union pegs. We argue that these two types of countries are similar in the sense that flexibility in exchange rate, to different extents, is expected.

Our measure of trade intensity is the ratio of bilateral trade volume to the product of the square roots of the GDP of the two countries, i.e., $trade^{HF}/\sqrt{GDP^H \cdot GDP^F}$. We obtain trade volume data from the UN Comtrade dataset and GDP data from the IFS. We measure capital flow as the average of two ratios: the ratio of FDI flow from the base country to the home country to the home GDP, and its counterpart of the base country.[9] Similarly, migration is the average of two ratios: the ratio of migrants from the

[8]As Obstfeld and Rogoff (1995b) mention, Eichengreen (1994), Obstfeld (1985), and Svensson (1994) argue that fixed exchange rates are inherently fragile.

[9]We do not use the geometric mean because the geometric mean becomes zero when either FDI flow is

base country to the home country to the home population, and its counterpart of the base country. The data on FDI and migration are obtained from the OECD Library.

Because, there are no systematic data on labor productivity in the nontradable sector, to the best of our knowledge, we use labor productivity in the overall economy instead. We obtain real output per worker from the Penn World Table, and apply the Hodrick-Prescott filter to extract the trend component ($a_t^j(z)$ in the model) and cyclical components ($\alpha_t^j(z)$ in the model) in labor productivity for each country.

The measure that we use for the term D_{jt} is the ratio of the CPI of tradable goods in the foreign country to its counterpart in the home country. We construct the CPI of tradable goods for country j, CPI_T^j as

$$\begin{aligned} CPI_T^j &= \left(\frac{1}{\omega_T^j}\right)\left(CPI^j - \omega_S^j \cdot CPI_S^j - \omega_R^j \cdot CPI_R^j\right) \\ &= \left(\frac{1}{1-\omega_S^j-\omega_R^j}\right)\left(CPI^j - \omega_S^j \cdot CPI_S^j - \omega_R^j \cdot CPI_R^j\right) \end{aligned}$$

where ω_T^j, ω_S^j, and ω_R^j are the weight of tradable goods, services, and housing in the CPI, respectively. CPI^j is the overall CPI, while CPI_T^j, CPI_S^j, and CPI_R^j are the corresponding sub-indices for tradable goods, services, and housing, respectively. When CPI_S^j and CPI_R^j are unavailable, we simply use the overall CPI as a proxy for the tradable CPI. The CPI data are obtained from the OCED Library.

The countries included in our sample are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hungary, Iceland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Turkey, and the UK. The US is not in the sample because the US does not have a dominant trade-partner to be used as the base country. Because we are looking at OECD countries, the

zero.

currency union is the EMU. Our sample covers data from the first quarter of 1973 to the fourth quarter of 2012. Details about the base country, episodes of exchange rate pegs, and data range for each country are documented in Table 1. We report summary statistics in Table 2.

We use the base countries definition of Klein and Shambaugh (2006). To be specific, country j's base country is the country to which country j pegs its exchange rate or the country with which country i has the most significant trade relationship. For each country in the sample, we use base countries identified by Klein and Shambaugh (2006) as its main economic partner.[10]

3.3 Main regression results

We run regressions with growth rates of nominal wages calculated over one year and four years to check whether regression results differ in the short run and in the long run as the model with and without downward nominal wage rigidity suggests. The top rows in Table 3 through Table 6 indicate the frequency of the data.

Table 3 reports the nominal wage comovements under different exchange rate regimes. In the odd-numbered columns, a country's exchange rate regime is considered to be fixed if it falls into type (1) or type (2) of Ilzetzki, Reinhart and Rogoff (2011). We will refer to this peg definition as a general peg. For general pegs, the coefficients on the interaction term ($peg_{jt} \times \Delta ln(W^F_{jt})$) are positive, but not statistically significant, suggesting that Proposition 2 receives little support.

As discussed in Section 3.2, however, it may not be appropriate to assume that the non-currency-union pegs and the monetary union have the same credibility and combine them to create a single indicator variable for pegs. Given that being in the EMU is a more credible exchange rate peg than a non-currency-union peg, we focus on the effects of the

[10]The description of their data can be found at www.dartmouth.edu/˜jshambau/.

EMU and thus define an indicator variable for this type of peg, EMU_{jt}. It is equal to 1 if country i and its base country are both in the EMU in period t, and 0 otherwise.

We report the results associated with this EMU indicator in even-numbered columns in Table 3. The interaction term between the EMU indicator and nominal wage growth in the base country ($EMU_{jt} \times \Delta ln(W_{jt}^F)$) is always positive and significant, suggesting that being in the EMU is associated with stronger nominal wage comovements. The magnitude of the coefficient is also economically significant. For instance, at the annual frequency, the coefficient on the interaction between the EMU indicator and nominal wage growth in the base country is 1.56. This estimate implies that if the nominal wages in country j's base country increase by 1%, being in the EMU with the base country predicts an additional increase of 1.56% in country j's nominal wages relative to cases where a country floats its exchange rate against the base country or engages in a non-currency-union peg.

The interaction between trade intensity and nominal wage growth in the base country is also positive and significant, confirming the result of numerical experiments that higher trade intensity is associated with stronger nominal wage comovements. We also find weak evidence for the numerical analysis result that downward nominal wage rigidity reduces the enhancing effect of the fixed exchange rate regime on nominal wage comovements. In the annual regression where rigidity is more likely, the coefficient on the interaction between the EMU indicator and nominal wage growth of the base country is 1.56, which is smaller than the coefficient of 2.10 in the quadrennial regression. However, the difference (-0.54) is statistically insignificant. Overall, the results are largely consistent with Proposition 2 and the numerical experiments related to trade costs and downward nominal wage rigidity.

In the regressions in Table 3, the interactions between FDI and foreign nominal wages are always insignificant. Meanwhile, the interactions related to migration are negative and significant at annual frequency, which is consistent with the prediction of Dornbusch et al. (1977) and Trefler (1997). Note that if $\zeta = 1$, i.e., the utility with respect to consumption has log form, equation (5) implies that the coefficients on $ln\,(D_{jt}/D_{jt-1})$, $\Delta a_{jt}^{H}\,(z) - \Delta a_{jt}^{F}\,(z)$, $\alpha_{jt-1}^{H}\,(z)$, and $\alpha_{jt-1}^{F}\,(z)$ are zero. Because some of these coefficients are statistically significant in the regressions, there is no strong evidence for or against the case that ζ is equal to 1.

3.4 EMU countries vs. non-EMU countries

In Table 4, we repeat the estimations in Table 3 but restrict the sample to countries currently in the EMU. More specifically, the countries included are Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain. The time range remains 1973 to 2012. The purpose of these estimations is to check whether nominal wage comovements became more positive during the EMU era than the pre-EMU era. Compared to Table 3, the coefficient of the interaction between the EMU indicator and the base country nominal wage growth ($EMU_{jt} \times \Delta ln(W_{jt}^{F})$) in Table 4 remains positive but is only significant at the quadrennial frequency. Hence, for the same 11 countries, there is some evidence that the positive nominal wage comovements with their base countries after joining the EMU are stronger than before joining the EMU. The results related to trade intensity, FDI, and migration are similar to those in Table 3.

We also run regressions with the countries not in the EMU to examine whether non-currency-union pegs affect nominal wage comovements. The results presented in Table 5 indicate that non-currency-union pegs have no statistically significant strengthening effect on nominal wage comovements in non-EMU countries.

3.5 Real wage comovements

In Table 6, we repeat the regressions in Table 3, but use real wage growth instead of nominal wage growth. In Table 6, the coefficient of the interaction between the EMU indicator and the foreign real wage growth is 0.76 in the annual regression and it is -1.50 in the quadrennial regression. Because the coefficient in quadrennial regressions is statistically insignificant, the evidence supports Proposition 3 that the exchange rate regime should not affect real wage comovements in a long-run equilibrium. Consistent with the results of numerical experiments, the effect of the fixed regime on real wage comovements is more positive in a shorter time horizon where nominal wage rigidity may play a role, although the difference between the coefficients is statistically insignificant. Meanwhile, the coefficient of the interaction between trade intensity and foreign real wage growth is always positive and significant, lending support to the results of numerical experiments that a reduction in trade costs boosts real wage comovements.

When we restrict the sample to the EMU members, and non-EMU countries, respectively, the results are very similar to those for nominal wage comovements reported above and hence not reported here. Overall, the evidence is generally consistent with Proposition 3 and the results of numerical experiments.

4 Conclusions

We have constructed a dynamic Ricardian model of trade with a nominal exchange rate and trade costs and obtained the prediction that two countries' nominal wages must exhibit strong and positive comovements if they fix the bilateral exchange rate. Meanwhile, comovements of real wages are not affected by the choice of exchange rate regime. Using numerical experiments, we have also shown that a reduction in trade costs tends to increase both nominal and real wage comovements regardless of exchange rate regimes. When downward nominal wage rigidity is introduced into the numerical experiments, the difference in nominal wage comovements under the fixed regime vs. the flexible regime decreases while that for real wages increases. We have used the data from 24 OECD countries between 1973 and 2012 to test these predictions. Based on panel regressions, we have three main empirical findings. First, if a country and its main trade partner were in the EMU, their nominal wages experienced significantly stronger comovements in both the short and long run. However, non-currency-union pegs are not associated with stronger nominal wage comovements. Second, the effect of pegs on real wage comovements is more positive in the short run than in the long run, although statistically insignificant. Third, the larger the trade intensity between the two countries, the stronger the comovements of both nominal and real wages. These findings are largely consistent with the predictions of our model.

Our results enhance the understanding of wages in international economics in a number of ways. Our paper adds to (1) the literature on exchange rates and wages by highlighting the role of exchange rate regimes; (2) the literature on nominal wage comovements by showing that fixing exchange rate to a major trade partner can provide a nominal anchor for wages; (3) the literature on the relationship between exchange rates and macroeconomic real variables; and (4) the literature on real exchange rates and the relative price of nontradable goods.

In addition, from a policy perspective, our empirical results are also relevant for the debate over whether the EMU is an optimum currency area. The existence of nominal wage comovements suggests that although relative to the US, the EMU originally was less likely to meet the criteria for optimum currency area (Feenstra and Taylor, 2008, p.879), it may have enhanced the economic integration of its members via nominal wage comovements.

Finally, it is worth noting that Schmitt-Grohé and Uribe (2013) have recently noted that there were not enough downward movements of nominal wages in the Eurozone after the crisis. It indicates that due to this downward nominal wage rigidity, the nominal wage comovements that we have found in this paper may not contain enough downward movements.

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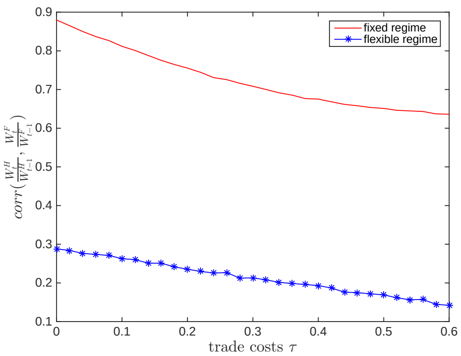

Figure 1: Trade costs and the nominal wage correlations, with no rigidity

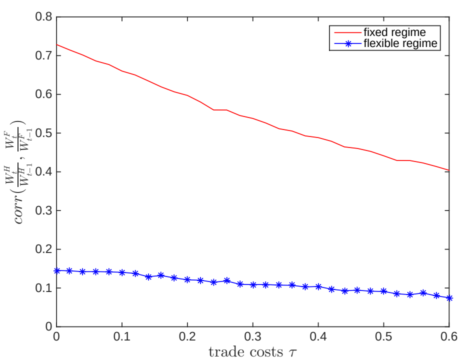

Figure 2: Trade costs and the nominal wage correlations, with downward nominal wage rigidity

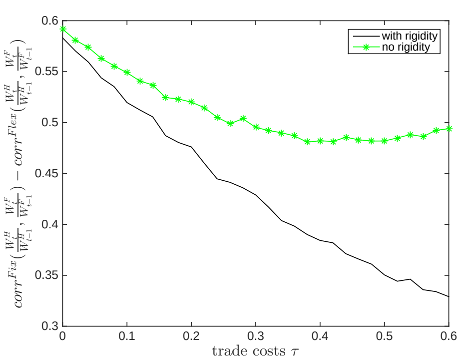

Figure 3: Difference in the nominal wage correlations b/w fixed and flexible regimes, with and without downward nominal wage rigidity

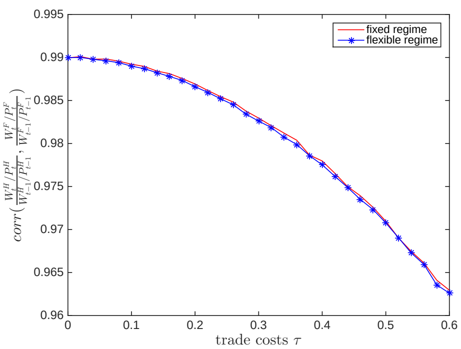

Figure 4: Trade costs and the real wage correlations, with no rigidity

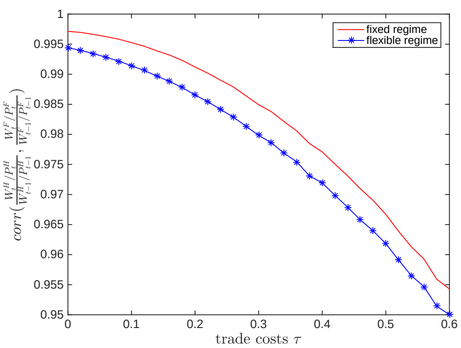

Figure 5: Trade costs and the real wage correlations, with downward nominal wage rigidity

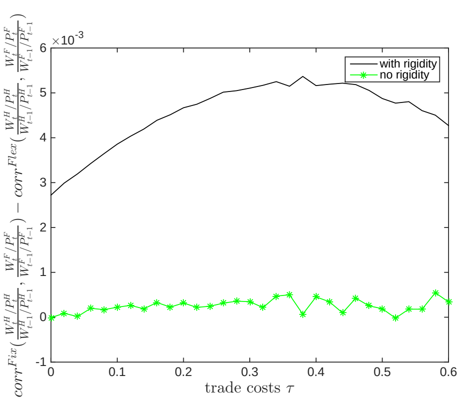

Figure 6: Difference in the real wage correlations b/w fixed and flexible regimes, with and without downward nominal wage rigidity

Table 1: Summary of peg episodes and data range

Country	Base country	Episodes of non-currency-union pegs with base country	Wage data range
EMU members since 1999			
Austria	Germany	1975-1998	1973q1-2012q3
Belgium	Germany	1975-1980, 1984-1992, 1994-1998	1973q1-2012q3
Finland	Germany	1975, 1979, 1987, 1990, 1997-1998	1973q1-2012q4
France	Germany	1979-1980, 1984-1985, 1987-1994, 1996-1998	1973q1-2012q4
Germany	US		1973q1-2012q3
Ireland	Germany	1979-1980, 1984-1985, 1987-1992, 1998	1979q1-2012q4
Italy	Germany	1980, 1984, 1986, 1988, 1990-1991, 1997-1998	1973q1-2012q4
Luxembourg	Belgium	1973-1998	1980q1-2012q4
Netherlands	Germany	1975-1976, 1978-1998	1973q1-2012q4
Portugal	Germany		2000q1-2012q4
Spain	Germany	1996-1998	1981q1-2012q4
Country in ERM II			
Denmark	Germany	1975-1976, 1978, 1980, 1983-1992, 1994-2012	1973q1-2012q4
Other countries			
Australia	US		1984q1-2012q4
Canada	US	1973-1974, 1983, 1986, 1990-1991, 1996	1973q1-2012q4
Japan	US		1973q1-2012q4
Korea	US	1992-1994	1992q1-2012q4
Mexico	US		1980q1-2012q4
Hungary	Germany	1999	1995q1-2010q3
New Zealand	Australia	1978-1980, 1988, 1992-1993	1989q1-2012q4
Norway	Germany	1975-1996, 1984, 1990-1991, 1994	1973q1-2012q4
Poland	Germany		1995q1-2012q4
Sweden	Germany	1974-1975, 2003-2004	1973q1-2012q4
Turkey	US		1988q1-2012q4
UK	Germany		1973q1-2012q4

Notes: (1) Prior to 1979, the UK had been the base country for Ireland, as the Irish pound had been pegged to the pound sterling. In all regressions, we discard the Irish data before 1979 to avoid complications. (2) ERM II stands for Exchange Rate Mechanism II.

Table 2: Summary statistics

	Mean	Standard deviation	Min	Max	Country-year observations
annual change in nominal wage (%)					
flexible	8.96	12.80	-26.12	120.52	510
non-currency-union pegs	4.64	6.24	-26.2	104.44	195
European Monetary Union	2.80	4.44	-26.2	22.12	150
annual change in nominal exchange rate (%)					
flexible	6.80	34.11	-237.44	475.00	614
non-currency-union pegs	0.6	5.76	-26.96	93.6	230
European Monetary Union	0	0	0	0	150

Notes: We classify country-year observations into three categories according to exchange rate regimes: flexible regime, non-currency-union pegs, and membership in the EMU.

Table 3: Nominal wage regressions

	annual	annual	quadrennial	quadrennial
Variables	(1)	(2)	(3)	(4)
$\Delta ln(W^F_{jt})$	-1.44	-1.34	-1.85	-1.76
	(0.63)**	(0.62)**	(0.83)**	(0.81)**
$peg_{jt} \times \Delta ln(W^F_{jt})$	0.48		0.47	
	(0.46)		(0.54)	
peg_{jt}	-.007		-.02	
	(0.01)		(0.04)	
$EMU_{jt} \times \Delta ln(W^F_{jt})$		1.56		2.10
		(0.46)***		(0.39)***
EMU_{jt}		0.02		0.1
		(0.01)*		(0.03)***
$trade_{jt} \times \Delta ln(W^F_{jt})$	0.27	0.3	0.3	0.34
	(0.09)***	(0.1)***	(0.11)***	(0.12)***
$trade_{jt}$	0.002	0.002	-.002	0.006
	(0.004)	(0.005)	(0.03)	(0.03)
$FDI_{jt} \times \Delta ln(W^F_{jt})$	-.09	-.12	0.65	0.45
	(0.14)	(0.15)	(0.64)	(0.61)
FDI_{jt}	0.0008	0.0009	0.03	0.03
	(0.0007)	(0.0008)	(0.03)	(0.03)
$migration_{jt} \times \Delta ln(W^F_{jt})$	-.03	-.03	-.03	-.03
	(0.01)***	(0.01)***	(0.03)	(0.03)
$migration_{jt}$	-.0002	-.0002	0.0003	-.0000444
	(0.0002)	(0.0003)	(0.002)	(0.002)
$\Delta ln(e_{jt})$	0.09	0.09	0.12	0.12
	(0.08)	(0.08)	(0.12)	(0.12)
$\Delta a^H_{jt}(z) - \Delta a^F_{jt}(z)$	0.06	0.08	0.29	0.29
	(0.03)**	(0.03)**	(0.17)*	(0.17)*
$\alpha^H_{jt-1}(z)$	0.19	0.17	1.93	1.93
	(0.08)**	(0.09)*	(1.64)	(1.74)
$\alpha^F_{jt-1}(z)$	0.08	0.05	-3.52	-3.15
	(0.16)	(0.17)	(2.77)	(3.04)
$ln(D_{jt}/D_{jt-1})$	-.006	-.02	0.01	0.01
	(0.02)	(0.02)	(0.08)	(0.08)
Obs.	1099	976	272	252
R^2	0.14	0.15	0.22	0.23

Notes: (1) The dependent variable is the log change in nominal wages. (2) The variable $\Delta\ ln(W^F_{jt})$ is the nominal wage growth rate of the base country, and peg_{jt} is an indicator for countries that peg exchange rates to their base countries via a currency union or other arrangements, and EMU_{jt} indicates joint membership of the European Monetary Union. The variable e_{jt} is the bilateral nominal exchange rate between country j and its base country, D_{jt} is the ratio of the CPI of tradable goods in the foreign country to its counterpart in the home country, and $\Delta a^H_{jt}(z) - \Delta a^F_{jt}(z)$ is the difference in the changes of deterministic components of nontradable productivities. The variables $\alpha^H_{jt-1}(z)$ and $\alpha^F_{jt-1}(z)$ are the cyclical components of home and foreign nontradable productivities, respectively. (3) The top row indicates the length of a period. (4) The numbers in the parentheses are clustered standard errors that are robust to heteroskedasticity across countries and serial correlation in error terms. (5) All regressions include country fixed effects. (6) *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 4: Nominal wage regressions: restricting the sample to EMU countries

Variables	annual (1)	annual (2)	quadrennial (3)	quadrennial (4)
$\Delta ln(W^F_{jt})$	-.20	-.40	-.39	-.67
	(0.36)	(0.54)	(0.54)	(0.54)
$peg_{jt} \times \Delta ln(W^F_{jt})$	-.10		-.38	
	(0.49)		(0.65)	
peg_{jt}	-.003		-.02	
	(0.01)		(0.06)	
$EMU_{jt} \times \Delta ln(W^F_{jt})$		0.28		0.99
		(0.35)		(0.47)**
EMU_{jt}		0.02		0.12
		(0.01)**		(0.02)***
$trade_{jt} \times \Delta ln(W^F_{jt})$	0.16	0.18	0.17	0.22
	(0.1)	(0.08)**	(0.13)	(0.09)**
$trade_{jt}$	-.001	0.003	-.005	0.02
	(0.004)	(0.004)	(0.02)	(0.02)
$FDI_{jt} \times \Delta ln(W^F_{jt})$	-.16	-.11	-.58	-.64
	(0.12)	(0.09)	(0.41)	(0.15)***
FDI_{jt}	-.001	-.0002	-.04	-.05
	(0.001)	(0.001)	(0.03)	(0.01)***
$migration_{jt} \times \Delta ln(W^F_{jt})$	-.02	-.02	-.04	-.03
	(0.006)***	(0.006)***	(0.02)**	(0.03)
$migration_{jt}$	-.00006	-.0002	-.001	-.0008
	(0.0001)	(0.0002)	(0.001)	(0.002)
$\Delta ln(e_{jt})$	0.007	-.001	-.04	-.02
	(0.04)	(0.04)	(0.13)	(0.19)
$\Delta a^H_{jt}(z) - \Delta a^F_{jt}(z)$	0.01	-.04	0.05	-.18
	(0.07)	(0.05)	(0.32)	(0.27)
$\alpha^H_{jt-1}(z)$	0.28	0.26	0.71	-.64
	(0.1)***	(0.11)**	(1.46)	(1.67)
$\alpha^F_{jt-1}(z)$	-.17	-.12	-1.13	0.97
	(0.09)*	(0.15)	(1.96)	(1.57)
$ln(D_{jt}/D_{jt-1})$	0.03	0.01	0.1	0.1
	(0.02)**	(0.01)	(0.06)*	(0.06)*
Obs.	479	403	119	104
R^2	0.42	0.52	0.51	0.62

Notes: (1) The dependent variable is the log change in nominal wages. (2) The variable $\Delta\ ln(W^F_{jt})$ is the nominal wage growth rate of the base country, and peg_{jt} is an indicator for countries that peg exchange rates to their base countries via a currency union or other arrangements, and EMU_{jt} indicates joint membership of the European Monetary Union. The variable e_{jt} is the bilateral nominal exchange rate between country j and its base country, D_{jt} is the ratio of the CPI of tradable goods in the foreign country to its counterpart in the home country, and $\Delta a^H_{jt}(z) - \Delta a^F_{jt}(z)$ is the difference in the changes of deterministic components of nontradable productivities. The variables $\alpha^H_{jt-1}(z)$ and $\alpha^F_{jt-1}(z)$ are the cyclical components of home and foreign nontradable productivities, respectively. (4) The numbers in the parentheses are clustered standard errors that are robust to heteroskedasticity across countries and serial correlation in error terms. (5) All regressions include country fixed effects. (6) *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 5: Nominal wage regressions: restricting the sample to non-EMU countries

	annual	quadrennial
Variables	(1)	(2)
$\Delta ln(W_{jt}^F)$	-1.96	-2.57
	(0.82)**	(1.00)***
$peg_{jt} \times \Delta ln(W_{jt}^F)$	0.16	0.96
	(0.57)	(0.93)
peg_{jt}	-.003	-.06
	(0.02)	(0.07)
$trade_{jt} \times \Delta ln(W_{jt}^F)$	0.44	0.4
	(0.18)**	(0.18)**
$trade_{jt}$	-.0008	-.02
	(0.005)	(0.03)
$FDI_{jt} \times \Delta ln(W_{jt}^F)$	-.33	0.2
	(0.69)	(1.42)
FDI_{jt}	0.03	0.25
	(0.01)**	(0.11)**
$migration_{jt} \times \Delta ln(W_{jt}^F)$	-.07	0.008
	(0.02)***	(0.07)
$migration_{jt}$	-.002	-.0004
	(0.001)	(0.004)
$\Delta ln(e_{jt})$	0.1	0.12
	(0.08)	(0.12)
$\Delta a_{jt}^H(z) - \Delta a_{jt}^F(z)$	0.08	0.37
	(0.03)***	(0.19)**
$\alpha_{jt-1}^H(z)$	0.11	2.59
	(0.13)	(2.29)
$\alpha_{jt-1}^F(z)$	0.15	-4.44
	(0.24)	(3.58)
$ln(D_{jt}/D_{jt-1})$	-.03	-.09
	(0.03)	(0.16)
Obs.	620	153
R^2	0.14	0.25

Notes: (1) The dependent variable is the log change in nominal wages. (2) The variable $\Delta\ ln(W_{jt}^F)$ is the nominal wage growth rate of the base country, and peg_{jt} is an indicator for countries that peg exchange rates to their base countries via a currency union or other arrangements. The variable e_{jt} is the bilateral nominal exchange rate between country j and its base country, D_{jt} is the ratio of the CPI of tradable goods in the foreign country to its counterpart in the home country, and $\Delta a_{jt}^H(z) - \Delta a_{jt}^F(z)$ is the difference in the changes of deterministic components of nontradable productivities. The variables $\alpha_{jt-1}^H(z)$ and $\alpha_{jt-1}^F(z)$ are the cyclical components of home and foreign nontradable productivities, respectively. (3) The top row indicates the length of a period. (4) The numbers in the parentheses are clustered standard errors that are robust to heteroskedasticity across countries and serial correlation in error terms. (5) All regressions include country fixed effects. (6) *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 6: Real wage regressions

	annual	annual	quadrennial	quadrennial
Variables	(1)	(2)	(3)	(4)
$\Delta ln(real\ W^F_{jt})$	-.69 (0.48)	-.90 (0.44)**	-.99 (0.62)	-.91 (0.6)
$peg_{jt} \times \Delta ln(real\ W^F_{jt})$	-.24 (0.42)		-.53 (0.47)	
peg_{jt}	-.005 (0.04)		-.10 (0.12)	
$EMU_{jt} \times \Delta ln(real\ W^F_{jt})$		0.76 (0.5)		-1.50 (1.78)
EMU_{jt}		0.01 (0.04)		0.06 (0.15)
$trade_{jt} \times \Delta ln(real\ W^F_{jt})$	0.17 (0.06)***	0.17 (0.08)**	0.26 (0.12)**	0.22 (0.13)*
$trade_{jt}$	0.005 (0.01)	0.006 (0.02)	0.05 (0.1)	0.03 (0.11)
$FDI_{jt} \times \Delta ln(real\ W^F_{jt})$	0.02 (0.06)	0.01 (0.06)	0.81 (1.42)	1.20 (1.46)
FDI_{jt}	0.0002 (0.004)	-.0005 (0.004)	0.03 (0.08)	0.06 (0.09)
$migration_{jt} \times \Delta ln(real\ W^F_{jt})$	0.002 (0.005)	-.004 (0.006)	-.04 (0.04)	-.02 (0.04)
$migration_{jt}$	0.0004 (0.0009)	-.0002 (0.001)	-.001 (0.005)	-.001 (0.005)
$\Delta ln(e_{jt})$	-.47 (0.31)	-.44 (0.31)	-.59 (0.47)	-.58 (0.47)
$\Delta a^H_{jt}(z) - \Delta a^F_{jt}(z)$	-.13 (0.09)	-.16 (0.12)	-.58 (0.57)	-.62 (0.61)
$\alpha^H_{jt-1}(z)$	-.29 (0.3)	-.21 (0.36)	-7.81 (5.54)	-7.41 (5.81)
$\alpha^F_{jt-1}(z)$	-.58 (0.35)	-.59 (0.33)*	0.49 (8.21)	0.53 (8.39)
$ln(D_{jt}/D_{jt-1})$	-.04 (0.04)	-.05 (0.04)	-.13 (0.24)	-.13 (0.25)
Obs.	1099	976	272	252
R^2	0.14	0.15	0.24	0.23

Notes: (1) The dependent variable is the log change in real wages. (2) The variable $\Delta\ ln(real\ W^F_{jt})$ is the real wage growth rate of the base country, and peg_{jt} is an indicator for countries that peg exchange rates to their base countries via a currency union or other arrangements, and EMU_{jt} indicates joint membership of the European Monetary Union. The variable e_{jt} is the bilateral nominal exchange rate between country j and its base country, D_{jt} is the ratio of the CPI of tradable goods in the foreign country to its counterpart in the home country, and $\Delta a^H_{jt}(z) - \Delta a^F_{jt}(z)$ is the difference in the changes of deterministic components of nontradable productivities. The variables $\alpha^H_{jt-1}(z)$ and $\alpha^F_{jt-1}(z)$ are the cyclical components of home and foreign nontradable productivities, respectively. (3) The top row indicates the length of a period. (4) The numbers in the parentheses are clustered standard errors that are robust to heteroskedasticity across countries and serial correlation in error terms. (5) All regressions include country fixed effects. (6) *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.