CEP 14-09

The Exchange Rate Pass-Through to Import and Export Prices: The Role of Nominal Rigidities and Currency Choice

Ehsan U. Choudhri
Carleton University

Dalia S. Hakura
International Monetary Fund

July 2014

CARLETON ECONOMIC PAPERS

Carleton University

Department of Economics

1125 Colonel By Drive
Ottawa, Ontario, Canada
K1S 5B6

The Exchange Rate Pass-Through to Import and Export Prices: The Role of Nominal Rigidities and Currency Choice

Ehsan U. Choudhri
Carleton University

Dalia S. Hakura
International Monetary Fund

July 2014

Abstract

Using both regression- and VAR-based estimates, the paper finds that the exchange rate pass-through to import prices for a large number of countries is incomplete and larger than the pass-through to export prices. Previous studies have reported similar results, which give rise to the puzzle that while local currency pricing is needed to account for incomplete import price pass-through, it would not imply a lower export price pass-through. Recent explanations of this puzzle have emphasized markup adjustment in response to exchange rate changes. This paper suggests an alternative explanation based on the presence of both producer and local currency pricing. Using a dynamic general equilibrium model, the paper shows that a mix of producer and local currency pricing can explain the pass-through evidence even with a constant markup. The model can also explain the observed variability of key variables as well as the fact that the regression and VAR estimates tend to be similar.

JEL Classification Numbers: E31; F42; E52; F41

Keywords: Exchange rate pass-through; import and export prices; nominal rigidities; currency choice

Author’s E-Mail Address: ehsan_choudhri@carleton.ca and dhakura@imf.org

I. INTRODUCTION

There continues to be much interest in understanding the mechanism that determines the exchange rate pass-through to import and export prices. A key issue is what role is played by nominal rigidities and currency choice (for setting the price of traded goods) in determining the behavior of import and export prices relative to the exchange rate. This question has important implications for the international transmission mechanism and the design of optimal monetary policy in an open economy. The conventional assumption—incorporated in the Mundell-Fleming model and adopted by Obstfeld and Rogoff's seminal (1995) contribution to new open economy macroeconomics—is that prices of traded goods are sticky in the currency of the producer. Models based on the assumption of producer currency pricing (PCP) imply that flexible exchange rates are desirable in achieving relative price adjustment. Moreover, optimal monetary policy rules are inward looking in that they stabilize domestic prices and output, and do not react to international variables like the exchange rate (Corsetti and Pesenti, 2001; Clarida, Gali, and Gertler, 2002). An alternative view assumes that prices of traded goods are sticky in the currency of local consumers (e.g., Betts and Devereux, 2000). The assumption of local currency pricing (LCP) leads to very different prescriptions for monetary policy. For example, Devereux and Engel (2003) show that under LCP, there is no benefit to exchange rate flexibility and fixed exchange rates are to be preferred. If exchange rates are flexible, optimal monetary policy under LCP would react to international variables (Corsetti and Pesenti, 2005).[1]

Both PCP and LCP hypotheses, however, have problems explaining the evidence on the exchange rate pass-through to import and export prices. In the baseline versions based on preset prices, PCP implies that the pass-through (the elasticity of the price in home currency with respect to the exchange rate) equals one for import prices and zero for export prices. These implications are reversed under LCP. Inconsistent with these predictions, the import price pass-through for OECD countries tends to be significantly different from zero and one, and on average, is close to one-half (Campa and Goldberg, 2005). Estimates of the export price pass-

[1] For a summary of results on optimal monetary policy in open economies and the role played by PCP and LCP, see Corsetti, Dedola, and Leduc (2010).

through also generally do not support the baseline versions of both PCP and LCP (e.g., see Bussière and Peltonen, 2008). Models based on staggered prices modify the values of pass-through predicted by PCP and LCP, but not sufficiently to conform to the evidence. For example, if prices are set according to the Calvo (1983) model, the pass-through to import prices under LCP would be positive but generally lower than the estimated value. More problematically, LCP would still imply a value of the pass-through to export price, which is too high. This inconsistency was highlighted by Obstfeld and Rogoff (2000), who pointed out that a depreciation of national currency (an increase in the exchange rate) should improve the terms of trade (the price of exports relative to imports) according to LCP, but in data, depreciation tends to be associated with a deterioration in the terms of trade (implying that the pass-through to export prices tends to be smaller than to import prices).

To explain the evidence on the pass-through to import and export prices and the behavior of the terms of trade, a number of recent studies have suggested variations of the basic model, which allow markup adjustment in response to exchange rate changes. Corsetti and Dedola (2005), for example, develop a model of price discrimination based on the assumption that sale of goods abroad requires an input of local (nontraded) distribution services. They show that even in the presence of flexible prices (in which case, currency choice does not matter), a sufficiently high distribution margin in this model can generate the import price pass-through and the exchange rate-terms of trade association observed in data.[2] Corsetti, Dedola, and Leduc (2008) extend this model to also explain exchange rate volatility and other empirical regularities. This literature suggests that markup adjustments rather than nominal rigidities and currency choice play a key role in determining the pass-through behavior.

This paper argues that the pass-through evidence can be explained by an alternative model, which assumes that there is a mix of firms using PCP and LCP in each economy. This assumption is consistent with data on the currency of invoicing of exports and imports (e.g., see Goldberg and Tille, 2008), which shows that international transactions are invoiced in national

[2] See Corsetti, Dedola, and Leduc (2007), and Gust, Leduc, and Vigfusson (2010) for alternative models of markup adjustment.

currency as well as trade partner currency or a vehicle currency like the US dollar, and the share of national currency invoicing varies across countries and industries. A hybrid model with both PCP and LCP is also found to help explain the degree of the exchange rate pass-through to various prices in non-US G6 countries (Choudhri, Faruqee, and Hakura, 2005). The literature on optimal currency choice (for pricing of export goods) suggests that the use of both PCP and LCP in an economy can arise under two types of equilibria. One possibility is an equilibrium where firms using PCP and LCP are indifferent between the two types of pricing (Devereux, Engel, and Storegaard, 2004). Another possibility is that PCP is preferred for one type of products while LCP is preferred for others (Bacchetta and van Wincoop, 2005). The key factors determining the currency choice are sensitive to how the model is specified. We do not attempt to explain the currency choice, but focus instead on whether a model with both PCP and LCP and without a markup adjustment mechanism is capable of explaining the evidence on the pass-through to trade prices for a wide range of countries. For this purpose, we estimate the exchange rate pass-through to import and export prices for a large number of countries and examine how well a Dynamic Stochastic General Equilibrium (DSGE) model with staggered prices, a mixture of both PCP and LCP and a constant markup can explain the pass-through estimates.

The standard empirical model for estimating import or export price pass-through is based on a micro or a partial-equilibrium framework, and examines the price response of an exporter to an exogenous exchange rate change. The pass-through elasticity in this model is estimated by a regression of the import/export price index on the exchange rate with additional variables included in the regression to control for the marginal cost, markup, and short-run dynamics. In a general equilibrium model suitable for analyzing the behavior of aggregate trade prices, the exchange rate as well as some control variables are endogenous, and thus the estimated coefficients would be sensitive to the combination of shocks affecting the economy and the policy regime influencing the transmission of the shocks.[3] An alternative approach uses a VAR model to estimate the exchange rate pass-through to a price as the elasticity of the price to an orthogonalized VAR innovation to the exchange rate (ordered as the first variable in the VAR).

[3] In addition to the endogeneity issues, the estimates are subject to omitted-variable and measurement-error biases since good measures of controls are not available and they are either omitted or represented by proxies.

An appealing feature of this approach is that it focuses on the price response to exogenous shocks. A limitation of this methodology, however, is that the exchange rate innovation represents a composite of structural disturbances that are difficult to identify.

We first review the evidence on the short-run (one quarter) exchange rate pass-through to import and export prices for a large sample of countries for which data on import and export price indexes are available for a sufficiently long period. Using simple versions of both regression and VAR models, we find that the pass-through to import as well as export prices tends to fall in the unit interval and the import price pass-through tends to be larger than the export price pass-through. Remarkably, the regression estimates of the pass-through are similar to the VAR estimates for import as well as export prices. We also use the regression model to estimate the long-run pass-through, and find that for both import and export prices, it is larger than the short-run pass-through but tends to be less than one.

To explain this evidence, we use a standard DSGE model of an open economy with a Calvo price-setting mechanism, but add a new feature that the proportion of firms using PCP (rather than LCP) can vary between zero and one. To explore the potential of nominal rigidities with a mix of PCP and LCP to explain the evidence on pass-through to trade prices, we abstract from features (such as requirements of nontraded goods in distribution) that allow the markup to vary and be a function of the exchange rate. We allow wages to be either sticky or flexible and incorporate both nominal and real shocks in the model.

A quantitative version of the model shows that reasonable values of the frequency of price adjustment and the proportion of PCP firms can explain the key empirical evidence on exchange rate pass-through. Stochastic simulation of the model shows that it can account for the average values of pass-through elasticities for import and export price levels as well as other features of the data for advanced countries. Only the flexible-wage version of the model, however, is able to match the observed variability of output. Both versions can explain the similarity of the regression and VAR estimates and the below-unity estimates of the long-run pass-through. We also undertake empirical analysis to examine if the model can explain the variation of pass-through values across countries. The model predicts that the import price pass-through increases as the proportion of foreign varieties with PCP increases, and the export price pass-through decreases as the proportion of home varieties with PCP increases. We find support for this prediction for a subset of countries in our sample for which data on currency of invoicing are available.

II. EMPIRICAL EVIDENCE

Let $P_{M,t}$ and $P_{X,t}$ denote the import and export price indexes for a country (expressed in home currency), and S_t the nominal exchange rate (an increase representing an appreciation of the foreign currency). Using lower-case letters to denote values in logs, and assuming that these series (in logs) are nonstationary and not cointegrated,[4] we can express the regression model typically used to estimate the exchange rate pass-through to the import or export price as

$$\Delta p_{T,t} = c + a\Delta s_t + \mathbf{b}\mathbf{g}_t + e_t, \quad T = M, X, \tag{1}$$

where $\mathbf{g}_t$ is a vector of variables (possibly including lagged values of $\Delta p_{T,t}$ and Δs_t) included to control for the effect of certain factors and to introduce dynamics in the relation. This model is motivated by a partial-equilibrium framework, in which the exchange rate pass-through can be defined as the price response to a 1% change in the exchange rate by an exporter who takes certain factors (such as marginal cost and demand functions) as given, and may change prices gradually in the presence of price adjustment costs or other nominal frictions. The short-run pass-through defined in this way can be measured by estimating coefficient a in (1). The short-run pass-through is sometimes estimated by a simple regression of $\Delta p_{T,t}$ on Δs_t (i.e., by estimating (1) without $\mathbf{g}_t$). The pass-through coefficient in this case can be interpreted as the price response that includes the direct as well as the indirect effect of the exchange rate (operating through variables in $\mathbf{g}_t$). If lagged values of $\Delta p_{T,t}$ or Δs_t are included in $\mathbf{g}_t$, (1) can also be used to estimate the long-run exchange rate pass-though (i.e., the long-run response of the import or export price to a 1% change in the exchange rate).

---

[4] This is a typical characterization of these series, which is generally supported by time-series unit root and cointegration tests (e.g., Campa and Goldberg, 2005).

An alternative methodology uses a VAR model to estimate the exchange rate pass-through.[5] Letting P_t and P_t^* denote the home and foreign CPI (expressed in home and foreign currency, respectively), we can express the basic VAR models (with n lags) as

$$\mathbf{h}_t = \mathbf{c} + \mathbf{D}_1\mathbf{h}_{t-1} + \mathbf{D}_2\mathbf{h}_{t-2} + ... + \mathbf{D}_n\mathbf{h}_{t-n} + \mathbf{e}_t \, , \qquad (2)$$

where $\mathbf{h}_t = \left[\Delta s_t, \Delta p_{T,t}, \Delta p_t, \Delta p_t^*\right]$ for $T = M, X$, lower-case letters represent values in logs, and $\mathbf{e}_t$ is a vector of reduced-form shocks.[6] Extended versions of this model include additional variables. Based on orthogonalized impulse response functions (with Δs_t as the first variable), the short-run pass-through to an import or export price index is defined as the (current period) elasticity of Δp_t to an innovation in Δs_t. The VAR model could also be used to measure the effect of the exchange rate innovation on prices over a long period. The exchange rate innovation could represent a combination of different shocks, but under certain conditions, it can be associated with a nominal shock to the exchange market or exchange rate parity relation shock.[7]

We use both regression and VAR models to estimate the exchange rate pass-through to import and export prices for a sample that includes all countries for which quarterly trade price data are available for at least 52 quarters since 1979. The regression model is used to estimate both the short- and the long-run exchange rate pass-through. For estimating the short-run pass-through, we use the simple regression (without $\mathbf{g}_t$) as it incorporates the indirect effects and is not sensitive to the choice of controls, which vary from one model to another and include variables that are difficult to measure. To estimate the long-run pass-through, we introduce lagged values in the regression. In the VAR model, orthogonalized impulse response functions are used to

---

[5] See McCarthy (2000) for an early use of this methodology.

[6] The basic version assumes that variables $s_t, p_{T,t}, p_t, p_t^*$ are $I(1)$ and not cointegrated. A vector error correction model can be used instead if the variables are cointegrated.

[7] For example, Choudhri, Faruqee and Hakura (2005) use the exclusion restriction that contemporaneous information on prices is not available to participants in the financial markets to identify the exchange rate innovation as the shock to the interest parity relation.

estimate the short-run pass-through and to examine the price dynamics in response to the exchange rate shock.

The regression results for the short-run pass-through are presented in Table 1 for two sets of countries. The first set includes 18 advanced countries, and the second set of 16 countries largely includes emerging economies in our sample. For advanced countries, the pass-through coefficient for the import price is, with one exception, between zero and one, is significantly different from zero for all countries, and also significantly different from one for most countries. The estimates of the export price pass-through coefficient for these countries are similar: the coefficient is between zero and one for all countries but one, and is generally significantly different from both zero and one. The pass-through coefficient for the export price tends to be smaller than the coefficient for the import price. The average value of the pass-through coefficient is 0.39 for the export price and 0.67 for the import price. The average pass-through coefficients for the two prices are significantly different from each other. The results for emerging market countries show a similar pattern. Some notable differences for this group are that the pass-through coefficients are negative for two countries and the import price pass-through is smaller than the export price pass-through for two countries. The average value of the import price pass-through coefficients is 0.63 and that for the export price is 0.53.

To obtain estimates of the long-run pass-through, we use regression (1) with 4 lagged values of Δs_t.[8] The results are presented in Table 2. Since estimates of the short-run pass-through in the regression with lagged values of Δs_t are similar to those without the lagged values (reported in Table 1), we only show estimates of the long-run pass-through in Table 2. These estimates exhibit considerable variation across countries. For both the advanced and emerging countries samples, the long-run pass-through to import as well as to export prices is less than one for a

[8] The regression is specified as $\Delta p_{T,t} = c + a\Delta s_t + \sum_{i=1}^{4} b_i \Delta s_{t-i} + e_t$. One appealing feature of this specification is that consistent estimates of the long-run pass-through ($= a + \sum_{i=1}^{4} b_i$) can be obtained by OLS. We did explore an alternative specification with one lagged value of the dependent variable (instead of 4 lagged values of Δs_t), and found that the results based on the alternative specification were not much different.

majority of cases and this difference is significant in many cases.[9] The average value of the long-run import price pass-through is 0.86 for advanced and 0.59 for emerging countries. The corresponding averages for the long-run export price pass-through are 0.50 and 0.58. All of these estimates are more than two standard deviations below unity. The long-run pass-through is generally larger than the short-run pass-through for both import and export prices. A notable exception for developing countries is the US where the long-run pass-through is the same as the short-run pass-through for import prices and is slightly smaller for export prices.

Table 3 shows the estimates of the short-run pass-through to import and export prices derived from the VAR model (2) for both advanced and emerging economies.[10] The VAR-based estimates are close to the estimates based on the simple regression (see Figure 1). For the advanced country group, the exchange rate pass-through to both price indexes is above zero and below one for all countries, and is significantly different from both zero and one for most countries (i.e., the two-standard deviation band for the pass-through estimate lies in the (0,1) interval). Moreover, the import price pass-through is larger than the export price pass-through for 17 out of 18 countries and this difference is significant (with the p-value of 0.1 or less) for 11 countries. The average value of the pass-through is 0.60 for the import price and 0.39 for the export price. The results for emerging countries show similar tendencies, but as in the case of the regression results, the pass-through coefficients are negative and the import price coefficient is smaller than the export-price coefficient in a few cases. For this group, the average values of the pass-through for the import and export prices are 0.54 and 0.51, respectively.

It has been suggested that the pass-through, especially to import or consumer price indexes has declined recently due to inflation stabilization (Gagnon and Ihrig, 2004) or trade integration resulting from lower trade costs (Gust, Leduc, and Vigfusson, 2010). To explore whether the exchange rate pass-through to trade prices has changed over time, we also obtained regression

---

[9] The long-run pass-through to import prices is significantly less than one (at the 5 % level) for 7 advanced and 11 emerging countries while the long-run pass-through to export prices is significantly less than one for 13 advanced and 8 emerging countries.

[10] We also experimented with a VAR that includes GDP as an additional variable, but this variation did not make much difference to the results.

and VAR estimates for the sub-periods 1985-1997 and 1998-2010. The pass-through estimates for the subperiods are reported in Appendix Tables 1 and 2 (for the countries which had sufficient data to conduct the estimations). These estimates are less precise, and show no clear pattern for change between the two periods. The estimates of the pass-through for both price indexes, for example, are higher for some countries but lower for others in the second relative to the first sub-period.

The impulse response functions derived from the VAR model can be used to examine the dynamic adjustment of import and export prices to the exchange rate shock. The results are summarized in Figure 2. For the advanced country sample, Figure 2 (a) shows the average response of Δs_t, $\Delta p_{M,t}$ and $\Delta p_{X,t}$ over 12 quarters to a one standard deviation shock to Δs_t. Most of the effect of the exchange rate shock on all three series occurs in the quarter in which the shock occurs, declines sharply in the next quarter and then damps out. The effect is negligible after 8 quarters in all cases. The average response of the three series for the emerging country sample is shown in Figure 2 (b). Even for emerging countries, much of the adjustment takes place in the quarter subject to shock. However, the effect of the exchange rate shock does not damp out as quickly as in the case of advanced countries. This difference could reflect a different mix of shocks in the exchange rate innovation or a more noisy import and export price data for the emerging economies.

III. THE MODEL

In this section, we develop a DSGE model to explain the evidence on the exchange rate pass-through to trade prices. We design our model for explaining the results for the advanced countries whose financial markets and monetary policies can be modeled by an interest rate parity relation and a Taylor-type interest rate rule. Our model, however, would also be relevant for a range of emerging countries with similar financial markets and monetary policies. To examine how well a staggered price model with a combination of PCP and LCP can by itself explain the pass-through results, we consider a simple framework without nontraded goods or distribution services and a CES index for aggregating varieties. This setup excludes adjustment mechanisms (e.g., via markup variation or distribution channels), which have been emphasized by alternative explanations of the pass-through evidence. In our basic setup, we assume that all traded goods are differentiated, and labor services are either homogeneous or differentiated. The adjustment of prices (and wages in the case of differentiated labor services) is based on the Calvo model. A novel feature of our model is Calvo price adjustment with a mix of PCP and LCP, and the discussion below focuses on the implications of this feature. The rest of the model is standard and is described briefly.

A. Basic Setup

For a continuum of households indexed by $i \in [0,1]$, preferences are given by

$$U_t(i) = E_t \sum_{k=t}^{\infty} \beta^{k-t} \left(\frac{C_k(i)^{1-\chi}}{1-\chi} + \varphi \frac{L_k(i)^{1+\mu}}{1+\mu} \right), \tag{3}$$

where $C_t(i)$ and $L_t(i)$ represent the household's aggregate real consumption and labor supply. Households hold one-period domestic and foreign bonds, and holding of foreign bonds (used for international borrowing or lending) is subject to transaction cost shocks. Their budget constraint is

$$\begin{aligned} B_{t+1}(i) + S_t B_{t+1}^*(i) = (1+R_{t-1})B_t(i) + S_t(1+R_{t-1}^*)B_t^*(i) X_{TC,t-1} \\ + W_t(i)L_t(i) + PF_t(i) - P_t C_t(i) \end{aligned}, \tag{4}$$

where $B_t(i)$ and $B_t^*(i)$ represent home and foreign bonds held at the beginning of period *t*; S_t is the exchange rate; R_{t-1} and R_{t-1}^* are the home and foreign interest rates, and $X_{TC,t-1}$ is the transaction cost in period $t-1$; P_t denotes the price level; $PF_t(i)$ is the household's shares of total profits, and $W_t(i)$ is the wage rate set by the household .

Optimization of utility in (3) subject to the budget constraint (4) implies the following standard conditions in symmetric equilibrium (where household index is dropped for simplicity):

$$\beta\left(\frac{E_t C_{t+1}}{C_t}\right)^{-\chi}\left(\frac{P_t}{E_t P_{t+1}}\right)=\frac{1}{1+R_t}, \tag{5}$$

$$\frac{S_t}{E_t S_{t+1}}=\frac{(1+R_t^*)X_{TC,t}}{1+R_t}, \tag{6}$$

where $X_{TC,t}$ can be interpreted as the shock to the interest parity relation.[11] The central bank sets the interest rate by the following simple rule that reacts to only the inflation rate:

$$1+R_t=(1+\bar{R})(\Pi_t/\bar{\Pi})^{\delta}X_{R,t}, \quad \delta>0, \tag{7}$$

where $\bar{R}$ is the steady-state interest rate and $\bar{\Pi}$ is the target value of $\Pi_t=P_t/P_{t-1}$ and $X_{R,t}$ is the shock to the monetary rule. Using (7) and its foreign counterpart to substitute for the home and foreign (gross) interest rates in (6), we can express the exchange rate as

$$S_t=\frac{E_t S_{t+1}(1+\bar{R}^*)(\Pi_t^*/\bar{\Pi}^*)^{\delta^*}X_t}{(1+\bar{R})(\Pi_t/\bar{\Pi})^{\delta}}, \tag{8}$$

where $X_t=X_{R,t}^*X_{TC,t}/X_{R,t}$ is a composite nominal shock.

Aggregate consumption is defined as

$$C_t=\left[(1-\gamma)^{1/\eta}(C_{H,t})^{(\eta-1)/\eta}+\gamma^{1/\eta}(C_{F,t})^{(\eta-1)/\eta}\right]^{\eta/(\eta-1)}, \tag{9}$$

where $C_{H,t}$ and $C_{F,t}$ are bundles of home and foreign varieties. Assume a continuum of home firms indexed by $j\in[0,1]$, and foreign firms indexed by $j^*\in[0,1]$, and define these bundles as

$$C_{H,t}=\left(\int_0^1 C_{H,t}(j)^{(\varepsilon-1)/\varepsilon}dj\right)^{\varepsilon/(\varepsilon-1)}, \quad C_{F,t}=\left(\int_0^1 C_{F,t}(j^*)^{(\varepsilon-1)/\varepsilon}dj^*\right)^{\varepsilon/(\varepsilon-1)}, \tag{10}$$

where $C_{H,t}(j)$ and $C_{F,t}(j^*)$ represent the consumption amounts for a home and a foreign variety. Let $P_{H,t}(j)$ and $P_{M,t}(j^*)$ denote the prices of a home and an imported (foreign) variety. The

[11] The shock to interest parity relation could also be motivated by Devereux and Engel's (2002) noise-trader model, where there is a stochastic bias in the expectations of foreign exchange dealers.

demand functions for the home and foreign bundles and the varieties within each bundle can then be derived as follows:

$$C_{H,t} = (1-\gamma)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t, \quad C_{F,t} = \gamma\left(\frac{P_{M,t}}{P_t}\right)^{-\eta} C_t, \tag{11}$$

$$C_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\varepsilon} C_{H,t}, \quad C_{F,t}(j^*) = \left(\frac{P_{M,t}(j^*)}{P_{M,t}}\right)^{-\varepsilon} C_{F,t}, \tag{12}$$

with price indexes defined as

$$P_t = \left[(1-\gamma)(P_{H,t})^{1-\eta} + \gamma(P_{M,t})^{1-\eta}\right]^{1/(1-\eta)}, \tag{13}$$

$$P_{H,t} = \left[\int_0^1 P_{H,t}(j)^{1-\varepsilon} dj\right]^{1/1-\varepsilon}, \quad P_{M,t} = \left[\int_0^1 P_{M,t}(j^*)^{1-\varepsilon} dj^*\right]^{1/1-\varepsilon}. \tag{14}$$

The home firm supplies its variety to the home and the foreign market and thus it output equals

$$Y_t(j) = C_{H,t}(j) + C^*_{H,t}(j), \tag{15}$$

where $C^*_{H,t}(j)$ is the foreign consumption of the home variety. Assuming that foreign consumption indexes are analogous to home indexes, we derive the foreign demand for the variety as

$$C^*_{H,t}(j) = \left(\frac{P^*_{X,t}(j)}{P^*_{X,t}}\right)^{-\varepsilon} C^*_{H,t}, \quad C^*_{H,t} = (1-\gamma^*)\left(\frac{P^*_{X,t}}{P^*_t}\right)^{-\eta} C^*_t, \tag{16}$$

where $P^*_{X,t}(j)$ is the export price of the home variety expressed in foreign currency. Price indexes $P^*_{X,t}$ and P^*_t are given by

$$P^*_{X,t} = \left[\int_0^1 P^*_{X,t}(j)^{1-\varepsilon} dj\right]^{1/1-\varepsilon}, \quad P^*_t = \left[(1-\gamma^*)(P^*_{F,t})^{1-\eta} + \gamma(P^*_{X,t})^{1-\eta}\right]^{1/(1-\eta)}, \tag{17}$$

where $P^*_{F,t}$ is the price of the bundle of foreign varieties in the foreign country.

The production function for a home variety is

$$Y_t(j) = A_t L_t(j), \tag{18}$$

where A_t is a stochastic productivity index that represents a real shock for the home economy and $L_t(j)$ is labor input. We assume that labor services are either homogeneous or differentiated. In the differentiated case, $L_t(j)$ represents a bundle of labor services defined as

$$L_t(j) = \left(\int_0^1 L_t(i,j)^{(\varepsilon-1)/\varepsilon} di \right)^{\varepsilon/(\varepsilon-1)}. \tag{19}$$

The marginal cost is the same for all home firms and equals

$$MC_t = W_t / A_t, \tag{20}$$

where W_t is the wage index, and $W_t = \left[\int_0^1 W(i)^{1-\varepsilon} di \right]^{1/1-\varepsilon}$ in the case of differentiated labor services.

Each home firm sets the home and export prices for its variety. The export price can be set either in producer or local currency. Let ψ and $1-\psi$ represent, respectively, the proportion of home firms setting prices using PCP and LCP. Partition the unit interval such that for $j \in [0,\psi]$, export price, $P_{XP,t}(j)$, is set in home currency, and for $j \in [\psi,1]$, export price, $P^*_{XL,t}(j)$, is set in foreign currency. The export price index expressed in home currency can then be defined as

$$P_{X,t} = \left[\int_0^{\psi} P_{XP,t}(j)^{1-\varepsilon} dj + S_t \int_{\psi}^1 P^*_{XL,t}(j)^{1-\varepsilon} dj \right]^{1/(1-\varepsilon)}. \tag{21}$$

Note that the foreign-currency export price in (17) can be converted into the home-currency export price in (21) as $P_{X,t} = S_t P^*_{X,t}$.

We allow the frequency of price change to differ between the home and foreign countries, and assume that it depends on the currency in which the price is set. In each period, there is probability, $1-\theta$, that a firm will change its price set in home currency, and probability, $1-\theta^*$, that it will change its price set in foreign currency. Let $\tilde{P}_{H,t}(j)$, $\tilde{P}_{XP,t}(j)$ and $\tilde{P}^*_{XL,t}$ denote, respectively, the new prices for home sales, for exports under PCP, and for exports under LCP if a firm sets new prices in period, t. The firm chooses these prices to maximize $Z_t(j) = \sum_{k=t}^{\infty} \theta^{k-t} D_{t,k}\left[PF_{H,k}(j) + PF_{X,k}(j)\right]$, where $PF_{H,\tau}(j)$ and $PF_{X,\tau}(j)$ are profits from home sales and exports, and $D_{t,k}$ is the discount factor. In view of the demand functions for $C_{H,t}(j)$ and $C^*_{H,t}(j)$ in (12) and (16), $PF_{H,\tau}(j)$ equals $(\tilde{P}_{H,t}(j) - MC_\tau)C_{H,\tau}(\tilde{P}_{H,t}(j)/P_{H,\tau})^{-\varepsilon}$ while $PF_{X,\tau}(j)$ equals $(\tilde{P}_{XP,t}(j) - MC_\tau)C^*_{H,\tau}(\tilde{P}_{XP,t}(j)/P_{X,\tau})^{-\varepsilon}$ for PCP and $S_\tau(\tilde{P}^*_{XL,t}(j) - MC_\tau / S_\tau)C^*_{H,\tau}(\tilde{P}^*_{XL.t}(j)/P^*_{X,\tau})^{-\varepsilon}$ for LCP. The optimal new prices can be shown to equal (for all firms changing prices in period t)

$$\tilde{P}_{H,t} = \frac{\varepsilon E_t \sum_{k=t}^{\infty} \theta^{k-t} D_{t,k} C_{H,k} P^{\varepsilon}_{H,k} MC_k}{(\varepsilon - 1) E_t \sum_{k=t}^{\infty} \theta^{k-t} D_{t,k} C_{H,k} P^{\varepsilon}_{H,k}}, \tag{22}$$

$$\tilde{P}_{XP,t} = \frac{\varepsilon E_t \sum_{k=t}^{\infty} \theta^{k-t} D_{t,k} C^*_{H,k} P^{\varepsilon}_{X,k} MC_k}{(\varepsilon - 1) E_t \sum_{k=t}^{\infty} \theta^{k-t} D_{t,k} C^*_{H,k} P^{\varepsilon}_{X,k}}, \quad \tilde{P}^*_{XL.t} = \frac{\varepsilon E_t \sum_{k=t}^{\infty} \theta^{*\tau-t} D_{t,k} C^*_{H,k} P^{*\varepsilon}_{X,k} MC_k}{(\varepsilon - 1) E_t \sum_{k=t}^{\infty} \theta^{k-t} D_{t,k} C^*_{H,k} S_k P^{*\varepsilon}_{X,k}}. \tag{23}$$

The home price index [as defined in (14)] equals $P_{H,t} = \left[\sum_{k=0}^{\infty} (1-\theta)\theta^k \tilde{P}_{H,t-k}{}^{1-\varepsilon}\right]^{1/(1-\varepsilon)}$ and can be expressed as

$$P_{H,t} = \left[(1-\theta)\tilde{P}_{H,t}{}^{1-\varepsilon} + \theta P_{H,t-1}{}^{1-\varepsilon}\right]^{1/(1-\varepsilon)}. \tag{24}$$

Similarly, the export price defined in (21) can be written as

$$P_{X,t} = \left[\psi P^{1-\varepsilon}_{XP,t} + (1-\psi)(S_t P^*_{XL,t})^{1-\varepsilon}\right]^{1/(1-\varepsilon)}, \tag{25}$$

where $P^{1-\varepsilon}_{XP,t} = \sum_{k=0}^{\infty} (1-\theta)\theta^k (\tilde{P}_{XP,t-k})^{1-\varepsilon}$ and $P^{*1-\varepsilon}_{XL,t} = \sum_{k=0}^{\infty} (1-\theta^*)\theta^{*k} (\tilde{P}^*_{XL,t-k})^{1-\varepsilon}$. The producer- and local-currency components of the export price can also be expressed as

$$P_{XP,t} = \left[(1-\theta)(\tilde{P}_{XP,t})^{1-\varepsilon} + \theta(P_{XP,t-1})^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}, P^*_{XL,t} = \left[(1-\theta^*)(\tilde{P}^*_{XL,t})^{1-\varepsilon} + \theta^*(P^*_{XL,t-1})^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}. \tag{26}$$

Assume that ψ^* and $1-\psi^*$ proportions of foreign firms set prices using PCP and LCP, and let $\tilde{P}^*_{MP,t}(j^*)$ and $\tilde{P}_{ML,t}(j^*)$ denote the new prices for home imports under PCP and LCP. Denoting the foreign marginal cost by MC^*, we can then derive analogous relations for determining the import price index (expressed in home currency) as follows:

$$\tilde{P}^*_{MP.t} = \frac{\varepsilon E_t \sum_{k=t}^{\infty} \theta^{*k-t} D_{t,k} C_{F,k} P^{*\varepsilon}_{M,k} MC^*_k}{(\varepsilon-1) E_t \sum_{k=t}^{\infty} \theta^{*k-t} D_{t,k} C_{F,k} P^{*\varepsilon}_{M,k}}, \quad \tilde{P}_{ML,t} = \frac{\varepsilon E_t \sum_{k=t}^{\infty} \theta^{k-t} D_{t,k} C_{F,k} P^{\varepsilon}_{M,k} MC^*_k}{(\varepsilon-1) E_t \sum_{k=t}^{\infty} \theta^{k-t} D_{t,k} C_{F,k} P^{\varepsilon}_{M,k} / S_k}, \quad (27)$$

$$P_{M,t} = \left[\psi^* (S_t P^*_{MP,t})^{1-\varepsilon} + (1-\psi^*) P^{1-\varepsilon}_{ML,t} \right]^{1/(1-\varepsilon)}, \quad (28)$$

$$P^*_{MP,t} = \left[(1-\theta^*)(\tilde{P}^*_{MP,t})^{1-\varepsilon} + \theta^* (P^*_{MP,t-1})^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}, P_{ML,t} = \left[(1-\theta)(\tilde{P}_{ML,t})^{1-\varepsilon} + \theta (P_{ML,t-1})^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}. \quad (29)$$

The demand for labor is affected by the price dispersion under the Calvo model. To derive labor demand, first use (15) and (18) to obtain $L_t = \frac{1}{A_t} \int_0^1 \left(C_{H,t}(j) + C^*_{H,t}(j) \right) dj$, and then use Calvo staggered price adjustment to express this relation as

$$L_t = \frac{1}{A_t} \begin{bmatrix} C_{H,t} \sum_{k=0}^{\infty} (1-\theta) \theta^k (\tilde{P}_{H,t-k} / P_{H,t})^{-\varepsilon} \\ + C^*_{H,t} \sum_{k=0}^{\infty} (1-\theta) \theta^k \left(\psi (\tilde{P}_{XP,t-k} / P_{X,t})^{-\varepsilon} + (1-\psi)(\tilde{P}^*_{XL,t-k} / P^*_{X,t})^{-\varepsilon} \right) \end{bmatrix}. \quad (30)$$

We allow the wage rate to be either flexible or sticky. In the flexible-wage case, households take the wage rate as given and supply labor services under perfect competition. Labor supply [based on optimization of lifetime utility (3) subject to budget constraint (4)] is given by

$$L_t^{\mu} = \frac{C_t^{-\chi} W_t}{P_t \varphi}. \quad (31)$$

In the sticky-wage case, the wage rate for each household’s labor services is set under monopolistic competition. In each period, there is probability, $1-\theta_W$, that a household will change its wage. Let $\tilde{W}_t(i)$ denote the new wage for a household setting a new wage in period, t. The household chooses the wage to maximize lifetime utility (3) subject to the budget constraint (4) and labor demand, $L_t(i) = L_t (W_t(i)/W_t)^{-\varepsilon}$. This wage equals

$$[\tilde{W}_t(i)]^{\varepsilon\mu+1} = \frac{\varphi\varepsilon\sum_{k=t}^{\infty}(\theta_W\beta)^{k-t}(L_k)^{1+\mu}W_k^{\ \varepsilon(1+\mu)}}{(\varepsilon-1)\sum_{k=t}^{\infty}(\theta_W\beta)^{k-t}\lambda_k L_k W_k^{\ \varepsilon}} \ , \tag{32}$$

where the wage index [defined in (20)] is determined as $W_t = \left[(1-\theta_W)\tilde{W}_t^{1-\varepsilon} + \theta_W W_{t-1}^{\ \ 1-\varepsilon}\right]^{1/(1-\varepsilon)}$.

The shocks in the model are assumed to follow the following autoregressive processes:

$$X_t = \left[1-\kappa\left(S_t B_t^* / P_t\right)^2\right] X_{t-1}^{\rho_X} e^{v_{X,t}}, \quad A_t = \bar{A}^{1-\rho_A} A_{t-1}^{\rho_A} e^{v_{A,t}} \ , \tag{33}$$

where $\kappa > 0$, $0 < \rho_X < 1$, $0 < \rho_A < 1$, $\bar{A}$ is the steady state value of the productivity index, and $v_{X,t}$ and $v_{A,t}$ are white noise disturbances. Note that the presence of the expression, $\kappa\left(S_t B_t^* / P_t\right)^2$ in the nominal shock process ensures convergence to a unique steady state with zero net foreign real assets ($S_t B_t^* / P = 0$).

B. Key Relations

A quantitative version of the model is analyzed in the next section. Here, we briefly discuss key relations that determine the exchange rate pass-through to trade prices. We simplify these relations by using a log-linear approximation around the steady state. Letting lower-case letters denote values in logs, express the linear versions of (28), (29) and (27) as

$$\Delta p_{M,t} = \psi^*(\Delta p_{MP,t}^* + \Delta s_t) + (1-\psi^*)\Delta p_{ML,t} \, , \tag{34}$$

$$\Delta p_{MP,t}^* = (1-\theta^*)(\tilde{p}_{MP,t}^* - p_{MP,t-1}^*), \quad \Delta p_{ML,t} = (1-\theta)(\tilde{p}_{ML,t} - p_{ML,t-1}) \, , \tag{35}$$

$$\begin{aligned} \tilde{p}_{MP,t}^* &= \mu + (1-\beta\theta^*)\sum_{k=0}^{\infty}(\beta\theta^*)^k E_t mc_{t+k}^* \, , \\ \tilde{p}_{ML,t} &= \mu + (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_t(mc_{t+k}^* + s_{t+k}), \end{aligned} \tag{36}$$

where $\mu = \ln \dfrac{\varepsilon}{\varepsilon - 1}$ is the markup in logs. Next use (36) to express (35) as[12]

$$\Delta p^*_{MP,t} = \beta E_t \Delta p^*_{MP,t+1} + \lambda^* m\tilde{c}^*_{P,t}, \quad \Delta p_{ML,t} = \beta E_t \Delta p_{ML,t+1} + \lambda m\tilde{c}^*_{L,t}, \tag{37}$$

where $\lambda^* = \dfrac{(1-\theta^*)(1-\beta\theta^*)}{\theta^*}$, $\lambda = \dfrac{(1-\theta)(1-\beta\theta)}{\theta}$, and $m\tilde{c}^*_{P,t} = w^*_t - a^*_t - p^*_{MP,t} + \mu$ and

$m\tilde{c}^*_{L,t} = w^*_t - a^*_t - (p_{ML,t} - s_t) + \mu$ are indexes based on real marginal costs for firms using PCP and LCP. Finally, substituting the values of $\Delta p^*_{MP,t}$ and $\Delta p_{ML,t}$ in (34), we obtain

$$\Delta p_{M,t} = \beta E_t \Delta p_{M,t+1} - \psi^* \beta E_t \Delta s_{t+1} + \psi^* \lambda^* m\tilde{c}^*_{P,t} + (1-\psi^*)\lambda m\tilde{c}^*_{L,t} + \psi^* \Delta s_t. \tag{38}$$

Similarly, we can use linear versions of (23), (25) and (26) to derive

$$\Delta p_{XP,t} = \beta E_t \Delta p_{XP,t+1} + \lambda m\tilde{c}_{P,t}, \quad \Delta p^*_{XL,t} = \beta E_t \Delta p^*_{XL,t+1} + \lambda^* m\tilde{c}_{L,t}, \tag{39}$$

$$\Delta p_{X,t} = \beta E_t \Delta p_{X,t+1} - (1-\psi)\beta E_t \Delta s_{t+1} + \psi\lambda m\tilde{c}_{P,t} + (1-\psi)\lambda^* m\tilde{c}_{L,t} + (1-\psi)\Delta s_t, \tag{40}$$

where $m\tilde{c}_{P,t} = w_t - a_t - p_{XP,t} + \mu$, and $m\tilde{c}_{L,t} = w_t - a_t - (p^*_{XL,t} + s_t) + \mu$.

Relations (38) and (40) identify the key channels that transmit the effects of different shocks to log differences of import and export prices. Note that the partial effect of the log difference of the exchange rate depends on the proportions of firms using PCP in the home and foreign economies, ψ and ψ^*. An increase in ψ^* would strengthen the partial effect of the exchange rate on the import prices while an increase in ψ would weaken the partial effect on the export price.

To examine the behavior of the exchange rate, we linearize (8) to obtain

$$s_t = E_t s_{t+1} + \bar{r}^* - \bar{r} + \delta^*(E_t \pi^*_t - \bar{\pi}^*) - \delta(E_t \pi_t - \bar{\pi}) + x_t, \tag{41}$$

where $\bar{r}^* = \ln(1+\bar{R}^*)$, $\bar{r} = \ln(1+\bar{R})$, $\pi^*_t = \ln(\Pi^*_t)$, $\bar{\pi}^* = \ln(\bar{\Pi}^*)$, $\pi_t = \ln(\Pi_t)$, and $\bar{\pi} = \ln(\bar{\Pi})$

[12] This derivation is standard for a Calvo model of price adjustment (e.g., see Yun, 1996).

From (33), the linear versions of the time series processes for the stochastic variables are: $x_t = \rho_X x_{t-1} + v_{X,t}, a_t = \rho_A a_{t-1} + v_{A,t}$, and $a_t^* = \rho_{A*} a_{t-1}^* + v_{A*,t}$. The pass-through elasticities for the import and export prices depend on the impact of nominal and real disturbances, $v_{X,t}, v_{A,t}, v_{A*,t}$, on s_t (and hence Δs_t) through (41) and on $\Delta p_{M,t}$ and $\Delta p_{X,t}$ via (38) and (40). The presence of the expected future values in these relations magnifies this impact (given the persistence in the stochastic variables). Both the nominal and real disturbances affect the exchange rate and trade prices, but the presence of x_t in (41) and Δs_t in (38) and (40) suggest that the impact of the nominal disturbance would be stronger. The relative strength of the effect of nominal and real disturbances is examined in the next section.

IV. QUANTITATIVE ANALYSIS

We undertake numerical analysis of the model to explore the role of different factors in determining the exchange rate pass-through to import and export prices. We also use the analysis to examine how well the model explains the key features of the data, especially the data for advanced countries that are more likely to conform to the interest parity and Taylor rule assumptions of the model.

A. Calibration

We calibrate our model as follows. We normalize the initial prices and home income to equal one. We set the share of imports in income (γ) equal to the median import share for advanced countries in our sample, which equals 0.3 (and is slightly lower than the average share of 0.32).We let the quarterly discount factor (β) equal 0.99, the coefficient of risk aversion (χ) equal 2.0, and the elasticity of labor supply ($1/\nu$) equal 0.5. We choose a value of 2.0 for the elasticity of substitution between home and foreign goods (η), and a value of 6.0 for the elasticity of substitution between varieties (ε).[13] The values of these parameters are similar to the ones used by other studies. Our sensitivity analysis indicates, moreover, that variations in these

[13] Given these choices, φ is determined by normalizing the steady-state values of $W, P,$ and L equal to one.

values have little effect on the pass-through results. For productivity shocks, we follow Corsetti, Dedola, and Leduc (2008) and let the autoregressive coefficients (ρ_A and ρ_{A*}) equal to 0.95, standard errors of white noise disturbances (v_A and v_{A*}) equal to 0.007, and the correlation coefficient for these disturbances equal to 0.25. For the nominal shock, we initially also let the standard error of the white noise disturbance (v_X) equal 0.007, but assume a more moderate persistence (let $\rho_X = 0.75$).[14]

We set the inflation-response parameters in the home and foreign interest rate rules (δ, δ^*) equal to 0.5, as in the simple versions of the Taylor rule. For the sticky wage version, we let the frequency of wage change ($1-\theta_W$) equal to 1/4 and the frequency of price change ($1-\theta$) equal to 1/3.[15] We assume the same frequency of price changes for the flexible wage version. The data on currency invoicing of exports and imports is used to determine the home and foreign PCP shares in the model as $\psi = 0.54$ and $\psi^* = 0.54$.[16] The currency of invoicing data have certain limitations as discussed in Section D below, but we use this data to obtain rough measures of the mix of PCP and LCP. We also use it below to explain cross-country variation in pass-through. The model assumes that the home economy is small and treats the foreign (rest of the world) real wage and inflation (W^*/P^* and Π^*) as exogenous.[17]

---

[14] The value of the autoregressive coefficient was chosen to keep the variability of Δs_t in the stochastic simulations of the model (discussed below) close to that in the data.

[15] The value of θ_w implies that the average duration of fixed wage equals one year, which is not too long in view of estimates for the Euro area (Smets and Wouters, 2003). However, we choose a smaller value of θ to let the average duration of price contracts to be shorter than wage contract as suggested by the estimates for the United States by Christiano, Eichenbaum, and Evans (2005).

[16] Goldberg and Tille (2008) and Kamps (2006) provide data on currency of invoicing for a number of countries. We use the latter source as it has wider coverage. Based on a sample of 10 advanced countries for which the invoicing data are available for both imports and exports, the home and foreign PCP shares are estimated as the average values of the shares of invoicing in exporter's currency for exports and imports.

[17] We also assume a very small value for the transactions cost parameter (κ), which ensures convergence of the economy to a unique steady state with zero net foreign assets but has a negligible effect on the dynamics of the model.

B. Impulse Response Analysis

To examine the model dynamics underlying the relation between the exchange rate and trade prices, Figure 3 shows the dynamic response (over 12 quarters) of the log differences of the exchange rate and import and export prices ($\Delta s, \Delta p_M, \Delta p_X$) to a one-standard-deviation increase in each shock (v_X, v_A, v_{A*}) for the baseline parameter values. These impulse response functions are similar for both sticky and flexible wage versions of the model and are illustrated only for the latter version. The figure highlights two important features of the dynamic adjustment of the three variables. First, the effect of each shock is concentrated in the same quarter in which the shock occurs. Second, the contemporaneous effect of the nominal shock is much larger than that of real shocks for each variable. These features suggest that the exchange rate innovation in a VAR model would be dominated by the nominal shock, and thus the adjustment of the exchange rate and import and export prices to this innovation would be rapid and occur mostly in the current quarter. The dynamic adjustment suggested by the model is broadly consistent with the impulse response functions from VAR's for the advanced countries (in Figure 2). Moreover, as changes in the exchange rate and trade prices largely reflect the effect of current rather than past shocks, the model also implies that the regression estimates of the short-run exchange rate pass-through (the effect of the current exchange rate change) would be similar to the VAR estimates of the pass-through (the effect of the current exchange rate innovation).

It is also interesting to examine how different shocks affect the short-run pass-through. Table 4 shows the current-period elasticity of the import and export prices to the exchange rate resulting from a one-standard-deviation increase in each shock for both sticky and flexible wage cases. For the nominal shock, the pass-through elasticity is 0.64 for the import price and 0.36 for the export price in the sticky wage case. For the real shocks, the pass-through elasticities are in fact negative in some cases. For example, under sticky wages, the import price pass-through is -0.34 for the foreign productivity shock and the export price pass-through is -0.42 for the home productivity shock. The negative values in these cases reflect the effect of productivity shocks on prices via the marginal cost channel [see (38) and (40)]. A positive foreign productivity shock, for example, reduces the foreign marginal cost and lowers import prices (for firms setting new prices). A home productivity shock has similar effect through changes in the home marginal cost.

The flexible wage case yields similar pass-through elasticities for the nominal shock. However, the export price pass-through for the home productivity shock in this case is higher (equals -0.06). This difference arises because under flexible wage, an increase in productivity increases the wage rate which weakens the productivity effect on the marginal cost.[18]

The table also shows the elasticities generated by a simultaneous one-standard-deviation increase in all three shocks. As we would expect from the impulse response functions in Figure 3 (which show the nominal shock to dominate the movements in the exchange rate and trade prices), the elasticity for the composite shock is not much different than the elasticity for only the nominal shock. The results in Table 4 suggest that the short-run pass-through is likely to be largely determined by the impact of nominal shocks even in the presence of both types of shocks. Productivity shocks may, however, have a stronger influence in the long run and nominal shocks may not be the main drivers of the long-run pass-though. The accumulated effect of a productivity shock could even be negative, which would explain why estimates of the long-run pass-through tend to be below one even though the long-run pass-though (to both import and export prices) produced by nominal shocks would equal one. To explore this issue further, we undertake stochastic simulations of the model below to examine whether the long-run pass-through would be less than one in an economy subject to both nominal and real shocks.

We next examine the sensitivity of pass-through elasticities to variations in the values of key parameters. Given the importance of the nominal shock in influencing the short-run pass-through, we focus on the elasticities determined by a one-standard deviation nominal shock. Figure 4(a) illustrates the effect of variations in the foreign PCP share on the import price elasticity, and Figure 4(b) illustrates the effect of variations in the home PCP share on the export price elasticity.[19] Again, the effects are similar for both the sticky and flexible wage cases and are shown only for the latter case. As Figure 4(a) shows, the import price pass-through is low (around 0.25) if the foreign PCP share is zero. The pass-through increases as the PCP share

---

[18] Since, for simplicity, we do not model wage adjustment in the large foreign economy, we are not able to examine the influence of a flexible foreign wage on the import price pass-through in the case of a foreign productivity shock.

[19] Home PCP share is kept at the baseline value of 0.54 in Figure 3(a). Similarly, the foreign PCP share equals 0.54 in Figure 3(b).

increases and reaches one when the PCP share equals one. In contrast, the export price pass-through in Figure 4(b) is high (above 0.8) at the zero value of the home PCP share, decreases as PCP share increases and falls to a low value (below 0.1) when the PCP share equals one. These figures also show that the pass-through for the import price clearly exceeds that for the export price at the baseline values of 0.54 for both home and foreign PCP shares.

The influence of other parameters on the pass-through elasticities is explored in Table 5. We first examine the effect of greater wage/price flexibility. We decrease θ_W to 0.667 and θ to 0.5 in the sticky wage case, and decrease θ to 0.5 in the flexible wage case. These changes have a significant impact on the pass-through, causing an increase in the import price pass-through and a decrease in the export price pass-through. The effect of greater flexibility in wage and prices or prices alone is thus similar to larger home and foreign PCP shares. We also explore how the degree of persistence in the exchange rate shock and the interest rate reaction to inflation influences the exchange rate pass-through. We varied ρ_x from 0.6 to 0.90, and δ from 0.1 to 1.0. The table shows that lower or higher persistence of the exchange rate shock or less or more aggressive reaction to inflation does not have a large effect on the pass-through values. Thus, our numerical analysis of the short-run pass-through generated by the nominal shock suggests that PCP shares and wage-price stickiness are the major sources of variation in the pass-through for import and export prices.

C. Stochastic Simulation

This section examines the performance of the model in matching the data for advanced countries. We first examine how well the model can account for the evidence on exchange rate pass-through to import and export prices. Although the model is designed to provide an explanation of the pass-through evidence, we also explore if it is capable of explaining other relevant features of the data. Open-economy models are expected to explain the variability of the exchange rate, inflation and output, and we evaluate the model's performance in matching these moments. In addition, since pass-though can play an important role in influencing the volatility of import and export volumes, it is interesting to examine if the model can also match these moments. Finally, we examine if the model can account for the correlation between the exchange rate and the terms of trade, as the sign of this coefficient has received considerable attention as a key test of LCP versus PCP.

Stochastic simulation of the model is used to generate artificial series for key variable over a period as long as our sample (127 quarters) for both sticky and flexible wage versions of the baseline model.[20] Series on $\Delta s_t, \Delta p_{M,t}, \Delta p_{X,t}$ and Δp_t were used to obtain both the regression and VAR estimates of import and export pass-through.[21] . The simulated data were also used to compute the standard deviations of Δs_t, Δp_t, $y_t (\equiv \ln Y_t)$, $c_{F,t} (\equiv \ln C_{F,t})$ and $c^*_{H,t} (\equiv \ln C^*_{H,t})$,[22] Table 6 summarizes the results on the comparison of the statistics generated by the model with statistics based on the data for advanced countries.[23]

Estimates of the short-run pass-though by regression are tracked very well by both versions of the model, especially the sticky wage version. The two versions also provide a good match for the VAR estimates of the short-run pass-through. In explaining the long-run pass-through, each version performs well for the import price, but for the export price, there is a discrepancy between the model and the data, which is large in the case of the sticky wage version. Model simulations, however, explain two key features of the estimates of the long-run pass-through: it tends to be less than one and larger for the import than the export price.[24]

---

[20] The series were, in fact, generated for 227 quarters, but the values for the first 100 quarters were dropped.

[21] The VAR model used for the simulated data is the same as that used for actual data except that it does not include Δp^*_t, which is constant in our model. We did experiment with introducing a shock to this variable in the model, but it did not affect the results much.

[22] Note that s_t and p_t are $I(1)$ series and need to be first-differenced to make these stationary while $y_t, c_{F,t}$ and $c^*_{H,t}$ are already stationary series.

[23] Each data-based statistic represents the mean value of the statistics for the 18 advanced countries in our sample. Output is measured by real GDP. To remove the effect of long-term growth (which is absent in our model), series on real GDP and volumes of imports and exports were detrended using the Hodrick-Prescott filter. Import and export volumes were not available for Australia, and this country is excluded in calculating the mean values of the standard deviations for these variables.

[24] An explanation of these results is that although nominal shocks generate a long-run pass-through equal to one, productivity shocks in our model produce negative long-run pass through, and the offsetting effect of productivity shocks is stronger in the case of the export price. In fact, the effect for the export price turns out to be sufficiently strong to make the long-run pass-through fall below the short-run pass-through.

The volatility of the exchange rate and inflation in the model is sensitive to the values of parameters for the nominal shock process (i.e., ρ_X and the standard error of ν_X). For our assumed values for these parameters, both versions of the model imply greater exchange rate variability and smaller inflation variability than the data, but the difference between the model and the data is not too large. An important test of the model, however, is whether it can also match the variability of real variables, especially that of output. In this regard, the sticky wage version does not perform well. Variability of output for this version is too large and, in fact, is even larger than the exchange rate variability. Interestingly, the flexible wage version is able to generate output variability that is reasonably close to that in data. Open economy models tend to have difficulties in accounting for high variability of the exchange rate relative to output. In the flexible wage version, however, the ratio of the standard deviation of the exchange rate to that of output is larger than that in data (it is 2.3 in the model compared to 1.7 in data). The differences between the two versions in accounting for output variability can be traced to differences in the response of labor supply. Under sticky wages, (monopolistically competitive) households supply labor to meet effective labor demand, and thus the response of employment and output to different shocks is very elastic. In contrast, employment response under flexible wages is constrained by labor supply and leads to less variation in output. The flexible wage version is also able to match the high variability of import and export volumes in data very well and outperform the sticky wage version in this respect.

Finally, we examine how the model fares in explaining the correlation between the exchange rate and the terms of trade. The correlation in (both versions of) the model is negative, but surprisingly much stronger than in the data (the correlation coefficient is -0.84 in the model but only -0.28 in data). One possible explanation of this difference is that import and export price indexes are generally based on unit values and involve substantial measurement errors. The absolute value of the estimated correlation coefficient would thus be much lower than the true value. Interestingly, it can be shown that while purely random measurement errors in price indexes for traded good would weaken the correlation between the exchange rate and the terms of trade, they would not affect the estimates of the short-run pass-through.[25] Thus, in the presence of measurement errors, the model could match the data for the short-run pass-through coefficients but differ for the correlation coefficient.

D. Currency of Invoicing and the Pass-Through

Our numerical analysis suggests that home and foreign PCP shares are key determinants of the pass-through to import and export prices. As currency of invoicing data can be used to measure PCP shares, we briefly explore in this section some empirical evidence on the importance of these shares in explaining cross-country variation in the pass-through values. We utilize data on currency of invoicing from Kamps (2006). This source provides data on shares of invoicing in exporter's currency and in US dollars for both imports and exports for 18 countries in our sample.[26] The data are typically available only for a small number of years mostly in the early 2000's. Another limitation of the data is that the coverage and the collection method vary from one source to another. Nevertheless, this data provide rough measures of the PCP shares in home and foreign economies and enable us to test one implication of the model.

Table 7 presents results of OLS regressions explaining VAR estimates of the import and export pass-through by an index of the home or foreign PCP share based on invoicing-currency data.

---

[25] Letting a tilde denote measured values, express $\Delta\tilde{p}_{T,t} = \Delta p_{T,t} + u_{T,t}$, $T = M, X$, where $u_{T,t}$ represents the measurement error. Measured and true values of the correlation coefficient are, respectively, $\tilde{r} = \dfrac{\text{cov}(\Delta x_t, \Delta t\tilde{o}t_t)}{sd(\Delta x_t) sd(\Delta t\tilde{o}t_t)}$ and $r = \dfrac{\text{cov}(\Delta x_t, \Delta tot)}{sd(\Delta x_t) sd(\Delta tot)}$, where $\Delta t\tilde{o}t_t = \Delta\tilde{p}_{X,t} - \Delta\tilde{p}_{M,t}$ and $\Delta tot_t = \Delta p_{X,t} - \Delta p_{M,t}$. Also, the measured and true values of the short-run pass-through (given by the coefficient of Δs_t in regression (1) without controls) are, respectively, $\tilde{a}_T = \dfrac{\text{cov}(\Delta x_t, \Delta\tilde{p}_{T,t})}{\text{var}(\Delta x_t)}$ and $a_T = \dfrac{\text{cov}(\Delta x_t, \Delta p_{T,t})}{\text{var}(\Delta x_t)}$ for $T = M, X$. Assume that $u_{M,t}$ and $u_{X,t}$ are white noise disturbances that are uncorrelated with $\Delta p_{M,t}, \Delta p_{X,t}$ and with each other, In this simple case, $E[\text{cov}(\Delta s_t, \Delta t\tilde{o}t)] = E[\text{cov}(\Delta s_t, \Delta tot)]$, $E[\text{cov}(\Delta s_t, \Delta\tilde{p}_{T,t})] = E[\text{cov}(\Delta s_t, \Delta p_{T,t})]$ and $sd(t\tilde{o}t) > sd(tot)$. Thus $E(\tilde{r}) < E(r)$ and $E(\tilde{a}_T) = E(a_T)$.

[26] The countries included in this dataset are: Australia, Belgium, Canada, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Japan, Netherlands, Poland, South Africa, Spain, Turkey, UK and US. The data on some invoicing shares are not available for Canada, Denmark and South Africa.

First, we examine the influence of the percentage share (averaged over the time period for which data are available) of exporter currency invoicing in exports as an index of the home PCP share.[27] Consistent with the model, this index has a negative and significant effect on the export price pass-through. Next, we explore the effect of the average percentage share of exporter currency invoicing in imports as an index of the foreign PCP share. This index has a positive effect on the import price pass-through (as predicted by the model), but this effect is insignificant. One problem with this measure of the foreign PCP is that it includes invoicing in Euro, which is also the home currency for a large number of countries in our sample.[28] As an alternative index of the foreign PCP share, we use the average percentage share of US dollar invoicing in imports (for US, we subtract the US dollar share from 100%).[29] The US dollar index is found to have a positive and significant effect on the import price pass-through.[30] The empirical evidence based on currency invoicing thus lends support to the model's predictions about the effect of PCP shares on the pass-through to the export and import prices.

V. Concluding Remarks

The debate on the nature of nominal rigidities in open economies has focused on whether firms use PCP or LCP. In view of the limitations of either PCP or LCP to account for the evidence on exchange rate pass-through to import and export prices, recent studies have emphasized the role of markup adjustment in explaining the pass-through evidence. This paper argues that even with no markup adjustment, a hybrid model with an appropriate mix of PCP and LCP can fit the data on not only pass-through elasticities but also measures of variability for key macro variables. The model also accounts for the finding that pass-through estimates based on regression equations tend to be similar to the ones derived from VAR models.

[27] This measure shows considerable variation across countries and varies from a low value of 1% for Turkey to a high value of 99.8% for US.

[28] The currency invoicing data are generally available after the monetary union in Europe.

[29] In addition to most imports from US, a large proportion of imports from non-US countries is also invoiced in US dollars (Goldberg and Tille, 2005).

[30] The range for the US dollar index of the foreign PCP share is 9.7-57.2 as compared to a larger range of 9.7-99.8 for the exporter currency index.

Studies based on models with variable markup (e.g., Corsetti, Dedola, and Leduc, 2008) can explain low pass-through elasticities and exchange rate volatility relative to output with minimal nominal rigidities and without the presence of nominal shocks. These studies, however, do not address the question of why regression estimates of the pass-through elasticities tend to be close to VAR estimates. Our model explains the similarity of the two types of estimates, and interestingly, nominal rigidities play a major role in this explanation. We show that in the presence of significant price stickiness, short run changes in the exchange rate and trade prices are determined largely by current innovations to shocks, and thus regression and VAR estimates of the pass-through do not differ much. The presence of nominal shocks is essential in our model not only in explaining this result, but also in accounting for the pattern of pass-through elasticities for import and export prices and the observed exchange rate and inflation variability. The model does not, however, require stickiness of wages. Indeed, the flexible wage version of the model performs much better than the sticky wage version in explaining the variability of output.

As well, the model is consistent with the evidence that a depreciation of the home currency would worsen the terms of trade, and thus changes in the exchange rate would bring about appropriate relative price adjustment in the transmission of shocks. The benefits of exchange rate flexibility would, therefore, be realized even in the hybrid case where both PCP and LCP are used.

Acknowledgements

The authors thank Zoltan Jakab and seminar participants at the IMF Institute for Capacity Development for comments, and Kazim Kazimov and Zaki Dernaoui for excellent research assistance.

References

Bacchetta, Philippe and Eric van Wincoop, 2005, “A Theory of the Currency Denomination of International Trade.” *Journal of International Economics*, 67(2), pp. 295-319.

Betts, C. and Devereux M., 2000, "Exchange Rate Dynamics in a Model of Pricing to Market," *Journal of International Economics* 50, pp. 215-44.

Bussière, Matthieu, and Tuomas Peltonen, 2008, "Exchange Rate Pass-Through in the Global Economy–The Role of Emerging Market Economies," Bank of Finland Discussion Paper No. 25.

Calvo, Guillermo A., 1983, "Staggered Prices in a Utility-Maximizing Framework," *Journal of Monetary Economics*, pp. 383-98.

Campa, Jose Manuel, and Linda S. Goldberg, 2005, “Exchange Rate Pass-Through to Import Prices,” R*eview of Economics and Statistics*, 87(4), pp. 679-690.

Choudhri, Ehsan U., Hamid Faruqee, and Dalia S. Hakura, 2005, “Explaining the Exchange Rate Pass-Through in Different Prices,” *Journal of International Economics*, 65 (March 2005), pp. 349-374.

Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans, 2005, " Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*, 113(1), pp.1-45.

Clarida, Richard, Jordi Gali, and Mark Gertler, 2002, “A Simple Framework for International Policy Analysis,” *Journal of Monetary Economics* 49, pp. 879-904.

Corsetti, Giancarlo, and Luca Dedola, 2005, "A Macroeconomic Model of International Price Discrimination," *Journal of International Economics* 67, pp. 129-56.

Corsetti, Giancarlo, Luca Dedola, and Sylvain Leduc, 2007, "Optimal Monetary Policy and the Sources of Local-Currency Price Stability," NBER Working Paper No. 13544.

Corsetti, Giancarlo, Luca Dedola, and Sylvain Leduc, 2008, "High Exchange-Rate Volatility and Low Pass-Through in Business Cycle Models," *Journal of Monetary Economics*, 55, pp.1113-28.

Corsetti, Giancarlo, Luca Dedola, and Sylvain Leduc, 2010, “Optimal Monetary Policy in Open Economies,” in Benjamin M. Friedman & Michael Woodford (eds.), *Handbook of Monetary Economics*, volume 3, number 3, Elsevier.

Corsetti, Giancarlo, and Paolo Pesenti, 2001, "Welfare and Macroeconomic Interdependence," *Quarterly Journal of Economics* 116, pp. 421-46.

Corsetti, Giancarlo and Paolo Pesenti, 2005, "International dimension of optimal monetary policy," *Journal of Monetary Economics* 52, pp. 281-305.

Devereux, Michael B., and Charles Engel, 2002, "Exchange Rate Pass-Through, Exchange Rate Volatility, and Exchange Rate Disconnect," *Journal of Monetary Economics*, Vol. 49, pp. 913-940.

Devereux, Michael B., and Charles Engel, 2003, "Monetary Policy in Open Economy Revisited: Price Setting and Exchange Rate Flexibility," *Review of Economic Studies* 70, pp. 765-83.

Devereux, Michael, Charles Engel, and Peter Storegaard, 2004, "Endogenous Exchange Rate Pass-Through when Nominal Prices are set in Advance." *Journal of International Economics*, 63(2), pp. 263-291.

Gagnon, Joseph E., and Jane Ihrig, 2004, "Monetary Policy and Exchange Rate Pass-Through," *International Journal of Finance and Economics*, 9, pp. 315–338 .

Goldberg Linda S., and Cedric Tille, 2008, "Vehicle Currency Use in International Trade," *Journal of International Economics* 76, pp. 177–192.

Gust, C., S. Leduc, and R. Vigfusson, 2010, "Trade integration, competition, and the decline in exchange rate pass-through," *Journal of Monetary Economics* 57, pp. 309–324.

Kamps, Anette, 2006, "The Euro as Invoicing Currency in International Trade," ECB. Working Paper Series No. 665 (August).

McCarthy J., 2000, "Pass-Through of Exchange Rates and Import Prices to Domestic Inflation in Some Industrialized Economies," Federal Reserve Bank of New York Staff Report No. 111.

Obstfeld, Maurice, and Kenneth Rogoff, 1995, "Exchange Rate Dynamics Redux," *Journal of Political Economy* 102, pp. 624-60.

Obstfeld, Maurice, and Kenneth Rogoff, 2000, "New Directions for Stochastic Open Economy Models," *Journal of International Economics*, 50, pp. 117-154.

Smets, Frank R., and Raf Wouters, 2003, "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area," *Journal of the European Economics*

Association, 5, 1123-1175.

Yun, Tack, 1996, "Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycles," *Journal of Monetary Economics* 37, pp. 345-370.

Table 1. Short-Run Exchange Rate Pass-Through, OLS Regressions, 1979-2010

	Import Price Pass-Through			Export Price Pass-Through		
	Log-change of NEER	No. of Obs.	R-squared	Log-change of NEER	No. of Obs.	R-squared
Advanced economies						
United States	0.387 (0.107)***###	113	0.164	0.152 (0.090)*###	109	0.063
United Kingdom	0.350 (0.052)***###	127	0.310	0.210 (0.066)***###	127	0.104
Belgium	0.622 (0.197)***#	71	0.135	0.548 (0.146)***###	71	0.196
Denmark	0.953 (0.133)***	127	0.452	0.592 (0.097)***###	127	0.297
France	0.554 (0.205)***##	120	0.093	0.300 (0.126)**###	120	0.072
Germany	0.686 (0.117)***###	127	0.247	0.202 (0.036)***###	127	0.210
Italy	0.748 (0.121)***##	126	0.228	0.427 (0.084)***###	126	0.203
Netherlands	1.045 (0.223)***	111	0.148	0.821 (0.235)***	111	0.102
Norway	0.491 (0.076)***###	127	0.203	-0.233 (0.266)###	127	0.007
Sweden	0.402 (0.091)***###	127	0.267	0.303 (0.044)***###	127	0.304
Switzerland	0.633 (0.113)***###	121	0.275	0.212 (0.080)***###	121	0.056
Canada	0.605 (0.065)***###	127	0.396	0.288 (0.138)**###	127	0.064
Japan	0.982 (0.095)***	127	0.560	0.528 (0.038)***###	127	0.653
Finland	0.581 (0.076)***###	125	0.208	0.461 (0.081)***###	125	0.209
Ireland	0.808 (0.081)***##	126	0.457	0.772 (0.097)***##	126	0.400
Spain	0.863 (0.150)***	127	0.231	0.410 (0.078)***###	127	0.142
Australia	0.658 (0.035)***###	97	0.748	0.442 (0.064)***###	107	0.299
New Zealand	0.698 (0.072)***###	127	0.509	0.626 (0.083)***###	127	0.390
Average	0.67(0.03)			0.39(0.03)		
Emerging market economies						
South Africa	0.302 (0.082)***###	108	0.2551	0.452 (0.06)***###	108	0.2343
Argentina	0.91 (0.046)***#	64	0.8915	0.879 (0.051)***##	69	0.7057
Colombia	0.491 (0.06)***###	123	0.059	0.503 (0.158)***###	123	0.0367
Brazil	0.997 (0.022)***	127	0.9118	0.986 (0.027)***	127	0.8693
Mexico	-0.021 (0.015)###	126	0.028	-0.160 (0.073)** ###	126	0.072
Jordan	0.733 (0.282)***	81	0.1815	0.554 (0.211)***##	81	0.0748
Hong Kong	0.311 (0.069)***###	127	0.2514	0.146 (0.0655)**###	127	0.0655
Republic of Korea	0.85 (0.097)***	127	0.5216	0.73 (0.096)***###	127	0.5705
Pakistan	0.618 (0.203)***#	125	0.1046	0.352 (0.137)**###	125	0.0663
Singapore	-0.18 (0.188)###	127	0.0119	-0.368 (0.199)*###	127	0.0373
Thailand	0.82 (0.107)***#	127	0.3552	0.769 (0.187)***	127	0.0282
Peru	0.785 (0.122)***#	71	0.402	0.773 (0.311)**	71	0.116
Hungary	0.606 (0.182)***##	127	0.187	0.586 (0.11)***###	127	0.359
Poland	0.888 (0.104)***	99	0.022	0.872 (0.066)***#	99	0.023
Turkey	0.955 (0.055)***	115	0.834	0.913 (0.024)***###	115	0.868
Chile	0.976 (0.106)***	59	0.659	0.475 (0.204)**#	59	0.112
Average	0.63(0.03)			0.53(0.04)		

Trade prices for advanced economies come from the OECD's Monthly International Statistics database. Trade prices for the emerging market economies come from the IMF's International Financial Statistics database and the nominal effective exchange rate data comes from the IMF's Information Notice System. An * indicates if the coefficient is significantly different from 0. A # indicates if the pass-through coefficient is significantly different from 1. ***, **, and * denote the 1, 5, and 10 percent levels, respectively. ###, ##, and # denote the 1, 5, and 10 percent levels, respectively. Robust standard errors are reported in parentheses. Countries are classified as advanced and emerging market economies based on the classification in the IMF's World Economic Outlook publications. A constant is included in the OLS regressions of each country. The estimated coefficients are not reported here.

Table 2. Long-Run Exchange Rate Pass-Through, OLS Regressions, 1979-2010

	Import Price Pass-Through				Export Price Pass-Through			
	Long-run pass through		No. of Obs.	R-squared	Long-run pass through		No. of Obs.	R-squared
Advanced economies								
United States	0.387 (0.183)	** ###	113	0.229	0.142 (0.158)	###	109	0.122
United Kingdom	0.495 (0.096)	*** ###	123	0.433	0.417 (0.122)	*** ###	123	0.186
Belgium	0.737 (0.310)	**	71	0.192	0.746 (0.231)	***	71	0.235
Denmark	1.35 (0.177)	*** ##	123	0.504	1.086 (0.132)	***	123	0.405
France	1.20 (0.229)	***	116	0.220	0.804 (0.166)	***	116	0.204
Germany	1.077 (0.167)	***	123	0.367	0.375 (0.050)	*** ###	123	0.348
Italy	0.879 (0.159)	***	122	0.296	0.637 (0.121)	*** ###	122	0.337
Netherlands	1.83 (0.439)	*** #	107	0.229	1.859 (0.381)	*** ##	107	0.244
Norway	0.466 (0.182)	*** ###	123	0.234	-0.772 (0.516)	###	123	0.234
Sweden	0.498 (0.108)	*** ###	123	0.340	0.431 (0.072)	*** ###	123	0.406
Switzerland	0.733 (0.165)	***	117	0.358	0.175 (0.151)	###	117	0.082
Canada	0.369 (0.100)	*** ###	156	0.504	-0.209 (0.235)	###	123	0.220
Japan	1.096 (0.176)	***	123	0.590	0.454 (0.069)	*** ###	123	0.654
Finland	0.581 (0.109)	*** ###	122	0.266	0.246 (0.111)	** ###	121	0.270
Ireland	1.281 (0.142)	*** #	122	0.570	1.452 (0.155)	*** ###	122	0.529
Spain	1.185 (0.223)	***	123	0.293	0.648 (0.150)	*** ##	123	0.192
Australia	0.646 (0.094)	*** ###	97	0.783	0.197 (0.109)	* ###	103	0.412
New Zealand	0.747 (0.139)	*** #	123	0.569	0.483 (0.171)	*** ###	123	0.446
Average	0.864 (0.046)				0.50 (0.048)			
Emerging market economies								
South Africa	0.426 (0.105)	*** ###	104	0.443	0.597 (0.102)	*** ###	104	0.325
Argentina	0.841 (0.072)	*** ##	64	0.901	0.879 (0.089)	***	69	0.739
Colombia	0.327 (0.231)	###	119	0.079	-0.023 (0.435)	##	119	0.084
Brazil	1.021 (0.027)	***	123	0.917	0.990 (0.033)	***	123	0.871
Mexico	-0.0154 (0.025)	###	122	0.027	-0.108 (0.075)	###	122	0.087
Jordan	1.059 (0.190)	***	81	0.219	1.147 (0.235)	***	81	0.209
Hong Kong	0.665 (0.099)	*** ###	123	0.455	0.502 (0.085)	*** ###	123	0.274
Republic of Korea	0.313 (0.216)	###	123	0.623	0.575 (0.181)	*** ###	123	0.581
Pakistan	0.143 (0.421)	##	121	0.155	0.545 (0.229)	** ##	121	0.132
Singapore	0.349 (0.247)	###	123	0.147	0.030 (0.300)	###	123	0.093
Thailand	0.516 (0.226)	** ##	123	0.431	1.183 (0.537)	**	123	0.035
Peru	1.115 (0.113)	***	71	0.505	0.733 (0.322)	**	71	0.145
Hungary	0.816 (0.232)	***	123	0.302	0.770 (0.143)	***	123	0.418
Poland	0.546 (0.192)	*** ##	99	0.038	0.861 (0.150)	***	99	0.023
Turkey	0.937 (0.069)	***	115	0.835	0.914 (0.046)	*** #	115	0.872
Chile	0.370 (0.227)	###	59	0.747	-0.380 (0.398)	###	59	0.386
Average	0.590 (0.049)				0.576 (0.064)			

Trade prices for advanced economies come from the OECD's Monthly International Statistics database. Trade prices for the emerging market economies come from the IMF's International Financial Statistics database and the nominal effective exchange rate data comes from the IMF's Information Notice System. An * indicates if the coefficient is significantly different from 0. A # indicates if the pass-through coefficient is significantly different from 1. ***, **, and * denote the 1, 5, and 10 percent levels, respectively. ###, ##, and # denote the 1, 5, and 10 percent levels, respectively. Robust standard errors are reported in parentheses. Countries are classified as advanced and emerging market economies based on the classification in the IMF's World Economic Outlook publications. The regression is specified as in equation () and includes a constant term. Only the long run exchange rate pass-through coefficients are reported here.

Table 3. Short-Run Exchange Rate Pass-Through, VAR, 1979–2010

Country	Import Price Response		Export Price Response		p-value for t test of difference in trade price responses
	Estimate	Std. error	Estimate	Std. error	
Advanced economies					
United States	0.38	(0.08)	0.17	(0.05)	0.02
United Kingdom	0.37	(0.05)	0.25	(0.05)	0.10
Belgium	0.50	(0.18)	0.48	(0.13)	0.92
Denmark	0.69	(0.10)	0.42	(0.08)	0.03
France	0.30	(0.14)	0.11	(0.09)	0.25
Germany	0.61	(0.09)	0.17	(0.03)	0.00
Italy	0.62	(0.11)	0.33	(0.06)	0.02
Netherlands	0.93	(0.20)	0.61	(0.18)	0.24
Norway	0.57	(0.09)	0.06	(0.26)	0.06
Sweden	0.39	(0.06)	0.30	(0.04)	0.19
Switzerland	0.52	(0.08)	0.27	(0.07)	0.03
Canada	0.59	(0.07)	0.39	(0.09)	0.08
Japan	0.90	(0.09)	0.55	(0.05)	0.00
Finland	0.63	(0.10)	0.57	(0.09)	0.69
Ireland	0.70	(0.08)	0.78	(0.09)	0.53
Spain	0.76	(0.14)	0.40	(0.09)	0.03
Australia	0.63	(0.06)	0.46	(0.07)	0.06
New Zealand	0.65	(0.07)	0.61	(0.07)	0.66
Average	0.60	(0.03)	0.39	(0.02)	0.00
Emerging market economies					
South Africa	0.31	(0.05)	0.38	(0.08)	0.43
Argentina	0.94	(0.10)	0.87	(0.09)	0.59
Colombia	0.51	(0.15)	0.76	(0.20)	0.32
Brazil	0.86	(0.08)	0.99	(0.09)	0.28
Mexico	-0.01	(0.01)	-0.15	(0.06)	0.02
Jordan	0.43	(0.24)	0.03	(0.20)	0.20
Hong Kong	0.24	(0.03)	0.10	(0.03)	0.00
Republic of Korea	0.87	(0.08)	0.70	(0.08)	0.14
Pakistan	0.45	(0.18)	0.44	(0.13)	0.97
Singapore	-0.22	(0.13)	-0.33	(0.15)	0.61
Thailand	0.87	(0.11)	0.60	(0.43)	0.53
Peru	0.80	(0.13)	1.34	(0.33)	0.13
Hungary	0.52	(0.10)	0.53	(0.08)	0.93
Poland	0.31	(1.61)	0.52	(1.57)	0.92
Turkey	0.94	(0.07)	0.89	(0.07)	0.62
Chile	0.86	(0.11)	0.52	(0.15)	0.07
Average	0.54	(0.10)	0.51	(0.11)	0.84

Trade prices come from the OECD's Monthly International Statistics database for advanced economies and the IMF's International Financial Statistics database for the emerging market economies. All other variables come from the IMF's Information Notice System database.

Table 4. Pass-Through Elasticities for Different Shocks

Shocks	Pass-Through Elasticities	
	Import Price	Export Price
Sticky Wage		
Nominal Shock	0.642	0.356
Home Productivity Shock	0.533	-0.421
Foreign Productivity Shock	-0.338	0.332
Composite Shock	0.569	0.294
Flexible Wage		
Nominal Shock	0.652	0.416
Home Productivity Shock	0.631	-0.056
Foreign Productivity Shock	-0.370	0.459
Composite Shock	0.583	0.384

In the case of nominal and home and foreign productivity shocks, the elasticities are based on a one-standard-deviation increase in each shock. The elasticities for the composite shock represent the effect of a simultaneous one-standard-deviation increase in all shocks.

Table 5. Wage-Price Stickiness, Exchange Rate Persistence, Inflation Reaction and the Pass-Through

	Import Price Pass-Through	Export Price Pass-Through
Sticky Wage		
Baseline	0.642	0.355
Less stickiness ($\theta = .5, \theta_W = .667$)	0.739	0.304
Lower persistence ($\rho_x = 0.6$)	0.626	0.370
Higher persistence ($\rho_x = 0.9$)	0.664	0.337
Weaker reaction ($\delta = 0.1$)	0.631	0.356
Stronger reaction ($\delta = 1.0$)	0.656	0.353
Flexible Wage		
Baseline	0.652	0.416
Less stickiness ($\theta = .5$)	0.750	0.374
Lower persistence ($\rho_x = 0.6$)	0.634	0.434
Higher persistence ($\rho_x = 0.9$)	0.671	0.373
Weaker reaction ($\delta = 0.1$)	0.640	0.427
Stronger reaction ($\delta = 1.0$)	0.664	0.394

Note: The pass-through values represent elasticities generated by the nominal shock..

Table 6. Stochastic Simulations

	Data	*Model*	
	Adv. Countries Average	Sticky Wage	Flexible Wage
Short-Run Pass-Through			
Import Price, OLS	0.67	0.68	0.68
Export Price, OLS	0.39	0.40	0.45
Import price, VAR	0.60	0.69	0.69
Export Price, VAR	0.39	0.39	0.45
Long-Run Pass-Through			
Import Price, OLS	0.86	0.79	0.81
Export price, OLS	0.50	0.26	0.41
Standard Deviations			
Exchange Rate (Δs_t)	0.0245	0.0315	0.0291
Inflation (Δp_t)	0.0087	0.0073	0.0073
Output (y_t)	0.0148	0.0427	0.0126
Import Volume (c_F)	0.0619	0.0640	0.0619
Export Volume (c_H^*)	0.0614	0.0754	0.0621
Correlation			
$\Delta s_t, \Delta tot$	-0.28	-0.84	-0.84

Table 7. Invoicing Currency Shares and the Pass-Through

	Export Price Pass-Through	Import price Pass-Through	
Constant	0.620 (0.064)*	0.438 (0.164)*	0.326 (0.129)*
Exp. curr. share in exports	-0.005 (0.001)*		
Exp. curr. share in imports		0.002 (0.002)	
US dollar share in imports			0.007 (0.003)*
No. of Obs.	17	14	16
R-squared	0.469	0.044	0.250

Standard errors are shown in brackets. * Indicates significance at the 5% level or less.

Figure 1. Regression and VAR Estimates of the Pass-Through

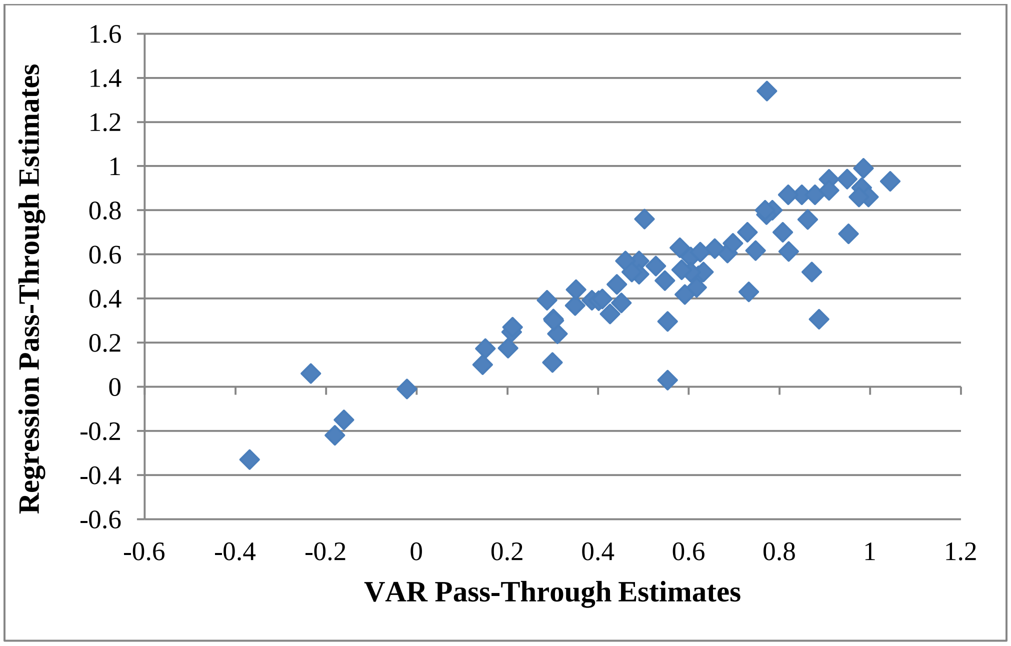
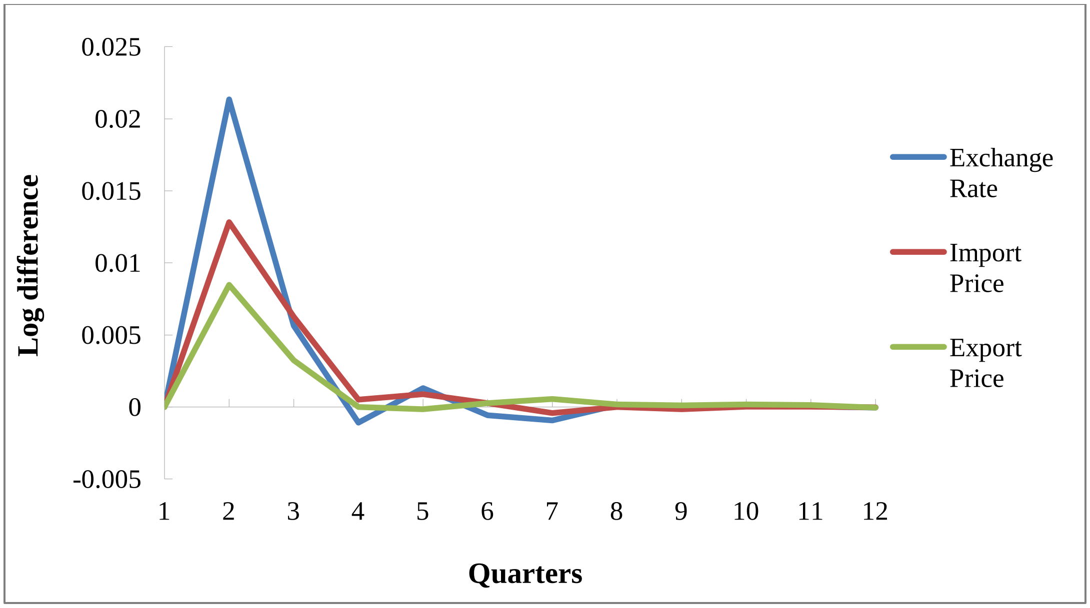


Figure 2. Impuse Response Functions for the Exchange Rate Shock , VAR, 1979-2010

(a) Advanced Countries



(b) Emerging Countries

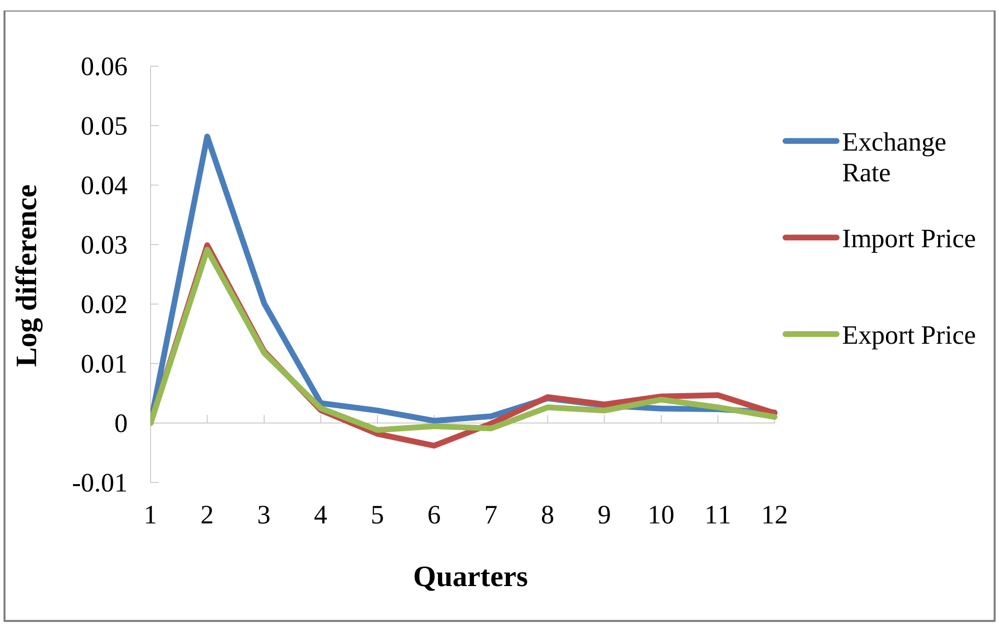
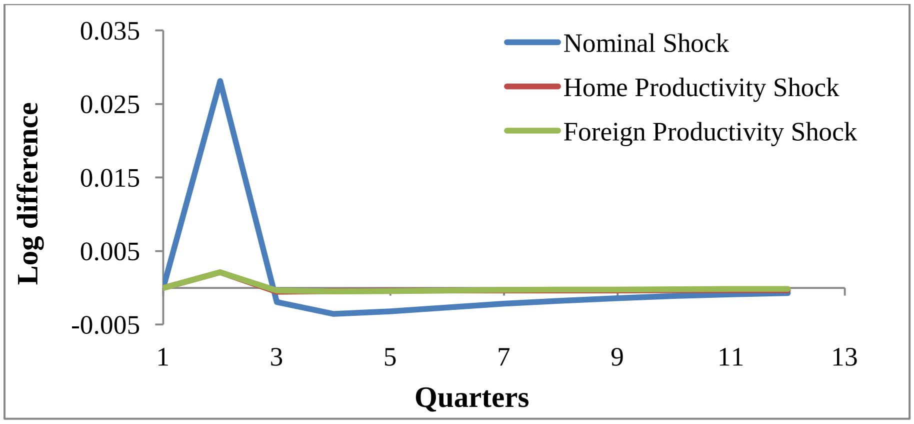
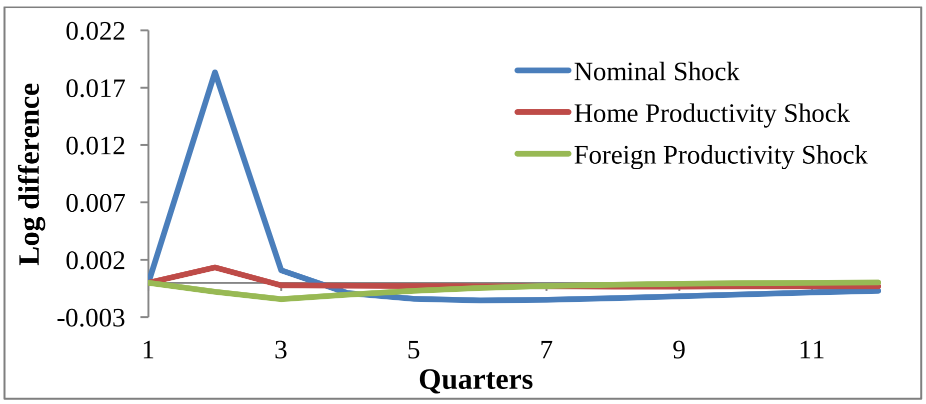


Figure 3. Model Impulse Response Functions

(a) Response of Δs_t



(b) Response of $\Delta p_{M,t}$



(c) Response of $\Delta p_{X,t}$

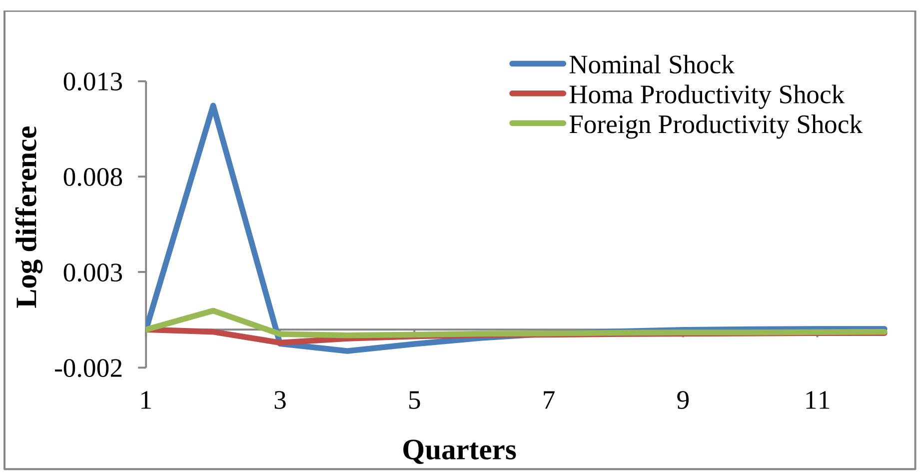
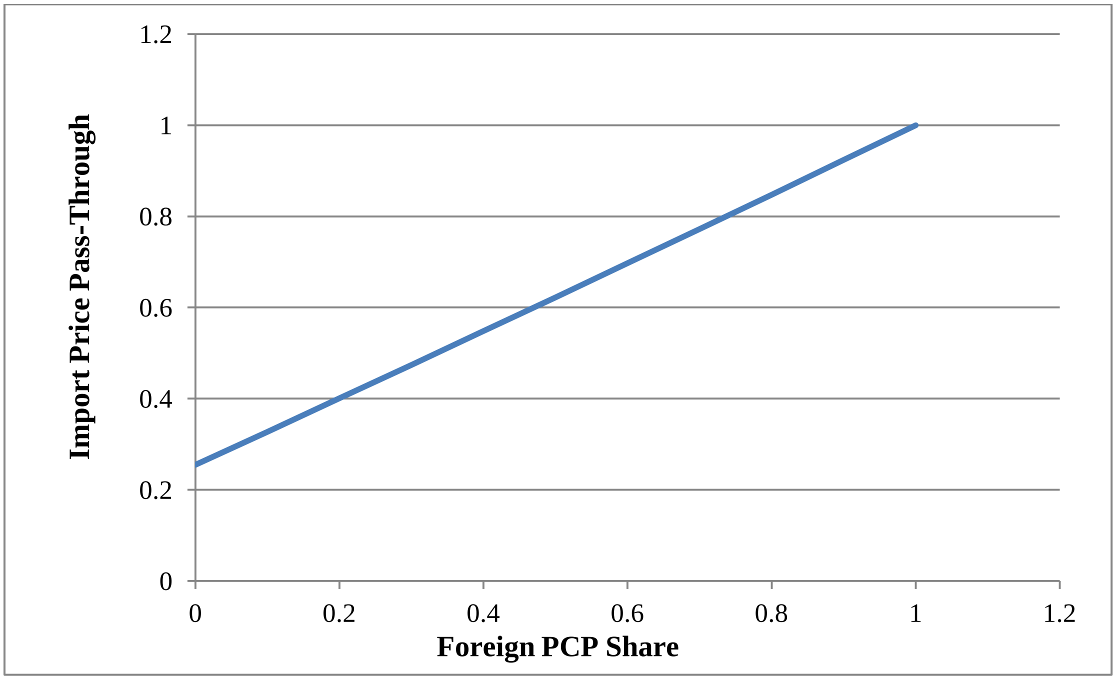
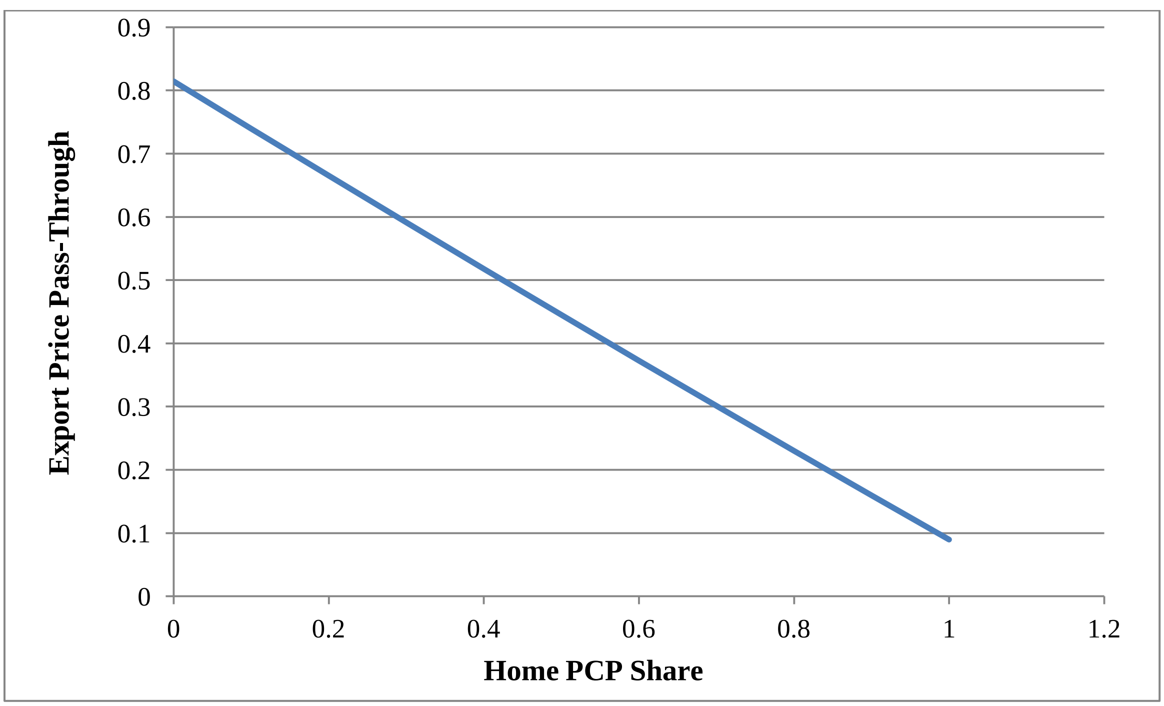


Figure 4. PCP Shares and the Pass-Through

(a) Foreign PCP Share and the Import Price Pass-Through



(b) Home PCP Share and the Export Price Pass-Through



Appendix Table 1: Short-Run Exchange Rate Pass-Through, VAR, 1985–1997

Country	Import Price Response		Export Price Response		p-value for t test of differences in trade price responses
	Estimate	Std. error	Estimate	Std. error	
Advanced economies					
United States	0.22	0.08	0.08	0.063	0.18
United Kingdom	0.41	0.08	0.29	0.086	0.29
Belgium	0.78	0.28	1.08	0.197	0.38
Denmark	0.38	0.12	0.13	0.114	0.13
France	0.05	0.13	0.07	0.114	0.92
Germany	0.40	0.11	0.16	0.029	0.04
Italy	0.52	0.12	0.25	0.072	0.05
Netherlands	0.66	0.22	0.32	0.225	0.29
Norway	0.77	0.23	-0.03	0.443	0.11
Sweden	0.49	0.08	0.43	0.073	0.56
Switzerland	0.57	0.11	0.24	0.068	0.01
Canada	0.42	0.15	0.15	0.145	0.19
Japan	1.06	0.15	0.63	0.081	0.01
Finland	0.64	0.12	0.56	0.108	0.63
Ireland	0.78	0.16	0.88	0.169	0.67
Spain	0.57	0.20	0.52	0.114	0.82
Australia	0.70	0.08	0.43	0.082	0.02
New Zealand	0.49	0.10	0.45	0.128	0.82
Average	0.55	0.036	0.37	0.037	0.00
Emerging market economies					
South Africa	0.20	(0.07)	0.38	(0.17)	0.33
Argentina	0.01	(0.24)	0.40	(0.54)	0.51
Colombia	0.30	(0.46)	0.61	(0.56)	0.67
Brazil	0.87	(0.12)	0.99	(0.12)	0.50
Mexico	0.03	(0.01)	-0.02	(0.08)	0.53
Hong Kong	0.14	(0.04)	0.02	(0.03)	0.01
Republic of Korea	0.72	(0.11)	0.37	(0.13)	0.04
Pakistan	-0.11	(0.33)	-0.01	(0.24)	0.79
Singapore	-0.12	(0.16)	-0.40	-(0.05)	0.09
Thailand	0.77	(0.14)	-0.54	(0.91)	0.16
Peru	0.83	(0.18)	0.61	(0.28)	0.51
Hungary	0.73	(0.20)	0.60	(0.16)	0.60
Poland	1.21	(3.15)	1.49	(3.07)	0.95
Turkey	1.07	(0.12)	0.97	(0.11)	0.55
Average	0.47	(0.86)	0.39	(0.89)	0.95

Trade prices come from the OECD's Monthly International Statistics database for advanced economies and the IMF's International Financial Statistics database for the emerging market economies. All other variables come from the IMF's Information Notice System database.

Appendix Table 2: Short-Run Exchange Rate Pass-Through, VAR,1998–2010

Country	Import Price Response		Export Price Response		p-value for t test of differences in trade price responses
	Estimate	Std. error	Estimate	Std. error	
Advanced economies					
United States	0.64	0.14	0.424	0.079	0.19
United Kingdom	0.39	0.10	0.468	0.115	0.60
Belgium	0.54	0.23	0.428	0.155	0.68
Denmark	0.46	0.16	0.496	0.154	0.86
France	-0.02	0.27	-0.178	0.172	0.61
Germany	0.07	0.13	0.056	0.039	0.92
Italy	0.74	0.25	0.330	0.100	0.12
Netherlands	0.17	0.49	0.591	0.381	0.50
Norway	0.55	0.09	0.300	0.392	0.53
Sweden	0.29	0.10	0.251	0.063	0.73
Switzerland	0.42	0.11	0.223	0.125	0.22
Canada	0.68	0.10	0.537	0.178	0.47
Japan	0.80	0.17	0.499	0.090	0.11
Finland	0.44	0.23	0.789	0.199	0.24
Ireland	0.55	0.11	0.756	0.184	0.34
Spain	0.82	0.30	0.783	0.222	0.93
Australia	0.63	0.10	0.871	0.189	0.25
New Zealand	0.65	0.11	0.624	0.113	0.89
Average	0.49	0.048	0.46	0.044	0.63
Emerging market economies					
South Africa	0.38	(0.08)	0.74	(0.12)	0.01
Argentina	0.95	(0.12)	0.86	(0.11)	0.58
Colombia	0.72	(0.09)	0.95	(0.16)	0.23
Brazil	0.91	(0.15)	1.13	(0.20)	0.39
Mexico	-0.17	(0.04)	-0.67	(0.14)	0.00
Jordan	1.45	(0.51)	0.69	(0.39)	0.23
Hong Kong	0.27	(0.08)	0.19	(0.07)	0.43
Republic of Korea	0.67	(0.16)	0.80	(0.14)	0.52
Pakistan	1.34	(0.31)	0.56	(0.19)	0.03
Singapore	-0.39	(0.35)	-0.46	(0.31)	0.88
Thailand	1.17	(0.18)	0.83	(0.14)	0.13
Peru	1.09	(0.18)	1.48	(0.35)	0.33
Hungary	0.75	(0.09)	0.74	(0.09)	0.92
Poland	0.60	(0.13)	0.43	(0.14)	0.36
Turkey	0.90	(0.10)	0.84	(0.09)	0.67
Chile	0.90	(0.12)	0.51	(0.15)	0.05
Average	0.72	(0.05)	0.60	(0.05)	0.09

Trade prices come from the OECD's Monthly International Statistics database for advanced economies and the IMF's International Financial Statistics database for the emerging market economies. All other variables come from the IMF's Information Notice System database.