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Abstract

In theory, nominal exchange rate movements can lead to "expenditure switching" when they generate changes in the relative prices of goods across countries. This paper explores whether the expenditure-switching role of exchange rates has changed in the current episode of significant global imbalances. We develop a multi-sector two-country model for the United States and the G6 countries, with the rest of the world captured by exogenous price and demand shocks, and estimate the model over two sub-samples, which cover the periods before and after the early 1990s. Our results indicate that both U.S. imports and exports have become much less responsive to exchange rate movements in recent years, mainly due to changes in firms' pricing behavior and the increased size of distribution margins. These findings suggest that the exchange rate would have to move by a much larger amount now than in the 1970s and 1980s to reduce the U.S. trade deficit by a given amount.

JEL classification: F3, F4
Bank classification: Exchange rates; International topics

Résumé

En théorie, les mouvements des taux de change nominaux peuvent entraîner des transferts de dépenses en provoquant des variations des prix relatifs des biens entre pays. L'auteure cherche à déterminer si, dans les faits, il en est encore ainsi compte tenu des importants déséquilibres mondiaux actuels. Pour ce faire, elle a mis au point un modèle multisectoriel comportant deux blocs économiques, les États-Unis et les autres pays du G7, et où le reste du monde est représenté au travers de chocs de prix et de demande exogènes. Elle estime son modèle sur deux périodes, l'une antérieure et l'autre postérieure au début des années 1990. D'après ses résultats, la sensibilité des importations et des exportations américaines à l'évolution des taux de change a beaucoup diminué durant la période récente, en raison surtout de modifications dans le comportement des entreprises en matière de prix et de la hausse des marges de distribution. Il semblerait donc que le taux de change doive varier bien davantage que dans les années 1970 et 1980 pour réduire le déficit commercial américain d'un montant donné.

Classification JEL : F3, F4
Classification de la Banque : Taux de change; Questions internationales

1 Introduction

Trade and financial globalization has been accompanied by large current account surpluses and deficits (Figure 1). In the past few decades the U.S. has experienced large current account deficits primarily as a result of substantial trade balance deficits (Figure 2). Numerous explanations have been put forth to account for the global imbalances, including low saving rates in the United States (Obstfeld and Rogoff, 2005); a "savings glut" in the rest of the world (Bernanke, 2005, Gruber and Kamin, 2007); U.S. fiscal deficits (Chinn, 2005, Erceg et al., 2005); *de facto* exchange rate pegs in emerging Asia (Taylor, 2006, Chinn and Wei, 2008); productivity differentials (Engel and Rogers, 2006); and the increasing role of the valuation component in net foreign asset positions (Lane, Milesi-Ferretti, 2005, Gourinchas and Rey, 2006, Devereux and Sutherland, 2009).

The rise in U.S. private sector saving and the sharp fall in investment, partly offset by a larger public sector deficit, appear to have narrowed the U.S. current account deficit from 6.6% of GDP in the fourth quarter of 2005 to 2.9% of GDP in first quarter of 2009. However, most of the reduction seems to be due to cyclical, rather than structural, factors. Moreover, recent exchange rate movements do not seem to have had a material impact on external imbalances. The risk of a hard landing for the U.S. economy, possibly originating in an unsustainable U.S. current account imbalance, was of major concern, until the current global financial crisis unfolded in an unexpected way. As it turned out, the trigger of the global financial crisis and its proximate causes were essentially financial in nature, and originated in the U.S. sub-prime markets. Nevertheless, these financial problems would not have developed to the same extent had the macroeconomic environment not been characterized by large saving-investment imbalances, low interest rates, and asset price misalignments (Obstfeld and Rogoff, 2009). One lesson learned from the crisis is that "external imbalances are often a reflection, and even a prediction, of internal imbalances. Therefore economic policies conducted in our member states, whether advanced or emerging, should not ignore external imbalances and just assume that they will sort themselves out" (Bini Smaghi, 2008). There is now a growing consensus about the importance of rebalancing global demand to achieve a more sustainable pattern of growth. Exchange rates would have to adjust to facilitate this rebalancing. But unless the shifts in trade flows are sufficiently large and sustained to make a substantial contribution to the correction of imbalances, the previous pattern of global imbalances might be restored, at least in part.

Motivated by these considerations, this paper examines the relationship between U.S. aggregate trade flows and nominal exchange rates to identify if there is a stable link between them. According to theory, a larger-than-expected trade deficit will lead to a depreciation of the domestic currency, lowering the price of domestic goods relative to foreign goods. Consequently, agents switch expenditure towards domestic-produced goods in order to re-establish a sustainable current account balance. This is called the expenditure-switching effect. The evolution of the U.S. trade balance and exchange rate in the 1980s seems to be consistent with the theory. However, the paths of U.S. current account balance and exchange rates in effective terms since the early 1990s have not been textbook examples. The above observations lead us to ask the following questions: Has the expenditure-switching role of exchange rates changed in the United States in the current episode of significant global imbalances? If so, what are the underlying reasons for the change and what are the macroeconomic implications?

In order to answer these questions, we adopt a structural general-equilibrium approach to examine the impact of exchange rate movements on U.S. trade flows. We emphasize three features of our framework. First, we develop a multi-sector sticky-price model for the United States (home) and the G6 countries (foreign), with the rest of the world (ROW) captured by exogenous price and demand shocks.[1] Recognizing that an important counterpart to the large U.S. deficits has been the surpluses recorded by emerging Asia, notably China, and oil exporters in the Middle East, we model the ROW block as partially exogenous, in that we allow it to trade with both the home and foreign country but the demand for exports and the prices of its imports are given by exogenous processes.[2] Second, our model allows for market segmentation and deviations from the law of one price via the presence of distribution services intensive in local inputs to facilitate the sale of foreign-produced imports. Due to these distribution services, large exchange-rate swings do not translate into large consumption price movements even when prices are fully flexible, as retail prices of imported goods reflect only a small proportion of movements in import prices at the border. Third, our model accounts for not only the importance of currency of pricing in determining the strength of the expenditure switching effect, but also its asymmetric pattern for the home and foreign economy. Specifically, we assume that firms exporting to the United States set their prices in the local market currency, and U.S. firms exporting abroad price their goods in producer's currency, which is consistent with empirical evidences that U.S. dollar is the dominant currency of invoice for both its exports and imports (Goldberg and Tille, 2008).

We estimate the model using a Bayesian approach over two sub-samples, which cover the period before and after the early 1990s. The break date of 1992Q1 seems to be a reasonable starting point, given the rapid expansion of financial liberalization and economic globalization in the early 1990s.[3] As structural shifts take time to build up and persist until disrupted, changing the break date, while marginally changing the values of structural parameters, is unlikely to modify the nature of our results.[4] Our estimation results suggest that both U.S. exports and imports have become much less responsive to exchange rate movements in recent years. The impacts of exchange rates on U.S. imports and exports

[1] We chose to explicitly model the U.S. and the advanced G6 countries and leave the rest of the world captured by exogenous trade shocks because of the following reasons. First, standard DSGE models are designed for a typical advanced economy. They are not able to capture the key characteristics of the more-managed developing economies and to replicate their macroeconomic dynamics. Second, modeling monetary policies in these economies is problematic given the diversity of implemented policies. Third, data limitations for developing Asia and Middle East countries prevent us from obtaining reliable structural estimates. Reliable macro data are only available starting from 2000 for China. For many other developing countries, available data are even more limited because the inflation and interest rate data prior to the mid-2000s were very volatile.

[2] The amount of home and foreign country's imports originating from the ROW are determined endogenously in the model.

[3] The boom in trade in computers and parts since the mid-1990s combined with rapid changes in computer prices have probably altered the underlying demand relationships, and also contributed to changes in the global trade pattern (Council of Economic Advisers, 2001).

[4] Even the concept of global imbalance was first greeted with skepticism before it became conventional wisdom. When at that time Federal Reserve Chairman Alan Greenspan gave a speech in 2003, the conventional view was still that the U.S. current account would most likely resolve itself in quite a benign manner. Switching to alternative break dates may drive the difference over two sub-samples to be more or less significant, but since the findings from structural estimation over a certain period of time capture activities in an "average" sense, our qualitative results are unlikely to be sensitive. In addition, splitting the sample at some point when U.S. deficit became more apparent, for example in 2002, would leave us too short a sub-sample to obtain convincing estimates.

both decline in the long run post-1992 can be explained, in part, by increasing distribution margins in both domestic and foreign markets. Additionally, foreign prices in U.S. dollars are more sticky than before, which may contribute to the smaller impacts of exchange rates on U.S. imports in the short run post-1992. Thus, a larger move in exchange rates might be required to rebalance the same amount of U.S. trade deficit now than two decades ago.

More broadly, this paper is related to the literature on the evolution of exchange rate pass-through to prices. Particularly, recent studies have debated whether exchange rate pass-through into import prices may have declined in recent years in industrialized countries. For the United States, Marazzi and Sheets (2007) estimate a significant decline in the pass-through coefficient around the year of 1997 with a reduced-form approach. However, as suggested by Bouakez and Rebei (2008), the reduced-form methodology has important drawbacks in terms of overlooking the joint determination of exchange rates and prices and treating pass-through as an unconditional phenomenon. We adopt a general equilibrium approach in this paper, but our model differs from that in Bouakez and Rebei (hereinafter, BR) in many important aspects. For example, our model is a two-and-a-half country model that allows for local currency pricing for imports to the U.S. and market segmentation via non-tradable distribution wedges. These distinctions make it possible to examine, analytically and quantitatively, the impacts of exchange rate movements on trade in the United States while accounting for the important roles of emerging Asia and oil exporters. By estimating our model, we show that these model setups are important in accounting for key features of U.S. data.[5]

The remainder of this paper is organized as follows: Section 2 presents the theoretical model. Section 3 describes the data and the methodology. The empirical results are stated in Section 4. Finally, Section 5 concludes the paper.

2 The Model

We develop a two-country model with the rest of the world captured by exogenous price and demand shocks. The rest of world block trades with both countries, which are denoted as home and foreign respectively. Each country is characterized by : (1) a continuum of infinitely lived households; (2) competitive final good producers; (3) a continuum of intermediate tradable good producers; (4) intermediate tradable good importers; (5) a continuum of non-tradable good producers; and (6) government and the monetary authority. Households provide capital and labor services to intermediate tradable good producers and non-tradable good producers. Each household acts as a price setter for a particular type of labor services. Domestic-produced intermediate goods are then combined with imports to produce final goods for consumption and investment. Non-tradable goods are used for making foreign-produced intermediate goods available to the domestic final good producers. The model structure is illustrated in Figure 3. In what follows, the model setup is described focusing on the home country, with the understanding that similar expressions also characterize the foreign country. Foreign variables

[5] Furthermore, our model allows for a stochastic technology trend, as opposed to a stationary model in BR(2008). With the presence of this stochastic trend, we are able to estimate the model with actual data without linear detrending.

are marked with an asterisk, or where necessary with an "F" subscript.

2.1 Households

Households maximize expected utility discounted at the rate of time preference. Households are indexed by i. The lifetime utility is a function of consumption and labor supply.

$$
\begin{aligned}
U_t &= E_t \Sigma_{t=0}^{\infty} \beta^t a_{\beta,t} U(C_t^i, L_t^i) \\
U &= \ln(C_t^i) - \vartheta \ln L_t^i.
\end{aligned}
$$

Utility is assumed to positively depend on the consumption of goods, and negatively depend on labor provided. $a_{\beta,t}$ represents a preference shock that follows an AR(1) stochastic process. The full consumption basket, C_t, is defined as the CES aggregate of consumption of tradable goods, $C_{T,t}$, and non-tradable goods, $C_{N,t}$, with a elasticity of substitution ς,

$$
C_t = \left[\alpha_T^{\frac{1}{\varsigma}} C_{T,t}^{1-\frac{1}{\varsigma}} + (1-\alpha_T)^{\frac{1}{\varsigma}} C_{N,t}^{1-\frac{1}{\varsigma}} \right]^{\frac{\varsigma}{\varsigma-1}}. \tag{2.1}
$$

The price index for the consumption bundle and the demand for tradable and non-tradable goods are given by

$$
\begin{aligned}
P_t &= \left[\alpha_T P_{T,t}^{1-\varsigma} + (1-\alpha_T) P_{N,t}^{1-\varsigma} \right]^{\frac{1}{1-\varsigma}} \\
C_{T,t} &= \alpha_T \left(\frac{P_{T,t}}{P_t} \right)^{-\varsigma} C_t \\
C_{N,t} &= (1-\alpha_T) \left(\frac{P_{N,t}}{P_t} \right)^{-\varsigma} C_t.
\end{aligned}
$$

Capital is assumed to be sector specific. $K_{T,t}$ denotes capital stock in the tradable sector, which is assumed to be owned by households and rented to intermediate firms at the rate $r_{T,t}$. $K_{N,t}$ denotes capital stock in the non-tradable sector, and the rental rate is $r_{N,t}$. Investment in new capital is assumed to involve quadratic adjustment costs given by

$$
\begin{aligned}
AC_{T,t} &= \frac{\chi}{2} \frac{(K_{T,t} - K_{T,t-1})^2}{K_{T,t-1}} \\
AC_{N,t} &= \frac{\chi}{2} \frac{(K_{N,t} - K_{N,t-1})^2}{K_{N,t-1}}.
\end{aligned}
$$

$K_{T,t}$ and $K_{N,t}$ evolves following the law of motion

$$K_{T,t} = (1-\delta)K_{T,t-1} + I_{T,t}$$
$$K_{N,t} = (1-\delta)K_{N,t-1} + I_{N,t}.$$

where δ represents the depreciation rate.

Households can provide labor service, $L_{N,t}$, to non-tradable good producers, and $L_{T,t}$ to intermediate tradable good producers, at the wage rate W_t. They receive dividends D_t from the firms and a lump sum transfer τ_t from the government. Households can purchase the domestic bond $B_{H,t}$ and foreign bond $B_{F,t}$. All bonds are denominated in the issuing country's currency, and there is a quadratic adjustment cost on bond holdings to ensure the stationarity in the net foreign asset position.[6] The representative household's budget constraint can then be expressed as

$$C_t + \frac{P_{T,t}I_{T,t}}{P_t} + \frac{P_{N,t}I_{N,t}}{P_t} + \frac{P_{T,t}AC_{T,t}}{P_t} + \frac{P_{N,t}AC_{N,t}}{P_t} + \frac{S_tB_{F,t}}{P_tR_t^*} + \frac{B_{H,t}}{P_tR_t} + \frac{1}{2}\mu(\frac{S_tB_{F,t}^2}{P_tY_t} - \frac{SB_F^2}{PY})$$
$$= \frac{D_t}{P_t} + \tau_t + \frac{r_{T,t}P_{T,t}K_{T,t-1}}{P_t} + \frac{r_{N,t}P_{N,t}K_{N,t-1}}{P_t} + \frac{W_tL_{T,t}}{P_t} + \frac{W_tL_{N,t}}{P_t} + \frac{S_tB_{F,t-1}}{P_{t-1}\pi_t} + \frac{B_{H,t-1}}{P_t},$$

where π_t is the gross consumption inflation rate, and S_t is the nominal exchange rate, which is defined as the price of foreign currency in terms of domestic currency. Household's utility maximization implies the following optimality conditions.

$$\frac{1}{P_tR_t} = E_t\Lambda_{t,t+1}\frac{1}{P_{t+1}} \qquad \Lambda_{t,t+1} = \frac{E_t\beta a_{\beta,t+1}C_{t+1}^{-1}}{a_{\beta,t}C_t^{-1}}$$
$$\frac{S_t}{P_tR_t^*} + \frac{\mu S_tB_{F,t}}{P_tY_t} = E_t\Lambda_{t,t+1}\frac{S_{t+1}}{P_{t+1}}$$
$$\frac{P_{T,t}}{P_t}\left[\frac{\chi(K_{T,t}-K_{T,t-1})}{K_{T,t-1}} + 1\right] = E_t\Lambda_{t,t+1}\frac{P_{T,t+1}}{P_{t+1}}\left[\frac{\chi(K_{T,t+1}^2 - K_{T,t}^2)}{2K_{T,t}^2} + 1 - \delta + r_{T,t+1}\right]$$
$$\frac{P_{N,t}}{P_t}\left[\frac{\chi(K_{N,t}-K_{N,t-1})}{K_{N,t-1}} + 1\right] = E_t\Lambda_{t,t+1}\frac{P_{N,t+1}}{P_{t+1}}\left[\frac{\chi(K_{N,t+1}^2 - K_{N,t}^2)}{2K_{N,t}^2} + 1 - \delta + r_{N,t+1}\right].$$

In the labor market, households act as price-setters and meet the demand for their particular type of labor service. Wage rates are assumed to be set in a staggered fashion, following Calvo (1983). In each period, only those households who receive random signals can optimally adjust their nominal wages. The probability that households receive such a signal in each period is $1-\psi_w$. For those households who do not receive such a signal to reoptimize, they simply index last period's wage rate by lagged inflation up to the degree of τ_w. Let ϖ_t be the new wage rate set at time t. The wage index W_t is given by

[6] In this case, the cost of increasing bond holdings by one unit is greater than one because it includes the marginal cost of adjusting the size of the portfolio. See Schmitt-Grohé and Uribe (2003) for more details.

$$W_t = \left\{ \psi_w \left[W_{t-1} \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\tau_w} \right]^{1-\gamma} + (1-\psi_w) \varpi_t^{1-\gamma} \right\}^{\frac{1}{1-\gamma}}, \tag{2.2}$$

where γ is the elasticity of substitution between various labor types.

2.2 Tradable Sector

2.2.1 Final Good Producers

Competitive final good producers combine domestically produced intermediate goods with imports to produce final goods for consumption and investment. The technology is given by a CES production function

$$Y_{T,t} = \left[\alpha_H^{\frac{1}{\sigma}} Y_{H,t}^{1-\frac{1}{\sigma}} + (1-\alpha_H)^{\frac{1}{\sigma}} Y_{IM,t}^{1-\frac{1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \tag{2.3}$$

where $Y_{H,t}$ and $Y_{IM,t}$ denote, respectively, the amount of home-produced and imported intermediate goods used in domestic final good production. The elasticity of substitution between domestic and import intermediate goods is assumed to be σ. Furthermore, the imports of intermediate goods are translated into a demand for exports from the foreign country and the rest of world via the following relationship

$$Y_{IM,t} = \left[\alpha_M^{\frac{1}{\sigma_m}} Y_{F,t}^{1-\frac{1}{\sigma_m}} + (1-\alpha_M)^{\frac{1}{\sigma_m}} Y_{ROW,t}^{1-\frac{1}{\sigma_m}} \right]^{\frac{\sigma_m}{\sigma_m-1}}, \tag{2.4}$$

with $Y_{F,t}$ representing the home country's imports from the foreign country, and $Y_{ROW,t}$ representing its imports from the rest of the world.

Profit maximization by final good producers implies

$$\begin{aligned}
Y_{H,t} &= \alpha_H \left(\frac{P_{H,t}}{P_{T,t}} \right)^{-\sigma} Y_{T,t} \\
Y_{IM,t} &= (1-\alpha_H) \left(\frac{P_{IM,t}}{P_{T,t}} \right)^{-\sigma} Y_{T,t} \\
P_{T,t} &= \left[\alpha_H P_{H,t}^{1-\sigma} + (1-\alpha_H) P_{IM,t}^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \\
Y_{F,t} &= \alpha_M \left(\frac{\tilde{P}_{F,t}}{P_{IM,t}} \right)^{-\sigma_m} Y_{IM,t} \\
Y_{ROW,t} &= (1-\alpha_M) \left(\frac{P_{ROW,t}}{P_{IM,t}} \right)^{-\sigma_m} Y_{IM,t} \\
P_{IM,t} &= \left[\alpha_M \tilde{P}_{F,t}^{1-\sigma_m} + (1-\alpha_M) P_{ROW,t}^{1-\sigma_m} \right]^{\frac{1}{1-\sigma_m}} .
\end{aligned}$$

$\tilde{P}_{F,t}$ denotes the retail price of imported intermediate goods from the foreign country. $P_{ROW,t}$ denotes the import price for goods produced in the rest of the world. $P_{ROW,t}$ is assumed to follow a first-order AR process. Let $p_{ROW,t} = \frac{P_{ROW,t}}{P_t}$, we assume $\ln p_{ROW,t} = (1-\rho_p)\ln p_{ROW} + \rho_p \ln p_{ROW,t-1} + \epsilon_{p,t}$, with the error term $\epsilon_{p,t}$ normally distributed with zero mean and variance σ_p^2. Final goods are used for consumption and investment by households and the government, as well as for paying adjustment costs associated with changing capital and bond holdings.

$$Y_{T,t} = C_{T,t} + I_{T,t} + G_{T,t} + AC_{T,t} + BAC_t. \tag{2.5}$$

2.2.2 Intermediate Good Producers

Each intermediate good producer produces its differentiated good with capital and labor according to the Cobb Douglas technology

$$Z_{T,t} = (A_t L_{T,t})^{1-\eta} K_{T,t-1}^{\eta} \tag{2.6}$$

where $Z_{T,t}$ denotes the intermediate output, $L_{T,t}$ is the aggregate labor input into the tradable good production, and A_t captures the technology shock. Let $f_t = \frac{A_t}{A_{t-1}}$, we assume that the technology growth follows a stochastic process

$$\ln f_t = (1-\rho_f)\ln f + \rho_f \ln f_{t-1} + \epsilon_{f,t},$$

where $\epsilon_{f,t}$ is normally distributed with zero mean and variance σ_f^2. Intermediate goods produced in the home country can be used domestically for the final good production, exported to the foreign country, or exported to the rest of the world. The demand for home-produced intermediate goods from the rest of the world is assumed to be exogenously given.

$$\begin{aligned} Z_{T,t} &= Y_{H,t} + Y_{H,t}^{*} + D_{ROW,t} \\ \ln d_{ROW,t} &= (1-\rho_d)\ln d_{ROW} + \rho_d \ln d_{ROW,t-1} + \epsilon_{d,t}. \end{aligned}$$

Intermediate good prices are sticky. We assume the probability that intermediate firms change prices in each period is $1-\psi_d$. Each intermediate firm acts as a monopolistic competitor in its price setting. Observed incomplete exchange rate pass-through has lead to different specifications for the currency of invoice in trade: producer currency pricing (PCP) versus local currency pricing (LCP). Empirical studies have reported that the dollar share in the invoicing of both U.S. exports and imports is over 90% (Goldberg and Tille, 2008). In light of the dominant role of U.S. dollar, there is important asymmetry between home exporters and foreign exporters in their price setting behavior. In other words, U.S. firms tend to employ PCP when setting export prices, while foreign firms use LCP for their export price setting.

Now, let us consider a domestic intermediate good producer using PCP, who is randomly selected to set new prices at time t. Let $X_{H,t}$ and $X^p_{H,t}$ denote the prices chosen by the firm in the home market and the foreign market, respectively, and ε capture the elasticity of substitution between varieties of intermediate goods produced within one country. The firm maximizes its present discounted value of profits and sets the optimal prices according to

$$
\begin{aligned}
X_{H,t} &= \frac{E_t\Sigma_{j=0}^{\infty}\psi_d^j\Gamma_{t,t+j}\varepsilon P^{\varepsilon}_{ht+j}Y_{ht+j}MC_{T,t+j}(P_{t+j-1}/P_{t-1})^{-\tau_d\varepsilon}}{E_t\Sigma_{j=0}^{\infty}\psi_d^j\Gamma_{t,t+j}(\varepsilon-1)P^{\varepsilon}_{ht+j}Y_{ht+j}(P_{t+j-1}/P_{t-1})^{-\tau_d(\varepsilon-1)}}\\
X^p_{H,t} &= \frac{E_t\Sigma_{j=0}^{\infty}\psi_d^j\Gamma_{t,t+j}\varepsilon(P^*_{ht+j}S_{t+j})^{\varepsilon}(Y^*_{ht+j}+D_{ROW,t+j})MC_{T,t+j}(P_{t+j-1}/P_{t-1})^{-\tau_d\varepsilon}}{E_t\Sigma_{j=0}^{\infty}\psi_d^j\Gamma_{t,t+j}(\varepsilon-1)(P^*_{ht+j}S_{t+j})^{\varepsilon}(Y^*_{ht+j}+D_{ROW,t+j})(P_{t+j-1}/P_{t-1})^{-\tau_d(\varepsilon-1)}}\\
MC_{T,t+j} &= \frac{(1-\eta)^{\eta-1}(r_{T,t+j}P_{T,t+j})^{\eta}}{\eta^{\eta}W^{\eta-1}_{t+j}A_{T,t+j}} \qquad \Gamma_{t,t+j} = \beta^j\frac{U_{c,t+j}/P_{t+j}}{U_{c,t}/P_t}.
\end{aligned}
$$

The domestic price index for intermediate goods, $P_{H,t}$, and the export price index, $P^*_{H,t}$, can be expressed as

$$
\begin{aligned}
P_{H,t} &= \left\{\psi_d\left[P_{H,t-1}\left(\frac{P_{t-1}}{P_{t-2}}\right)^{\tau_d}\right]^{1-\varepsilon} + (1-\psi_d)X^{1-\varepsilon}_{H,t}\right\}^{\frac{1}{1-\varepsilon}}\\
P^*_{H,t} &= \left\{\psi_d\left[P^*_{H,t-1}\left(\frac{P^*_{t-1}}{P^*_{t-2}}\right)^{\tau_d}\right]^{1-\varepsilon} + (1-\psi_d)\left(\frac{X^p_{H,t}}{S_t}\right)^{1-\varepsilon}\right\}^{\frac{1}{1-\varepsilon}}.
\end{aligned}
$$

Next, for a foreign intermediate good producer who employs LCP for its export price setting, when it is randomly selected to set new prices at time t, profit maximization suggests that the optimal prices chosen for domestic and foreign markets, $X^*_{F,t}$ and $X^l_{F,t}$, are given by

$$
\begin{aligned}
X^*_{F,t} &= \frac{E_t\Sigma_{j=0}^{\infty}(\psi_d^*)^j\Gamma^*_{t,t+j}\varepsilon(P^*_{ft+j})^{\varepsilon}Y^*_{ft+j}MC^*_{T,t+j}(P^*_{t+j-1}/P^*_{t-1})^{-\tau_d^*\varepsilon}}{E_t\Sigma_{j=0}^{\infty}(\psi_d^*)^j\Gamma^*_{t,t+j}(\varepsilon-1)(P^*_{ft+j})^{\varepsilon}Y^*_{ft+j}(P^*_{t+j-1}/P^*_{t-1})^{-\tau_d^*(\varepsilon-1)}}\\
X^l_{F,t} &= \frac{E_t\Sigma_{j=0}^{\infty}(\psi_d^*)^j\Gamma^*_{t,t+j}\varepsilon(P_{ft+j})^{\varepsilon}(Y_{ft+j}+D^*_{ROW,t+j})MC^*_{T,t+j}S_{t+j}(P_{t+j-1}/P_{t-1})^{-\tau_d\varepsilon}}{E_t\Sigma_{j=0}^{\infty}(\psi_d^*)^j\Gamma^*_{t,t+j}(\varepsilon-1)(P_{ft+j})^{\varepsilon}(Y_{ft+j}+D^*_{ROW,t+j})(P_{t+j-1}/P_{t-1})^{-\tau_d(\varepsilon-1)}}.
\end{aligned}
$$

For the foreign country, the price index for intermediate goods sold domestically, $P^*_{F,t}$, and the export price index, $P_{F,t}$, can be expressed as

$$
\begin{aligned}
P^*_{F,t} &= \left\{\psi^*_d\left[P^*_{F,t-1}\left(\frac{P^*_{t-1}}{P^*_{t-2}}\right)^{\tau^*_d}\right]^{1-\varepsilon} + (1-\psi^*_d)(X^*_{F,t})^{1-\varepsilon}\right\}^{\frac{1}{1-\varepsilon}}\\
P_{F,t} &= \left\{\psi^*_d\left[P_{F,t-1}\left(\frac{P_{t-1}}{P_{t-2}}\right)^{\tau^*_d}\right]^{1-\varepsilon} + (1-\psi^*_d)\left(X^l_{F,t}\right)^{1-\varepsilon}\right\}^{\frac{1}{1-\varepsilon}}.
\end{aligned}
$$

2.2.3 Intermediate Good Importers

Intermediate good importers bring intermediate inputs produced in the foreign country or the rest of the world to the domestic market. Similar to Burstein, Neves and Rebelo (2001) and Corsetti, Dedola and Leduc (2008), we assume that importing one unit of the intermediate good incurs distribution costs equal to λ units of a basket of the differentiated non-tradable goods,

$$\lambda = \left[\int_0^1 \lambda(n)^{1-\frac{1}{\nu}} dn \right]^{\frac{\nu}{\nu-1}},$$

where n is the index of non-tradable good varieties, and ν is the elasticity of substitution among varieties of non-tradable goods. With a competitive distribution sector, the retail price index for foreign-produced intermediate goods in the home market, $\tilde{P}_{F,t}$, is given by

$$\tilde{P}_{F,t} = P_{F,t} + \lambda P_{N,t}. \tag{2.7}$$

2.3 Non-tradable Sector

Non-tradable goods are produced using capital and labor as inputs,

$$Y_{N,t}(n) = (A_t L_{N,t}(n))^{1-\theta} K_{N,t-1}(n)^{\theta}. \tag{2.8}$$

Taking wages and capital rental rates as given, non-tradable good producers solve the profit maximization problem and set their prices. For simplicity, we assume the probability that non-tradable good producers re-optimize in each period is also $1 - \psi_d$. The first order condition implies that, if firm n is selected to reset its price at time t, the optimal price it chooses, $X_{N,t}(n)$, and the non-tradable good price index are given by

$$X_{N,t}(n) = \frac{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} \nu P_{N,t+j}^{\nu} Y_{N,t+j} MC_{N,t+j} (P_{t+j-1}/P_{t-1})^{-\tau_d \varepsilon}}{E_t \Sigma_{j=0}^{\infty} \psi_d^j \Gamma_{t,t+j} (\nu - 1) P_{N,t+j}^{\nu} Y_{N,t+j} (P_{t+j-1}/P_{t-1})^{-\tau_d(\varepsilon-1)}}$$

$$MC_{N,t+j} = \frac{(1-\theta)^{\theta-1} (r_{N,t+j} P_{N,t+j})^{\theta}}{\theta^{\theta} W_{t+j}^{\theta-1} A_{N,t+j}}$$

$$P_{N,t} = \left\{ \psi_d \left[P_{N,t-1} \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\tau_d} \right]^{1-\nu} + (1-\psi_d) X_{N,t}^{1-\nu} \right\}^{\frac{1}{1-\nu}}.$$

Finally, the market clearing condition implies that

$$Y_{N,t} = C_{N,t} + I_{N,t} + G_{N,t} + AC_{N,t} + \lambda(Y_{F,t} + Y_{ROW,t}). \tag{2.9}$$

2.4 Government and Monetary Authority

The government adjusts the lump sum transfer in each period to meet its budget constraint. Government spending, G_t, is assumed to be an exogenous process, reflecting a combination of tradable and non-tradable goods.

$$
\begin{aligned}
&P_t G_t + P_t \tau_t + B_{H,t-1} + B^*_{H,t-1} = \frac{B_{H,t}}{R_t} + \frac{B^*_{H,t}}{R_t} \\
&\ln(G_t/A_t) = (1-\rho_g)\ln(G/A) + \rho_g \ln(G_{t-1}/A_{t-1}) + \epsilon_{g,t} \\
&G_{T,t} = \alpha_T \left(\frac{P_{T,t}}{P_t}\right)^{-\varsigma} G_t \\
&G_{N,t} = (1-\alpha_T)\left(\frac{P_{N,t}}{P_t}\right)^{-\varsigma} G_t.
\end{aligned}
$$

The monetary policy authority uses interest rate as an instrument to respond to inflation and output deviations from their steady states.

$$
\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + (1-\rho_r)[\alpha_\pi \ln(\pi_t/\pi) + \alpha_y \ln(y_t/y)] + \epsilon_{r,t}.
$$

where ρ_r is a parameter that captures interest-rate smoothing, and $\epsilon_{r,t}$ is a monetary policy shock, which is assumed to be i.i.d. normal with zero mean and variance σ_r^2.

2.5 Linearized Relations

The non-stationary technology shock induces a common stochastic trend in the real variables of the model. We use the following transformations to achieve stationarity.

$$
\begin{array}{llllll}
p_{T,t} = \dfrac{P_{T,t}}{P_t} & p_{N,t} = \dfrac{P_{N,t}}{P_t} & p_{H,t} = \dfrac{P_{H,t}}{P_t} & p_{F,t} = \dfrac{P_{F,t}}{P_t} & \tilde{p}_{F,t} = \dfrac{\tilde{P}_{F,t}}{P_t} & p^*_{H,t} = \dfrac{P^*_{H,t}}{P^*_t} \\
p^*_{T,t} = \dfrac{P^*_{T,t}}{P^*_t} & p^*_{N,t} = \dfrac{P^*_{N,t}}{P^*_t} & p^*_{F,t} = \dfrac{P^*_{F,t}}{P^*_t} & \tilde{p}^*_{H,t} = \dfrac{\tilde{P}^*_{H,t}}{P^*_t} & x_{N,t} = \dfrac{X_{N,t}}{P_t} & x^*_{N,t} = \dfrac{X^*_{N,t}}{P^*_t} \\
x_{H,t} = \dfrac{X_{H,t}}{P_t} & x^p_{H,t} = \dfrac{X^p_{H,t}}{P_t} & x^*_{F,t} = \dfrac{X^*_{F,t}}{P^*_t} & x^l_{F,t} = \dfrac{X^l_{F,t}}{P_t} & \pi_t = \dfrac{P_t}{P_{t-1}} & \pi^*_t = \dfrac{P^*_t}{P^*_{t-1}} \\
w_t = \dfrac{W_t}{P_t A_t} & \omega_t = \dfrac{\varpi_t}{P_t A_t} & w^*_t = \dfrac{W^*_t}{P^*_t A_t} & \omega^*_t = \dfrac{\varpi^*_t}{P^*_t A_t} & q_t = \dfrac{S_t P^*_t}{P_t} & \\
b_{H,t} = \dfrac{B_{H,t}}{P_t A_t} & b^*_{H,t} = \dfrac{B^*_{H,t}}{P_t A_t} & b^*_{F,t} = \dfrac{B^*_{F,t}}{P^*_t A_t} & b_{F,t} = \dfrac{B_{F,t}}{P^*_t A_t} & &
\end{array}
$$

In addition, all quantity variables are transformed according to $h_t = \dfrac{H_t}{A_t}$. The model is then log-linearized around a nonstochastic steady state of the transformed variables. The log-linearization yields a system of equations that are linear in log deviations, and can be solved using standard methods. The linearized equation system is described in Appendix A.

3 Empirical Approach

3.1 Bayesian Method and Priors

The model is estimated using a Bayesian technique, similar to Smets and Wouters (2003) and Lubik and Schorfheide (2005). Bayesian inferences start from prior distributions capturing information outside of the data set used for the estimation, for example, results from past studies. The time series data is subsequently brought in to update researchers' beliefs about the parameter values and generate posterior estimates.

Generally, for prior densities, Beta distributions are chosen for parameters that are constrained in the unit interval; Gamma distributions are set for parameters defined to be non-negative; and inverse Gamma distributions are selected for standard deviations of shocks. The prior distributions are set to be the same for the two sub-samples. Specifically, the priors for Calvo adjustment parameters are set at 0.7 and 0.8 respectively for firms and households, which suggests that they re-optimize once every 3-5 quarters. The degree of partial indexation is given a prior of 0.3. Recall that we assume an asymmetry between home and foreign country in terms of the currency of invoicing. In particular, we emphasize the dominant role of the U.S. dollar in trade by assuming that both U.S. firms and foreign firms set their export prices in U.S. dollars. The prior means for the elasticity of substitution between domestic goods and imports σ and σ^* are set at 1.5, with a relatively large standard deviation of 0.15. Priors on the policy coefficients are chosen to match values generally associated with the Taylor rule. The distribution margin ϱ measures the share of distribution costs in import prices.[7] A prior mean of 0.4 is specified for both ϱ and ϱ^*, with a standard deviation of 0.1. Finally, for the parameters of the shocks, relatively loose priors are specified, since there is little guidance provided from the literature.

In addition to the parameters estimated, we choose to calibrate a number of parameters that are not of major interest to this paper in light of the computational intensity. The subjective discount factor β is given a value of 0.99, which implies an annual real interest rate of 4% in the steady state. The elasticity of substitution between tradables and non-tradables — ς and ς^*, both take a value of 0.6 based on previous estimates.[8] The quarterly capital depreciation rate is set to 0.025 for both the home and foreign country. Based on Valentinyi and Herrendorf (2008)'s average measure on the U.S. income shares of capital and labor across sectors, the share of capital in tradable good production, η, is set to 0.36; the share of capital in non-tradable good production, θ, is set to 0.32. This implies that the steady-state shares of labor income in tradable and non-tradable production are 64% and 68%, respectively. The fraction of labor effort in the tradable good sector, L_T/L, is inferred from the data on the distribution of civilian employment by economic sector for several industrialized countries.[9] In the pre-1992 sub-sample, this share is approximately 0.32 for the U.S., and 0.42 for the G6 countries; in the post-1992 period, it is 0.24 for the U.S. and 0.32 for the G6 countries. Other calibrated parameters can

[7] The distribution margins ϱ and ϱ^* are defined as in: $\hat{\hat{p}}_{F,t}$=(1-ϱ)$\hat{p}_{F,t}$+$\varrho\hat{p}_{N,t}$ and $\hat{\hat{p}}^*_{H,t}$=(1-ϱ^*)$\hat{p}^*_{H,t}$+$\varrho^*\hat{p}^*_{N,t}$.

[8] Stockman and Tesar (1995) estimate the elasticity to be 0.44 for an "average" industrialized country out of the G7 countries. Mendoza (1991) estimates it to be 0.74 for Canada.

[9] The time series data covering 1960-2008 are from the *Bureau of Labour Statistics* website.

be related to the steady state values of the observed variables in the model, and are therefore calibrated so as to match their sample means in each sub-sample. For example, the parameter $\bar{\alpha}_H$ that captures U.S. final good producers' preference for domestic intermediate inputs is smaller in the post-1992 sample than in the pre-1992 sample. This suggests that U.S. firms have shifted their preferences from domestic to imported intermediate goods in recent years.

3.2 Data

We use seasonally adjusted quarterly data over two sub-samples, 1974:3–1991:4 and 1992:1–2008:1, to match the following variables for the United States and the aggregate G6 countries: output growth, interest rates, inflation rates, exports to the rest of the world, government consumption and the terms of trade. The data are obtained from the *International Financial Statistics* Database. These variables capture both the important macro aspects of the domestic economy and its external trade, particularly the link with the rest of the world from both the home and foreign country. There are 11 observable series, corresponding to the 11 exogenous shocks in the model.

The foreign output series is constructed as a geometric weighted average of the G6 countries, with the time-varying weights based on each country's trade share. The foreign price index used to derive the foreign inflation is computed in a similar manner. Likewise, we gathered short-term interest rates, treasury bill rates, or equivalent rates for the G6 countries and averaged them using the same trade weighting scheme to compute the foreign interest rate. Since we assume that the non-stationary technology shock generates a common stochastic trend across countries, we use the log-linearized first differences of home and foreign variables as observables, except for inflation and interest rates.

4 Empirical Results

4.1 Parameter Estimates

Posterior parameter estimates are reported in Table 1 for each sub-sample. The table presents an overview of the prior distributions specified for the parameters along with the mean and the 90% confidence interval of the posterior distributions obtained by using the Monte Carlo Metropolis Hastings algorithm. It is subject to 1,000,000 draws, and the first 500,000 draws are dropped.

The estimation results suggest the following:

(i) The nominal price rigidity parameter is estimated to be 0.53 and 0.49 for the home country in the pre-1992 and post-1992 sub-sample, respectively. For the foreign country, the corresponding estimates are 0.68 and 0.85. Thus, on average, domestic firms adjust their prices once every two quarters, while foreign firms re-optimize approximately every three to six quarters. Prices are more rigid outside the United States, and became more so after 1992. This is consistent with findings from other studies. For example, Álvarez et al. (2006) review the micro evidence on price setting practices and find that prices in the euro area are changed infrequently (on average around once a year) and are more sticky than in the U.S.. The degree of price indexation is also estimated to be larger for the foreign country, suggesting that inflation would be more persistent in the G6 in both sub-samples. Since foreign firms employ local currency pricing to set prices in the U.S. market, the results imply that foreign good prices in the U.S. market have become less responsive to the exchange rate over time. Wages are generally revised at lower frequencies than prices for both countries, reflecting that wages are more sluggish than prices.[10]

(ii) The estimate of the elasticity of substitution between domestic and foreign varieties in the home market, σ, is close to 1.13 in the pre-1992 sample, and 1.23 in the post-1992 sample. The foreign counterpart σ^* is estimated to be 1.33 and 1.49. These estimation results are in the upper half of the range of macro estimates,[11] while micro studies tend to find much higher estimates in the range of 5 to 6.[12] On the reconciliation of macro and micro estimates of the trade elasticity of substitution, Ruhl (2008) relates trade liberalization with increasing extensive margin, and Drozd and Nosal (2008) attribute the short and long run discrepancy of the price elasticity of trade flows to the market share sluggishness. The size of the expenditure-switching effect depends on the elasticity of substitution between domestic and import goods, in addition to the responses of prices to exchange rate movements. Our estimates of σ and σ^* suggest that the magnitude of the expenditure switching effect in both the home and foreign market would be marginally larger in the second sub-sample, ceteris paribus, since both σ and σ^* are estimated to be larger in the post-1992 sample. However, the differences are not significant.

(iii) Estimates of the monetary policy rule coefficients lie within the range of values in previous empirical studies. Interest rates are quite persistent in both countries and coefficients on inflation are larger than one. It is interesting to note that our estimation implies that the home country (U.S.) seems to respond more aggressively to output deviation; while the foreign country (aggregate G6) tends to respond more to inflation. Comparing across two periods, both regions have responded more forcefully to inflation in the recent period.

(iv) The distribution margins ϱ and ϱ^* measure the fraction of import prices accounted for by distribution costs in the home and foreign market respectively. ϱ is estimated to be approximately 0.25 in the first period, and 0.30 in the post-1992 period; while ϱ^* is estimated to be around 0.32 in the pre-1992 sample and 0.67 in the post-1992 sample. There are only a handful of estimates of the size of the distribution wedge in the literature. Burstein, Neves, Rebelo (2003) estimate that distribution wedges for tradable consumption goods are on average around 40 percent of the retail price of these goods for the United States. Berger et al. (2009) analyze micro data between January 1994 and July 2007 and find that overall U.S. distribution wedges are about 10 to 20 percentage points higher than previously reported by Burstein, Neves, Rebelo (2003). Our estimates of ϱ and ϱ^* seem to be consistent with these studies. Rapid expansion of economic glob-

[10] Allowing for wage stickiness plays an important role in the structural estimation, as it allows the model to generate reasonable price stickiness.

[11] For example, Lubik and Schorfheide (2005) report estimates of the elasticity of substitution parameter to be 0.43 in their benchmark two-country structural model to fit data for the U.S. and Euro area.

[12] For example, Trefler and Lai (2002).

alization leads to much lower manufacturing costs; while expenditures on transportation, storage, insurance, wholesaling, and retailing are local-value-added components to the final consumption value of imports, which are less subject to the effect of globalization.[13]

We can derive the following relationship from the log-linearized equation system such that

$$\begin{aligned}
\hat{y}_{H,t} - \hat{y}_{F,t} &= \sigma(\hat{\hat{p}}_{F,t} - \hat{p}_{H,t}) \\
&= \sigma[(1-\varrho)\hat{p}_{F,t} + \varrho\hat{p}_{N,t} - \hat{p}_{H,t}] \\
\hat{y}^*_{F,t} - \hat{y}^*_{H,t} &= \sigma^*(\hat{\hat{p}}^*_{H,t} - \hat{p}^*_{F,t}) \\
&= \sigma^*[(1-\varrho^*)\hat{p}^*_{H,t} + \varrho^*\hat{p}^*_{N,t} - \hat{p}^*_{F,t}].
\end{aligned}$$

The effect of the exchange rate on the relative demands for home- to foreign-produced goods is determined by the magnitude of its impact on relative prices, and by the degree of substitutability between domestic and foreign goods. The effect of the exchange rate on the relative prices further depends, among other things, on the currency of invoice for trade, price stickiness, and size of the distribution margin. The larger the distribution margin, the smaller the effect of exchange rate movements on the relative quantities. The estimates of ϱ and ϱ^* suggest that in the post-1992 period, the distribution margin is about 20% larger in the U.S. market and more than double in the foreign market than in the previous period. This finding would explain, in part, the decline over time in the pass-through of exchange rate changes to retail prices, since an increasing share of non-tradable content has insulated the prices from exchange rate fluctuations.

(v) The posterior mode of the persistence parameter in the unit-root technology process is estimated to be 0.37 in the first period, and 0.33 in the second sub-sample. The other stationary shocks are all estimated to be quite persistent. The standard deviations of innovations to exogenous processes vary widely in magnitude, despite being given the same prior distributions. The volatility of import price and export demand shocks from the rest of the world is generally large in both periods, suggesting the importance of the rest of world shocks in explaining business cycle fluctuations. The standard deviations of almost all the shocks are estimated to be smaller in the second sub-sample.[14] This result is most likely driven by the substantial decline in macroeconomic volatilities since the late-1980s (Blanchard and Simon, 2001, Kim and Nelson, 1999, McConnell and Perez-Quiros, 2000).

Finally, it is worth noting that, at an aggregate level, abstracting from various import and export categories, changes in the degree of pass-through or expenditure switching can be attributed to factors like aggregate price stickiness and aggregate distribution margin etc. Changes in these aggregate factors may reflect either corresponding shifts at the level of disaggregated products, or changes in the

[13] Additionally, the U.S. distribution sector seems to be more efficient than the foreign, which is consistent with the Wal-mart effect. Wal-Mart's higher levels of capital investment in distribution innovations and greater efficiency in its whole supply chain has contributed to smaller distribution wedges not only for themselves, but also for other retailers through competition effects.

[14] The only exception is the ROW export demand shock for home-produced goods, in which case it is estimated to be slightly larger in the post-1992 sample.

underlying composition of products in a country's import or export bundle.[15]

4.2 Model Assessment

Next, to assess the conformity of the model to the data, unconditional second moments are computed and reported in Table 2-3. The first two columns in Table 2 report the standard errors and first order autocorrelations of the data, and the next two columns present the means along with the 90% confidence intervals derived from simulations of the model out of 1000 random draws from the posterior distributions. Generally, in both sub-samples, the volatility of all variables are reasonably matched by the estimated model. In most cases, the data values lie in the confidence bands suggested by the model simulations. In particular, the high volatilities of exports to the rest of the world are well captured by the model, though at the cost of generating somewhat excessive volatilities for the terms of trade relative to the data. As for persistence, since most variables are in first differences, the first order autocorrelations are in general small and insignificant. The exceptions are interest rates, which are quite persistent in the data and well matched by the model.

Turning to the cross correlations between variables, Table 3 displays the values from the data as well as the model simulations for the pre-1992 sample in the left panel and the post-1992 sample in the right panel. In some cases, the estimated model fits the data in the first sub-sample better than in the second sub-sample, while in other cases, it is the other way around. The model is able to match the strong positive correlation between inflation and interest rate, and negative correlation between inflation and output growth in both countries. The model is also able to generate the same magnitude of observed correlations between the terms of trade and output, though the estimated model does a better job matching moments for the home than foreign country. Similarly, for the correlations of exports to the rest of world with other variables, the model simulation confidence bands contain the corresponding data values in most cases. The model can generate a positive cross-country correlation of output growth in the pre-1992 period as observed in the data. In the post-1992 period, however, this correlation is negative, though very small.[16]

There are several important issues to keep in mind when assessing the model's goodness of fit to the data. First, we assume the fundamental structure of our economies haven't changed across samples, and only the size of the structural parameters may have shifted. Second, we estimate the structural model with the actual data without detrending. Thus, we are matching the actual levels or differences of data series without any filtering. Third, we do not explicitly model commodity exports. The presence of global oil price shocks may bring more trade dynamics particularly in the second sub-sample, and represent another possible channel for common shocks across countries. However, due to data limitations,[17] we leave it to the ROW block to capture this channel as terms of trade shocks. In

[15] Specifically, Campa and Goldberg (2005) find that the pass-through to disaggregated import prices is highly stable over time and shifts in the composition of country import bundles are far more important in explaining changes in the overall pass-through rates.

[16] As we have always assumed in the estimation that all shocks are orthogonal, allowing for a correlation structure in the innovations may help to improve the fit of the estimated model.

[17] We only have access to a breakdown of trade in petroleum and non-petroleum goods for the United States, but not

summary, adding more features to the model or complicating the shock specifications could improve its performance in terms of reproducing the features of the data. Nevertheless, the current model does a reasonably good job in terms of both capturing important properties of the data and providing a simple framework for intuitive economic interpretation of the results.

4.3 Role of Expenditure-Switching

In this section, we investigate whether the responsiveness of trade to exchange rate fluctuations has changed over time by plotting the unconditional effects of exchange rates on U.S. imports and exports. Because these effects are conditional on the horizon, our model can be used to study expenditure switching both in the short and long run.

We examine the aggregate impacts of exchange rates on imports and exports in the general equilibrium context of our model.[18] We generate impulse responses showing percentage changes of nominal exchange rates, U.S. imports and exports to a one-unit increase in the exogenous shock. Then, similar to BR (2008), conditional impact is computed as the ratio of the impulse responses of the variable of interest (imports or exports) and nominal exchange rates to a given shock. Unconditional impact, or aggregate impact, is expressed as a weighted sum of conditional impacts, where the weights reflect the contribution of various shocks in accounting for exchange rate variation.[19] Specifically, we define the aggregate impact of exchange rates on home imports as the following:

$$PT_{t+j} = \frac{cov_{t-1}(\hat{y}_{F,t}, \hat{s}_t)}{Var_{t-1}(\hat{s}_t)}$$

Let $\varphi_{\tau,i}/\kappa_{\tau,i}$ represent the ratio of the impulse response function of $\hat{y}_{F,t}$ to that of $\hat{s}_t$ at horizon τ following shock i, the aggregate impact of exchange rates on imports is then given by:

$$PT_{t+j} = \sum_i \sum_{\tau=0}^{j} \frac{\varphi_{\tau,i}}{\kappa_{\tau,i}} \frac{\kappa_{\tau,i}^2 \sigma_i^2}{\sum_i \sum_{\tau=0}^{j} \kappa_{\tau,i}^2 \sigma_i^2}$$

for the G6 countries.

[18]Many studies have examined exchange rate pass-through to import and consumption prices. Traditionally, exchange rate pass-through is defined as the percentage change in local currency import prices resulting from a one percent change in the exchange rate. A typical pass-through regression estimates how import prices respond to exchange rate fluctuations (e.g. Campa and Goldberg, 2005). But since exchange rate changes also have feedback effects on domestic prices through marginal cost adjustment, some pass-though studies estimate an equation in which the relative price is a function of the exchange rate, cost and other factors (e.g. Corsetti, Dedola and Leduc, 2008). In this case, costs, and thus errors in cost measurements, will influence the ratio only when there is a difference in the demand elasticity in the two markets (for an extended survey of the theory of exchange rate pass-through, see Goldberg and Knetter, 1997). While these studies are useful for policy analysis, they are subject to criticism due to their partial-equilibrium reduced-form approach. As suggested by BR (2008), these studies overlook the joint determination of exchange rates and prices. More importantly, they ignore that the degree of pass-through may differ depending on what type of shocks are impinging on the economy.

[19]For a more detailed explanation of the relationship between the aggregate and conditional measures of impacts in a general equilibrium context, see BR (2008).

Thus, a change in aggregate impact can either result from changes in the degree of conditional impact or differences in the relative importance of shocks in accounting for nominal exchange rate movements.

Figure 4 presents the unconditional impacts of exchange rates on U.S. imports and exports. At the aggregate level, exchange rates' impact on U.S. exports is much lower by about 18% in the medium to long run in the post-1992 period, while there is only a minor change in the unconditional impact on $\hat{y}^*_{H,t}$ in the short run. The unconditional impact of nominal exchange rates on U.S. imports, $\hat{y}_{F,t}$, is much smaller in general than the impact on U.S. exports. This is in line with results from previous empirical studies. For example, Chinn (2002) finds that there is a statistically significant relationship between total U.S. exports, U.S. income and the real exchange rate; while for total U.S. imports, there appears to be little evidence of such a link. Similarly, Bahmani-Oskooee and Ardalani (2006) analyze disaggregated trade data and find that a real depreciation of the U.S. dollar stimulates the exports of many U.S. industries, while it has no significant impact on most importing industries.

In the pre-1992 sample, the impact of nominal exchange rates on U.S. imports is always negative, such that a U.S. dollar depreciation leads to a decline in its imports. In the post-1992 sample, the U.S. imports sensitivity to exchange rate movements decreases to almost zero after 20 quarters, and turns positive at longer horizons. One possible interpretation is that the income effect dominates the intra-temporal substitution effect at longer horizons. The income effect of currency depreciation from rising exports may drive the demand for imports to increase. In other words, the impact of a depreciation on imports can be determined either by intra-temporal elasticity considerations, or by inter-temporal, "consumption smoothing" considerations. In a sticky price world, where U.S. firms set export prices in their own currency while foreign firms price to the U.S. market in U.S. dollars, the inter-temporal consumptions smoothing motive can dominate at longer horizons.

Smaller effects of exchange rates on imports in the short run post-1992 can be explained, in part, by stickier foreign prices. The impacts on U.S. imports and exports decline in the long run post-1992 because distribution margins are higher than in the previous period. Additionally, the generally lower volatility of shocks in the post-1992 episode may also partially account for the smaller impacts of exchange rates on trade, as the volatility of output and inflation decreased substantially while the volatility of the exchange rate did not.

4.4 Counterfactual Analysis

To identify the factors that contribute to the muted responsiveness of U.S. imports and exports to exchange rate movements in the second sub-sample and their relative importance, we carry out some counterfactual experiments. In particular, we examine the role of five factors: price adjustment sluggishness, distribution margin, monetary policy, and the variance and persistence of structural shocks. In each counterfactual experiment, we vary one factor while keeping the other factors constant. We then compare aggregate impacts of exchange rates on U.S. imports and exports computed from the counterfactual simulations with those from the benchmark case.

Figure 5 displays results of exchange rates' impacts on U.S. exports from counterfactual analysis. The first three graphs show how the impact of exchange rates on exports changes with structural shifts (price adjustment, distribution margin and monetary policy), followed by two graphs presenting the effect from changes to shocks (variance and persistence). All three structural factors contribute to explaining the decline of U.S. exports' responsiveness to exchange rate movements. As stated before, the distribution margin in the foreign market increased in the post-1992 period, which translates into a lower degree of aggregate impact on U.S. exports. Reduced volatility of shocks in the post-1992 sample also drives a smaller response of U.S. exports to exchange rate shifts, although its contribution is almost negligible. On the contrary, changes in the persistence of shocks lead to increases in the impacts of exchange rate on $\hat{y}^*_{H,t}$.

The counterfactual experiment results of exchange rates' impacts on U.S. imports are illustrated in Figure 6. Here, changes in price adjustment, distribution margin, and variance and persistence of shocks are all responsible for the observed drop in the aggregate impact. However, the analysis seems to preclude monetary policy change as a potential explanation, as it leads to slightly increased impact on imports in the long run. Overall, changes in shock volatilities and structural shifts in price adjustment mainly account for the decline in the impact of exchange rates on U.S. imports, while changes in distribution margins and persistence of shocks play less important roles.

5 Conclusion

We adopt a structural general-equilibrium approach to study whether the expenditure-switching role of exchange rates has changed in the G7 countries in the current episode of significant global imbalances. Our approach consists in developing a multi-sector two-country model for the United States and the G6 countries with the rest of the world captured by exogenous price and demand shocks, and estimating the model over two sub-samples, which covers the periods before and after the early 1990s. We find that both U.S. imports and exports have become much less responsive to exchange rate movements, mainly due to changes in firms' pricing behavior and larger distribution margins. In the post-1992 period, U.S. exports' responsiveness to exchange rate movements is 18% less than in the earlier period; and U.S. imports' responsiveness to exchange rate movements is nearly zero in the long run post-1992. This suggests that closing the same amount of U.S. trade deficit would require a larger movement in exchange rates now than in the 1970s and 1980s.

Obstfeld and Rogoff (2007) show that adjustments to large current account shifts depend mainly on the flexibility and global integration of goods and factor markets and that for the U.S. current account deficit to shrink from 5 percent of GDP to zero, it may require a 20% depreciation of the U.S. dollar or even larger (40%) if the adjustment takes place quickly so that exchange rate pass-through to prices is incomplete. Our structural estimation results suggest that, taking into consideration of current data and possible shifts in elasticities, U.S. current account adjustment would entail an even larger potential decline in the dollar than they estimated, given that the responsiveness of both exports and imports to exchange rate movements has declined in recent years.

A The Linearized Equation System

A.1 Prices and Wages

$$0 = \bar{\alpha}_T \hat{p}_{T,t} + (1-\bar{\alpha}_T)\hat{p}_{N,t} \qquad 0 = \bar{\alpha}^*_T \hat{p}^*_{T,t} + (1-\bar{\alpha}^*_T)\hat{p}^*_{N,t}$$
$$\hat{p}_{T,t} = \bar{\alpha}_H \hat{p}_{H,t} + (1-\bar{\alpha}_H)\hat{p}_{IM,t} \qquad \hat{p}^*_{T,t} = \bar{\alpha}^*_H \hat{p}^*_{F,t} + (1-\bar{\alpha}^*_H)\hat{p}^*_{IM,t}$$
$$\hat{p}_{IM,t} = \bar{\alpha}_M \hat{\tilde{p}}_{F,t} + (1-\bar{\alpha}_M)\hat{p}_{ROW,t} \qquad \hat{p}^*_{IM,t} = \bar{\alpha}^*_M \hat{\tilde{p}}^*_{H,t} + (1-\bar{\alpha}^*_M)\hat{p}^*_{ROW,t}$$

$$\hat{x}_{H,t} = \psi_d \beta E_t \hat{x}_{H,t+1} + \psi_d \beta \hat{\pi}_{t+1} - \psi_d \beta \tau_d \hat{\pi}_t + (1-\psi_d\beta)[(1-\eta)\hat{w}_t + \eta \hat{r}_{T,t}]$$
$$\hat{x}^p_{H,t} = \hat{x}_{H,t}$$
$$\hat{x}^*_{F,t} = \psi^*_d \beta E_t \hat{x}^*_{F,t+1} + \psi^*_d \beta \hat{\pi}^*_{t+1} - \psi^*_d \beta \tau^*_d \hat{\pi}^*_t + (1-\psi^*_d\beta)[(1-\eta^*)\hat{w}^*_t + \eta^* \hat{r}^*_{T,t}]$$
$$\hat{x}^l_{F,t} = \psi^*_d \beta E_t \hat{x}^{*l}_{F,t+1} + \psi^*_d \beta \hat{\pi}_{t+1} - \psi^*_d \beta \tau^*_d \hat{\pi}_t + (1-\psi^*_d\beta)[(1-\eta^*)\hat{w}^*_t + \hat{q}_t + \eta^* \hat{r}^*_{T,t}]$$
$$\hat{x}_{N,t} = \psi_d \beta E_t \hat{x}_{N,t+1} + \psi_d \beta \hat{\pi}_{t+1} - \psi_d \beta \tau_d \hat{\pi}_t + (1-\psi_d\beta)[(1-\theta)\hat{w}_t + \theta \hat{r}_{N,t}]$$
$$\hat{x}^*_{N,t} = \psi^*_d \beta E_t \hat{x}^*_{N,t+1} + \psi^*_d \beta \hat{\pi}^*_{t+1} - \psi^*_d \beta \tau^*_d \hat{\pi}^*_t + (1-\psi^*_d\beta)[(1-\theta^*)\hat{w}^*_t + \theta^* \hat{r}^*_{N,t}]$$
$$\hat{p}_{H,t} = \psi_d \hat{p}_{H,t-1} - \psi_d \hat{\pi}_t + \psi_d \tau_d \hat{\pi}_{t-1} + (1-\psi_d)\hat{x}_{H,t}$$
$$\hat{p}^*_{F,t} = \psi^*_d \hat{p}^*_{F,t-1} - \psi^*_d \hat{\pi}^*_t + \psi^*_d \tau^*_d \hat{\pi}^*_{t-1} + (1-\psi^*_d)\hat{x}^*_{F,t}$$
$$\hat{p}_{N,t} = \psi_d \hat{p}_{N,t-1} - \psi_d \hat{\pi}_t + \psi_d \tau_d \hat{\pi}_{t-1} + (1-\psi_d)\hat{x}_{N,t}$$
$$\hat{p}^*_{N,t} = \psi^*_d \hat{p}^*_{N,t-1} - \psi^*_d \hat{\pi}^*_t + \psi^*_d \tau^*_d \hat{\pi}^*_{t-1} + (1-\psi^*_d)\hat{x}^*_{N,t}$$
$$\hat{p}_{F,t} = \psi^*_d \hat{p}_{F,t-1} - \psi^*_d \hat{\pi}_t + \psi^*_d \tau^*_d \hat{\pi}_{t-1} + (1-\psi^*_d)\hat{x}^l_{F,t}$$
$$\hat{p}^*_{H,t} = \psi_d \hat{p}^*_{H,t-1} - \psi_d \hat{\pi}^*_t + \psi_d \tau_d \hat{\pi}^*_{t-1} + (1-\psi_d)(\hat{x}^p_{H,t} - \hat{q}_t)$$
$$\hat{\tilde{p}}_{F,t} = \frac{P_F}{\tilde{P}_F}\hat{p}_{F,t} + \frac{\lambda P_N}{\tilde{P}_F}\hat{p}_{N,t} \qquad \hat{\tilde{p}}^*_{H,t} = \frac{P^*_H}{\tilde{P}^*_H}\hat{p}^*_{H,t} + \frac{\lambda^* P^*_N}{\tilde{P}^*_H}\hat{p}^*_{N,t}$$

$$\hat{\omega}_t = \psi_w \beta E_t \hat{\omega}_{t+1} + \psi_w \beta \hat{\pi}_{t+1} + \psi_w \beta \hat{f}_{t+1} - \psi_w \beta \tau_w \hat{\pi}_t + \frac{1-\psi_w\beta}{\gamma-1}(\gamma \hat{w}_t + \hat{l}_t - \hat{c}_t)$$
$$\hat{\omega}^*_t = \psi^*_w \beta E_t \hat{\omega}^*_{t+1} + \psi^*_w \beta \hat{\pi}^*_{t+1} + \psi^*_w \beta \hat{f}_{t+1} - \psi^*_w \beta \tau^*_w \hat{\pi}^*_t + \frac{1-\psi^*_w\beta}{\gamma^*-1}(\gamma^* \hat{w}^*_t + \hat{l}^*_t - \hat{c}^*_t)$$
$$\hat{w}_t = \psi_w \hat{w}_{t-1} - \psi_w \hat{\pi}_t + \psi_w \tau_w \hat{\pi}_{t-1} + (1-\psi_w)\hat{\omega}_t - \psi_w \hat{f}_t$$
$$\hat{w}^*_t = \psi^*_w \hat{w}^*_{t-1} - \psi^*_w \hat{\pi}^*_t + \psi^*_w \tau^*_w \hat{\pi}^*_{t-1} + (1-\psi^*_w)\hat{\omega}^*_t - \psi_w \hat{f}_t$$

A.2 Output, Capital and Employment

Output

$$\hat{y}_{H,t} = \hat{y}_{T,t} - \sigma(\hat{p}_{H,t} - \hat{p}_{T,t}) \qquad \hat{y}_{IM,t} = \hat{y}_{T,t} - \sigma(\hat{p}_{IM,t} - \hat{p}_{T,t})$$
$$\hat{y}_{F,t} = \hat{y}_{IM,t} - \sigma_m(\hat{\tilde{p}}_{F,t} - \hat{p}_{IM,t}) \qquad \hat{y}_{ROW,t} = \hat{y}_{IM,t} - \sigma_m(\hat{p}_{ROW,t} - \hat{p}_{IM,t})$$

$$\hat{y}^*_{F,t} = \hat{y}^*_{T,t} - \sigma^*(\hat{p}^*_{F,t} - \hat{p}^*_{T,t}) \qquad \hat{y}^*_{IM,t} = \hat{y}^*_{T,t} - \sigma^*(\hat{p}^*_{IM,t} - \hat{p}^*_{T,t})$$
$$\hat{y}^*_{H,t} = \hat{y}^*_{IM,t} - \sigma^*_m(\hat{\tilde{p}}^*_{H,t} - \hat{p}^*_{IM,t}) \qquad \hat{y}^*_{ROW,t} = \hat{y}^*_{IM,t} - \sigma^*_m(\hat{p}^*_{ROW,t} - \hat{p}^*_{IM,t})$$

$$
\begin{aligned}
\hat{z}_t &= \frac{Y_H}{Z}\hat{y}_{H,t} + \frac{Y_H^*}{Z}\hat{y}_{H,t}^* + \frac{D_{ROW}}{Z}\hat{d}_{ROW,t} \\
\hat{z}_t^* &= \frac{Y_F^*}{Z^*}\hat{y}_{F,t}^* + \frac{Y_F}{Z^*}\hat{y}_{F,t} + \frac{D_{ROW}^*}{Z^*}\hat{d}_{ROW,t}^* \\
\hat{y}_t &= \frac{P_T Y_T}{PY}(\hat{p}_{T,t} + \hat{y}_{T,t}) + \frac{P_N Y_N}{PY}(\hat{p}_{N,t} + \hat{y}_{N,t}) \\
\hat{y}_t^* &= \frac{P_T^* Y_T^*}{P^* Y^*}(\hat{p}_{T,t}^* + \hat{y}_{T,t}^*) + \frac{P_N^* Y_N^*}{P^* Y^*}(\hat{p}_{N,t}^* + \hat{y}_{N,t}^*) \\
\hat{y}_{T,t} &= \frac{C_T}{Y_T}\hat{c}_{T,t} + \frac{G_T}{Y_T}\hat{g}_{T,t} + \frac{I_T}{Y_T}\hat{i}_{T,t} \\
\hat{y}_{N,t} &= \frac{C_N}{Y_N}\hat{c}_{N,t} + \frac{G_N}{Y_N}\hat{g}_{N,t} + \frac{I_N}{Y_N}\hat{i}_{N,t} + \frac{\lambda Y_F}{Y_N}\hat{y}_{F,t} + \frac{\lambda Y_{ROW}}{Y_N}\hat{y}_{ROW,t} \\
\hat{y}_{T,t}^* &= \frac{C_T^*}{Y_T^*}\hat{c}_{T,t}^* + \frac{G_T^*}{Y_T^*}\hat{g}_{T,t}^* + \frac{I_T^*}{Y_T^*}\hat{i}_{T,t}^* \\
\hat{y}_{N,t}^* &= \frac{C_N^*}{Y_N^*}\hat{c}_{N,t}^* + \frac{G_N^*}{Y_N^*}\hat{g}_{N,t}^* + \frac{I_N^*}{Y_N^*}\hat{i}_{N,t}^* + \frac{\lambda^* Y_H^*}{Y_N^*}\hat{y}_{H,t}^* + \frac{\lambda^* Y_{ROW}^*}{Y_N^*}\hat{y}_{ROW,t}^*
\end{aligned}
$$

Capital and labor

$$
\begin{aligned}
\hat{k}_{T,t-1} &= \hat{z}_t - (1-\eta)\hat{r}_{T,t} + (1-\eta)\hat{w}_t - (1-\eta)\hat{p}_{T,t} \\
\hat{k}_{N,t-1} &= \hat{y}_{N,t} - (1-\theta)\hat{r}_{N,t} + (1-\theta)\hat{w}_t - (1-\theta)\hat{p}_{N,t} \\
\hat{k}_{T,t-1}^* &= \hat{z}_t^* - (1-\eta^*)\hat{r}_{T,t}^* + (1-\eta^*)\hat{w}_t^* - (1-\eta^*)\hat{p}_{T,t}^* \\
\hat{k}_{N,t-1}^* &= \hat{y}_{N,t}^* - (1-\theta^*)\hat{r}_{N,t}^* + (1-\theta^*)\hat{w}_t^* - (1-\theta^*)\hat{p}_{N,t}^*
\end{aligned}
$$

$$
\begin{aligned}
&\hat{c}_t - \hat{c}_{t+1} + \hat{a}_{\beta,t+1} - \hat{a}_{\beta,t} + \hat{\pi}_{T,t+1} - \hat{\pi}_{t+1} - \hat{f}_{t+1} \\
&= \chi(\hat{k}_{T,t} - \hat{k}_{T,t-1} + \hat{f}_{t+1}) - \beta\chi E_t(\hat{k}_{T,t+1} - \hat{k}_{T,t} + \hat{f}_{t+2}) - \beta r_T \hat{r}_{T,t+1} \\
&\hat{c}_t - \hat{c}_{t+1} + \hat{a}_{\beta,t+1} - \hat{a}_{\beta,t} + \hat{\pi}_{N,t+1} - \hat{\pi}_{t+1} - \hat{f}_{t+1} \\
&= \chi(\hat{k}_{N,t} - \hat{k}_{N,t-1} + \hat{f}_{t+1}) - \beta\chi E_t(\hat{k}_{N,t+1} - \hat{k}_{N,t} + \hat{f}_{t+2}) - \beta r_N \hat{r}_{N,t+1} \\
&\hat{c}_t^* - \hat{c}_{t+1}^* + \hat{a}_{\beta,t+1}^* - \hat{a}_{\beta,t}^* + \hat{\pi}_{T,t+1}^* - \hat{\pi}_{t+1}^* - \hat{f}_{t+1} \\
&= \chi^*(\hat{k}_{T,t}^* - \hat{k}_{T,t-1}^* + \hat{f}_{t+1}) - \beta\chi^* E_t(\hat{k}_{T,t+1}^* - \hat{k}_{T,t}^* + \hat{f}_{t+2}) - \beta r_T^* \hat{r}_{T,t+1}^* \\
&\hat{c}_t^* - \hat{c}_{t+1}^* + \hat{a}_{\beta,t+1}^* - \hat{a}_{\beta,t}^* + \hat{\pi}_{N,t+1}^* - \hat{\pi}_{t+1}^* - \hat{f}_{t+1} \\
&= \chi^*(\hat{k}_{N,t}^* - \hat{k}_{N,t-1}^* + \hat{f}_{t+1}) - \beta\chi^* E_t(\hat{k}_{N,t+1}^* - \hat{k}_{N,t}^* + \hat{f}_{t+2}) - \beta r_N^* \hat{r}_{N,t+1}^*
\end{aligned}
$$

$$
\begin{aligned}
\hat{k}_{T,t} &= (1-\delta)\hat{k}_{T,t-1} + \delta\hat{i}_{T,t} - (1-\delta)\hat{f}_{t+1} \quad \hat{k}_{N,t} = (1-\delta)\hat{k}_{N,t-1} + \delta\hat{i}_{N,t} - (1-\delta)\hat{f}_{t+1} \\
\hat{k}_{T,t}^* &= (1-\delta)\hat{k}_{T,t-1}^* + \delta\hat{i}_{T,t}^* - (1-\delta)\hat{f}_{t+1} \quad \hat{k}_{N,t}^* = (1-\delta)\hat{k}_{N,t-1}^* + \delta\hat{i}_{N,t}^* - (1-\delta)\hat{f}_{t+1}
\end{aligned}
$$

$$
\hat{l}_t = \frac{L_T}{L}\hat{l}_{T,t} + \frac{L_N}{L}\hat{l}_{N,t} \quad \hat{l}_t^* = \frac{L_T^*}{L^*}\hat{l}_{T,t}^* + \frac{L_N^*}{L^*}\hat{l}_{N,t}^*
$$

$$
\begin{aligned}
\hat{l}_{T,t} &= \hat{z}_t + \eta\hat{r}_{T,t} - \eta\hat{w}_t + \eta\hat{p}_{T,t} \qquad \hat{l}_{N,t} = \hat{y}_{N,t} + \theta\hat{r}_{N,t} - \theta\hat{w}_t + \theta\hat{p}_{N,t} \\
\hat{l}_{T,t}^* &= \hat{z}_t^* + \eta\hat{r}_{T,t}^* - \eta^*\hat{w}_t^* + \eta^*\hat{p}_{T,t}^* \quad \hat{l}_{N,t}^* = \hat{y}_{N,t}^* + \theta^*\hat{r}_{N,t}^* - \theta^*\hat{w}_t^* + \theta^*\hat{p}_{N,t}^*
\end{aligned}
$$

Consumption and bond

$$\hat{\pi}_{t+1} - \hat{r}_t = \hat{c}_t - \hat{c}_{t+1} - \hat{f}_{t+1} + \hat{a}_{\beta,t+1} - \hat{a}_{\beta,t}$$
$$\hat{\pi}^*_{t+1} - \hat{r}^*_t = \hat{c}^*_t - \hat{c}^*_{t+1} - \hat{f}_{t+1} + \hat{a}^*_{\beta,t+1} - \hat{a}^*_{\beta,t}$$

$$\hat{q}_{t+1} - \hat{c}_{t+1} + \hat{a}_{\beta,t+1} - \hat{f}_{t+1} - \hat{\pi}^*_{t+1} = \hat{q}_t - \hat{c}_t + \hat{a}_{\beta,t} - (1-\mu)\hat{r}^*_t + \mu\hat{b}_{F,t} - \mu\hat{y}_t$$
$$- \hat{q}_{t+1} - \hat{c}^*_{t+1} + \hat{a}^*_{\beta,t+1} - \hat{f}_{t+1} - \hat{\pi}_{t+1} = -\hat{q}_t - \hat{c}^*_t + \hat{a}^*_{\beta,t} - (1-\mu^*)\hat{r}_t + \mu^*\hat{b}^*_{H,t} - \mu^*\hat{y}^*_t$$

$$\hat{c}_{T,t} = \hat{c}_t - \varsigma\hat{p}_{T,t} \quad \hat{c}_{N,t} = \hat{c}_t - \varsigma\hat{p}_{N,t} \quad \hat{g}_{T,t} = \hat{g}_t - \varsigma\hat{p}_{T,t} \quad \hat{g}_{N,t} = \hat{g}_t - \varsigma\hat{p}_{N,t}$$
$$\hat{c}^*_{T,t} = \hat{c}^*_t - \varsigma^*\hat{p}^*_{T,t} \quad \hat{c}^*_{N,t} = \hat{c}^*_t - \varsigma^*\hat{p}^*_{N,t} \quad \hat{g}^*_{T,t} = \hat{g}^*_t - \varsigma^*\hat{p}^*_{T,t} \quad \hat{g}^*_{N,t} = \hat{g}^*_t - \varsigma^*\hat{p}^*_{N,t}$$

Monetary policy

$$\hat{r}_t = \rho_r\hat{r}_{t-1} + (1-\rho_r)(\alpha_\pi\hat{\pi}_t + \alpha_y\hat{y}_t) + \epsilon_{r,t}$$
$$\hat{r}^*_t = \rho^*_r\hat{r}^*_{t-1} + (1-\rho^*_r)(\alpha^*_\pi\hat{\pi}^*_t + \alpha^*_y\hat{y}^*_t) + \epsilon_{r^*,t}$$

Balance of payment condition

$$(\hat{b}_{H,t} - \hat{b}_{F,t}) - R(\hat{b}_{H,t-1} - \hat{b}_{F,t-1}) - (\hat{r}_t - \hat{r}^*_t) - (1-R)\hat{q}_t + R(\hat{\pi}_t - \hat{\pi}^*_t) = \frac{SP^*_H Y^*_H}{PY}\hat{y}^*_{H,t}$$
$$+ \frac{SP^*_H D_{ROW}}{PY}\hat{d}_{ROW,t} + \left(\frac{SP^*_H Y^*_H}{PY} + \frac{SP^*_H D_{ROW}}{PY}\right)(\hat{p}^*_{H,t} + \hat{q}_t) - \frac{P_{IM}Y_{IM}}{PY}(\hat{p}_{IM,t} + \hat{y}_{IM,t})$$

A.3 Stochastic Shocks

$$\hat{g}_t = \rho_g\hat{g}_{t-1} + \epsilon_{g,t} \qquad \hat{g}^*_t = \rho^*_g\hat{g}^*_{t-1} + \epsilon_{g^*,t}$$
$$\hat{a}_{\beta,t} = \rho_\beta\hat{a}_{\beta,t-1} + \epsilon_{\beta,t} \qquad \hat{a}^*_{\beta,t} = \rho^*_\beta\hat{a}^*_{\beta,t-1} + \epsilon^*_{\beta,t}$$
$$\hat{d}_{ROW,t} = \rho_d\hat{d}_{ROW,t-1} + \epsilon_{d,t} \qquad \hat{d}^*_{ROW,t} = \rho^*_d\hat{d}^*_{ROW,t-1} + \epsilon^*_{d,t}$$
$$\hat{p}_{ROW,t} = \rho_p\hat{p}_{ROW,t-1} + \epsilon_{p,t} \qquad \hat{p}^*_{ROW,t} = \rho^*_p\hat{p}^*_{ROW,t-1} + \epsilon^*_{p,t}$$
$$\hat{f}_t = \rho_f\hat{f}_{t-1} + \epsilon_{ft}$$

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Table 1: Structural Parameter Estimates

				1974:3 − 1991:4			1992:1 − 2008:1		
	Prior Distribution			Posterior Distribution			Posterior Distribution		
Parameters	Distribution	Mean	Std	Mean	10%	90%	Mean	10%	90%
ψ_d	Beta	0.70	0.05	0.5312	0.4931	0.5821	0.4861	0.4119	0.5644
ψ_w	Beta	0.80	0.05	0.9168	0.9033	0.9305	0.9364	0.9073	0.9655
τ_d	Beta	0.30	0.10	0.1318	0.0590	0.1886	0.1140	0.0421	0.1865
τ_w	Beta	0.30	0.10	0.6049	0.5262	0.6866	0.1849	0.0788	0.2913
ψ_d^*	Beta	0.70	0.05	0.6765	0.6339	0.7163	0.8456	0.7828	0.9011
ψ_w^*	Beta	0.80	0.05	0.9158	0.9069	0.9244	0.8289	0.6986	0.9508
τ_d^*	Beta	0.30	0.10	0.1706	0.0579	0.2920	0.1869	0.0934	0.2806
τ_w^*	Beta	0.30	0.10	0.3644	0.2912	0.4516	0.4806	0.2316	0.7380
σ	Gamma	1.50	0.15	1.1324	1.0439	1.2261	1.2281	0.9938	1.4410
σ^*	Gamma	1.50	0.15	1.3296	1.2225	1.4461	1.4940	1.3013	1.6871
ρ_r	Beta	0.70	0.10	0.8563	0.8301	0.8818	0.8674	0.8312	0.9051
α_π	Gamma	1.40	0.10	1.1745	1.0815	1.2565	1.3390	1.2299	1.4510
α_y	Gamma	0.40	0.10	0.5076	0.4583	0.5527	0.5642	0.3726	0.7457
ρ_r^*	Beta	0.70	0.10	0.9138	0.9002	0.9272	0.8716	0.8425	0.9026
α_π^*	Gamma	1.40	0.10	1.4824	1.4122	1.5340	1.6054	1.4521	1.7433
α_y^*	Gamma	0.40	0.10	0.0513	0.0449	0.0564	0.0473	0.0448	0.0506
ϱ	Beta	0.40	0.10	0.2496	0.1693	0.3503	0.2952	0.1718	0.4130
ϱ^*	Beta	0.40	0.10	0.3223	0.2756	0.3728	0.6694	0.5440	0.7832
ρ_f	Beta	0.50	0.10	0.3738	0.2863	0.4562	0.3312	0.2327	0.4424
ρ_g	Beta	0.75	0.10	0.8458	0.7488	0.9479	0.9550	0.9331	0.9780
ρ_g^*	Beta	0.75	0.10	0.9137	0.8711	0.9515	0.9126	0.8766	0.9495
ρ_β	Beta	0.75	0.10	0.8428	0.8106	0.8750	0.8681	0.8263	0.9122
ρ_β^*	Beta	0.75	0.10	0.8891	0.8638	0.9179	0.8710	0.8299	0.9125
ρ_p	Beta	0.75	0.10	0.9358	0.8827	0.9756	0.9304	0.8781	0.9851
ρ_p^*	Beta	0.75	0.10	0.9956	0.9925	0.9983	0.9025	0.7703	0.9874
ρ_d	Beta	0.75	0.10	0.9110	0.8818	0.9419	0.7141	0.6187	0.8129
ρ_d^*	Beta	0.75	0.10	0.8353	0.7446	0.9308	0.8721	0.8172	0.9292
σ_f	Inv Gamma	0.50	4.00	0.5634	0.4717	0.6541	0.4983	0.4119	0.5827
σ_g	Inv Gamma	0.50	4.00	0.9844	0.8311	1.1374	0.8642	0.7325	0.9935
σ_g^*	Inv Gamma	0.50	4.00	3.9938	3.3763	4.5633	3.2215	2.7412	3.7014
σ_β	Inv Gamma	0.50	4.00	4.6936	3.9549	5.4421	2.2426	1.7940	2.6902
σ_β^*	Inv Gamma	0.50	4.00	7.1860	6.2753	8.0806	4.7576	3.8728	5.6139
σ_r	Inv Gamma	0.50	4.00	0.2384	0.2020	0.2745	0.1415	0.1163	0.1654
σ_r^*	Inv Gamma	0.50	4.00	0.2424	0.2034	0.2794	0.1119	0.0939	0.1296
σ_p	Inv Gamma	0.50	4.00	2.7975	2.3711	3.2143	1.7663	1.4633	2.0606
σ_p^*	Inv Gamma	0.50	4.00	8.4587	6.7003	10.485	2.4610	1.6708	3.2627
σ_d	Inv Gamma	0.50	4.00	5.7907	4.9847	6.6431	6.0181	5.0812	6.9612
σ_d^*	Inv Gamma	0.50	4.00	8.8314	7.9483	9.6356	7.2971	6.2076	8.3466

Table 2: Model Validation: Persistence and Volatility

	Data		**Model**	
	Std.	Autocorrelation	Std.	Autocorrelation
		1974:3-1991:4		
$\Delta\hat{y}_t$	0.9997	0.3520	1.8138	-0.0417
			(1.6157,2.0353)	(-0.1717,0.0837)
$\Delta\hat{y}^*_t$	3.7703	0.4130	5.0766	-0.1101
			(4.5937,5.6325)	(-0.2381,0.0153)
$\Delta\hat{tot}_t$	1.4607	0.3810	3.9716	-0.1329
			(3.5059,4.4687)	(-0.2518,-0.0040)
$\Delta\hat{tot}^*_t$	1.2149	0.2930	4.0678	0.2058
			(3.4738,4.6577)	(0.0475,0.3746)
$\Delta\hat{d}_{ROW,t}$	6.0803	-0.3210	6.0542	-0.0436
			(5.4409,6.8629)	(-0.1865,0.0765)
$\Delta\hat{d}^*_{ROW,t}$	9.8193	-0.6870	8.0436	-0.0406
			(7.2753,8.9098)	(-0.1814,0.0892)
$\hat{r}_t$	2.5947	0.9140	0.5998	0.9211
			(0.4355,0.8338)	(0.7858,0.9896)
$\hat{r}^*_t$	2.1400	0.9310	1.2774	0.9321
			(0.6489,2.5791)	(0.7839,1.0092)
$\hat{\pi}_t$	0.8409	0.7690	0.7569	0.7267
			(0.6116,0.9601)	(0.5860,0.8435)
$\hat{\pi}^*_t$	1.2346	0.6700	1.5363	0.7489
			(1.0298,2.7563)	(0.5272,0.9057)
		1992:1-2008:1		
$\Delta\hat{y}_t$	0.4894	0.1210	0.9874	0.0797
			(0.8543,1.1232)	(-0.0805,0.2512)
$\Delta\hat{y}^*_t$	3.0289	0.1460	3.0227	0.1057
			(2.5947,3.5968)	(-0.1017,0.3447)
$\Delta\hat{tot}_t$	0.8140	0.1830	1.6240	0.0572
			(1.3674,1.9326)	(-0.1236,0.2651)
$\Delta\hat{tot}^*_t$	0.7538	-0.1180	1.7640	0.0118
			(1.4691,2.0882)	(-0.1621,0.1949)
$\Delta\hat{d}_{ROW,t}$	6.0421	-0.5090	6.2044	-0.1469
			(5.3530,7.2338)	(-0.2998,0.0007)
$\Delta\hat{d}^*_{ROW,t}$	7.4838	-0.4970	7.5030	-0.0845
			(6.4575,8.6001)	(-0.2363,0.0917)
$\hat{r}_t$	1.5252	0.9480	0.3015	0.8806
			(0.2175,0.4153)	(0.7007,0.9770)
$\hat{r}^*_t$	1.7970	0.9120	2.0417	0.9644
			(0.9972,4.0017)	(0.7675,1.0471)
$\hat{\pi}_t$	0.3096	0.0930	0.4320	0.6624
			(0.3485,0.5401)	(0.4931,0.8066)
$\hat{\pi}^*_t$	0.1847	0.2670	1.9550	0.9535
			(1.0348,3.7120)	(0.7688,1.0409)

Table 3: Model Validation: Cross Correlations

	1974:3 – 1991:4		1992:1-2008:1	
	Data	**Model**	**Data**	**Model**
$\Delta\hat{y}_t$, $\hat{\pi}_t$	-0.1720	-0.1542 (-0.2803,-0.0133)	-0.1348	-0.4103 (-0.5445,-0.2637)
$\Delta\hat{y}^*_t$, $\hat{\pi}^*_t$	-0.3725	0.1063 (-0.0221,0.2357)	-0.1133	-0.0723 (-0.2392,0.1261)
$\hat{\pi}_t$, $\hat{r}_t$	0.4698	0.5256 (0.2626,0.7175)	0.0570	0.5198 (0.2672,0.7082)
$\hat{\pi}^*_t$, $\hat{r}^*_t$	0.4518	0.6979 (0.2850,0.9155)	0.4136	0.8961 (0.7713,0.9599)
$\Delta\hat{y}_t$, $\Delta\hat{tot}_t$	0.0858	0.0057 (-0.1347,0.1442)	-0.0660	-0.0500 (-0.2120,0.1222)
$\Delta\hat{y}^*_t$, $\Delta\hat{tot}^*_t$	0.2727	0.0777 (-0.0614,0.2036)	0.2200	-0.1564 (-0.3467,0.0434)
$\hat{r}_t$, $\Delta\hat{d}_{ROW,t}$	-0.1108	0.0003 (-0.1090,0.1096)	0.0262	-0.0099 (-0.1123,0.0916)
$\hat{r}^*_t$, $\Delta\hat{d}^*_{ROW,t}$	-0.1477	-0.0093 (-0.0980,0.0969)	-0.1301	-0.0117 (-0.1117,0.0837)
$\Delta\hat{y}_t$, $\Delta\hat{y}^*_t$	0.0046	0.1126 (-0.0183,0.2477)	-0.0444	0.1728 (0.0101,0.3436)

Figure 1: Global Imbalances: 1970-2009

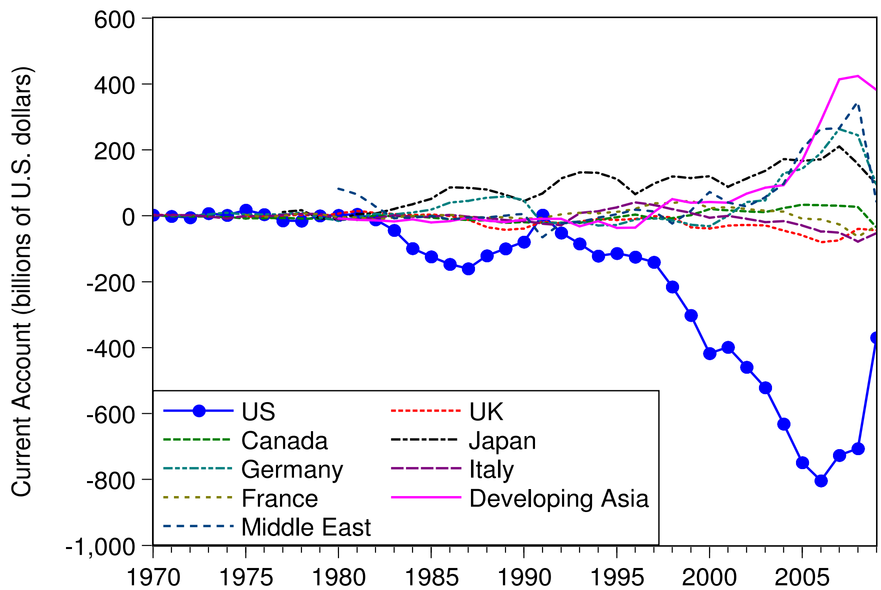

Figure 2: U.S. Trade Balance and Effective Exchange Rates

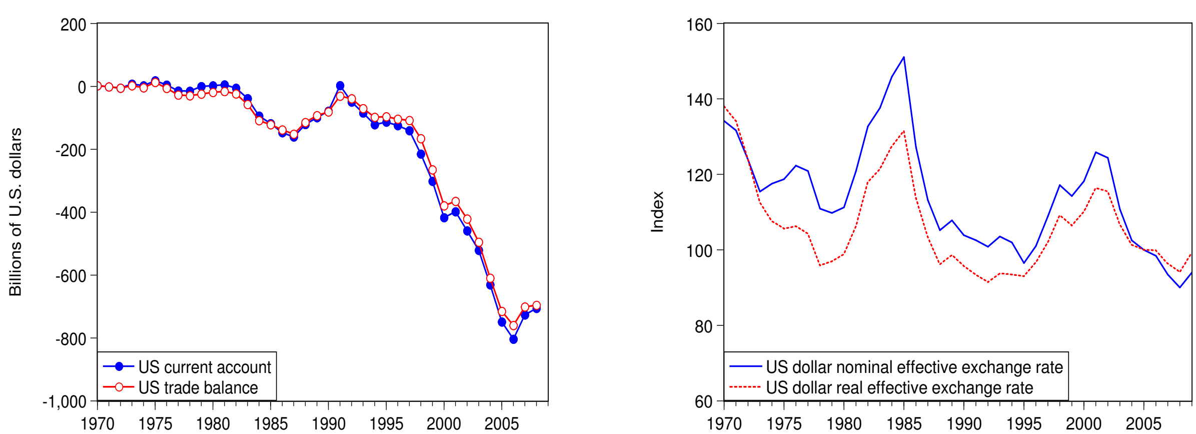

Figure 3: Model Structure

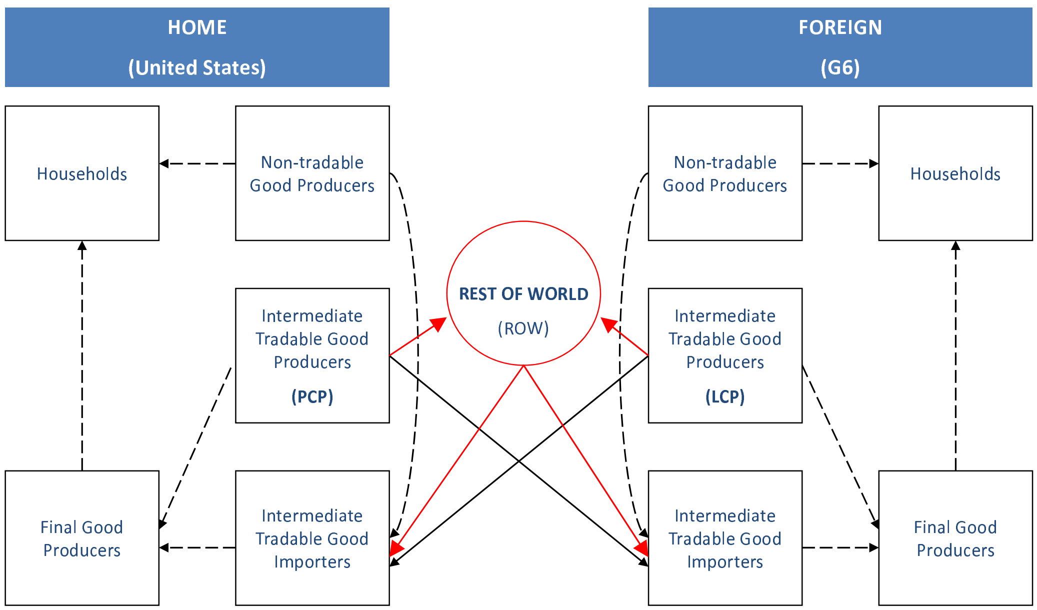

Figure 4: Impacts of Exchange Rates on U.S. Exports ($\hat{y}^*_{H,t}$) and Imports ($\hat{y}_{F,t}$)

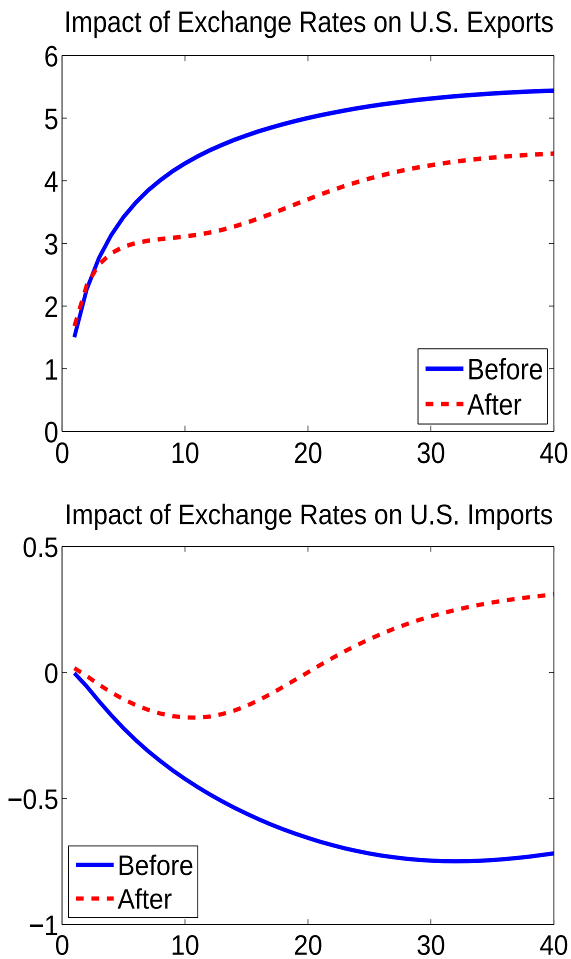

Figure 5: Counterfactual Analysis: Impacts of Exchange Rates on U.S. Exports ($\hat{y}^*_{H,t}$)

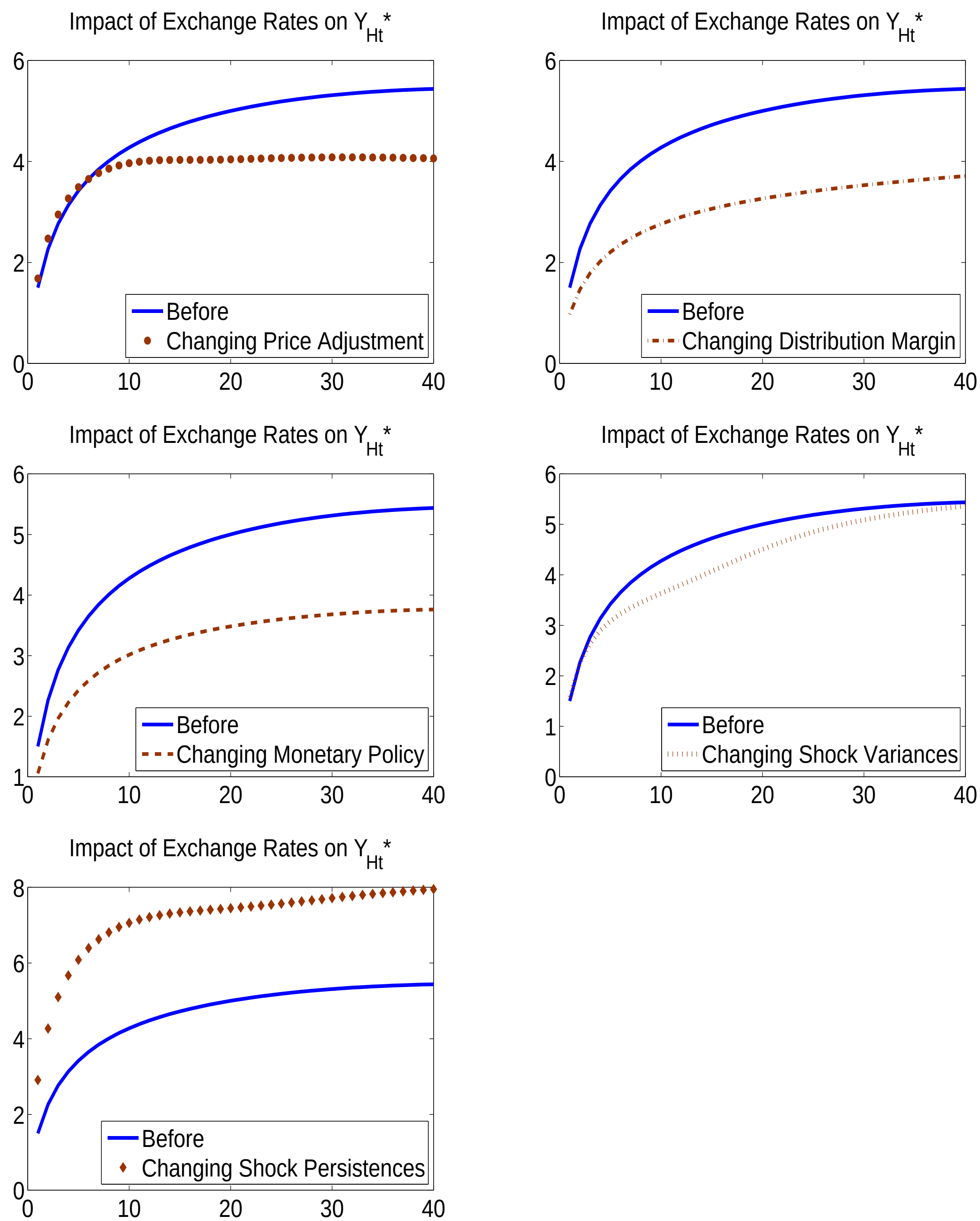

Figure 6: Counterfactual Analysis: Impacts of Exchange Rates on U.S. Imports ($\hat{y}_{F,t}$)