Vertical Trade, Exchange Rate Pass-Through, and the Exchange Rate Regime

Ke Pang*and Yao Tang†

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Abstract

We compare the welfare of different combinations of monetary and currency policies in an open-economy macroeconomic model that incorporates two important features of many small open economies: a high level of vertical international trade and a high degree of exchange rate pass-through. In this environment, a small economy prefers a fixed exchange rate regime over a flexible regime, while the larger economy prefers a flexible exchange rate regime. There are two main causes underlying our results. First, in the presence of sticky prices, relative prices adjust through changes in the exchange rate. Multiple stages of production and trade make it more difficult for one exchange rate to balance the whole economy by adjusting several relative prices simultaneously throughout the vertical chain of production and trade. More specifically, there is a tradeoff between delivering an efficient relative price between home and foreign final goods and delivering an efficient relative price between home and foreign intermediate goods. Second, because the small economy faces a high degree of exchange rate pass-through under a flexible regime, it suffers from a lack of efficient relative prices in vertical trade. The larger economy, however, does not face this problem because its level of exchange rate pass-through is low.

JEL classification: F3, F4

Keywords: vertical production and trade, exchange rate pass-through, monetary policy

*Corresponding author. Department of Economics, Wilfrid Laurier University, 75 University Avenue, Waterloo, ON N2L 3C5, Canada. E-mail addresses: kpang@wlu.ca. Tel: 1-519-8840710 (x.6295). Fax: 1-519-8881015. We are grateful to SSHRC, Wilfrid Laurier University, and Bowdoin College for financial support. We thank the anonymous referee and the editor for insightful suggestions. We also thank Shutao Cao, Julian Diaz, Wei Dong, Kevin Huang, Larry Schembri, Pierre Siklos, Jian Wang, and seminar participants at the Canadian Economic Association Meeting in Ottawa, Shanghai University of Finance and Economics, Wilfrid Laurier University, and Zhejiang University for helpful comments.

†Department of Economics, Bowdoin College, 9700 College Station, Brunswick, Maine 04011-8497, USA. Email: ytang@bowdoin.edu. Tel: 1-207-7984260. Fax: 1-207-7253691.

1 Introduction

Many small open economies have two prominent features. First, they engage in extensive vertical trade with one or more large economies; these countries trade not only final goods but also a large quantity of intermediate goods. Second, they are subject to a high degree of exchange rate pass-through because their international trade transactions are primarily invoiced in the currencies of their large trade partners, such as the U.S. dollar and the euro. Two important examples of this type of small open economies are Canada and Mexico, the two trade partners of the United States in the North American Free Trade Agreement (NAFTA).

There is a substantial amount of vertical trade between Canada and the United States, especially in machinery and equipment, industrial goods and materials, and automotive products. Vertical trade accounted for approximately 30% to 35% of Canadas total exports in 1990, and more important, approximately 51% of the country's export growth between 1970 and 1990 (Hummels et al., 2001). As for Mexico, the vertical specialization share of total exports rose steadily between 1984 and 1997, reaching 32% in 1997 based on data from Mexican maquiladoras (Hummels et al., 2001). From the perspective of the United States, vertical trade is also a pronounced phenomenon. Multinationals accounted for over half of U.S. total exports in 1999, and 93% of exports by US parent firms to their foreign manufacturing affiliates were inputs for further processing (Hanson et al., 2005). In addition, the increase in intra-industry trade between the United States and the other NAFTA countries from 1990 to 2007 was almost entirely due to two-way trade in vertical differentiation (Ekanayake et al., 2009).[1]

The data on trade between the Central and Eastern European Countries (CEEC) versus the European Union (EU) also indicate the importance of vertical trade. The EU is the largest trade partner of the CEECs. In 1998, trade with the EU accounted for 81.8% of CEEC total parts imports and 79.4% of their total parts exports.[2] Trade in parts has been the most rapidly growing

[1]An alternative measurement of vertical trade is the production-sharing intensity of trade, defined as the ratio of affiliate sales of manufactured goods to the U.S. parent as a share of total manufacturing exports to the United States in a country (or region). Based on trade flows between U.S. multinationals and their affiliates, Burstein et al. (2008) reported that the production-sharing intensity of trade was approximately 50% for Canada and 25% for Mexico in 2003. When maquiladoras were included, the production-sharing intensity of trade increased dramatically from 25% to 55% for Mexico. As the authors explained in their paper, these data likely understated the degree of production sharing because they captured only intra-firm trade and omitted arm's-length production sharing.

[2]Up to 2004, there were fifteen member states in the EU: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherland, Portugal, Spain, Sweden, and the United Kingdom. Out of them,

component of international trade for the CEECs (Kaminski and Ng, 2001).[3] The value of CEEC total parts trade turnover grew almost threefold from 1993 to 1997, with both exports and imports increasing at a similar pace, concentrating in three sectors: motor vehicle parts, office machinery, and telecommunications equipment.

There is plenty of empirical evidence suggesting that small open economies face a high degree of exchange rate pass-through because the currencies of large economies are often the invoicing currencies in international trade. For instance, the U.S. dollar is the dominant invoicing currency in Canada-U.S. trade. Between 1996 and 1998, 92.8% of Canada's exports to the United States were invoiced in U.S. dollars with only 4.8% in Canadian dollars and 2.4% in other currencies (Donnenfeld and Haug, 2008). Similarly, from 2002 to 2009, over 95% of Canada's imports from the United States were invoiced in U.S. dollars by count and over 80% by value (Goldberg and Tille, 2009). A firm-level survey conducted by the Bank of Canada in 2002 further confirmed that the U.S. dollar is dominant in invoicing Canadian exports (Murray et al., 2003). More generally, Goldberg and Tille (2008), Kamps (2006), and Ligthart and Werner (2010) documented that the U.S. dollar is the primary invoice currency choice in flows to and from the United States, and there is an increasing role of the euro in the EU and its accession countries.

As Bacchetta and van Wincoop (2005) noted, when exporters in small open economies face strong international competition in a large foreign market, it is often optimal for these exporters to price in the importer's currency because they have small market shares and/or because the substitutability between products is high. Similarly, Goldberg and Tille (2008) emphasized a "co-alescing"effect where exporters try to minimize the movements of their prices relative to their competitors.

Although the literature on international trade and finance has recognized the existence and importance of vertical trade (Feenstra, 1998; Hummels et al., 1998, 2001; Yeats, 2001; Yi, 2003, 2010) and the high level of exchange rate pass-through faced by small open economies (Donnenfeld and Haug, 2008; Goldberg and Tille, 2008, 2009; Murray et al., 2003; Kamps, 2006; Ligthart and Werner, 2010), the joint effects of these two features on monetary policy and exchange rate regimes

the most important trading partner with the CEECs has been Germany, which accounted for 39.4% of CEEC total parts imports and 49.7% of their total parts exports.

[3] Kaminski and Ng (2001) focused on ten CEECs: the Czech Republic, Estonia, Hungary, Poland, Slovenia, Bulgaria, Romania, Slovakia, Latvia, and Lithuania.

have not been formally studied. Intuitively, the economic integration fostered by increased vertical trade makes it more difficult for a flexible exchange rate to balance the whole economy. Moreover, a high degree of exchange rate pass-through faced by these small open economies implies that they are more exposed to exchange rate fluctuations than larger countries such as the United States. Consequently, these smaller countries face a higher cost of a flexible exchange rate regime. These factors give rise to the following question: do the trends of increasing vertical trade and high levels of exchange rate pass-through alter the comparison of economic welfare for these small open economies under different monetary systems? In particular, how does a flexible exchange rate regime compare to a currency peg or a monetary union?

To answer these questions, we construct a two-country, open-economy macroeconomic model with vertical trade and a high level of exchange rate pass-through in the smaller economy. There are two stages of production in each country. The final goods sector in each country produces tradable final goods using domestic and imported intermediate goods, while the intermediate goods are produced by labor. The production of each type of good in each country faces a stage-specific and country-specific productivity shock. Because the production of tradable final goods requires both domestic and imported intermediate goods, vertical trade is necessary. We assume that all goods are priced in the currency of the larger economy. To complete the model, we specify the monetary policy as a money supply rule and focus on practical targeting rules. We then compare the welfare of each country under three exchange rate regimes: unilateral peg, monetary union, and inflation targeting with a flexible exchange rate.[4]

Our main result is that, when vertical trade and a high level of exchange rate pass-through are present, a fixed exchange rate regime is typically more desirable than a flexible exchange rate regime for the small economy. This result contrasts sharply with the standard result in the open-economy macroeconomics literature that open economies (of all sizes) should favor a flexible exchange rate regime. Intuitively, in the face of vertical trade, there are multiple relative prices that need to be adjusted in response to the underlying shocks in different stages of production. When prices are sticky, international relative prices adjust through changes in exchange rates. However, there is

[4] To facilitate the comparison of our results with those of the standard new open-economy macroeconomic models, we assume that the financial market is complete and that a production subsidy exists in each stage of production. Consequently, we abstract away from distortions caused by incomplete international risk-sharing and monopolistic competition and focus on a single friction: nominal price rigidity.

only one exchange rate, which makes it difficult to balance the entire economy. Indeed, the economy may face costly spillovers of shocks from one stage of production to another via the vertical chain of production and trade if the exchange rate is flexible. Furthermore, the degree of the exchange rate pass-through plays a crucial role in our model. If there is a high degree of exchange rate pass-through into the economy, the effects of the negative spillovers will be strong. Therefore, the exchange rate risk under a flexible exchange rate regime will be more costly for the smaller country because its exports and imports are priced in the currency of the larger country. In comparison, the larger country's trade is priced in its own currency; hence, the exchange rate does not affect its relative prices, and the negative spillovers will not occur. The larger country would then favor a flexible exchange rate regime even when there is vertical trade.

Our paper builds on the new open-economy macroeconomics (NOEM) literature on evaluating monetary policies.[5] A long-standing idea in international economics is that a flexible exchange rate regime is desirable because, when prices are sticky, nominal exchange rate movements can adjust the relative prices of home and foreign goods (Friedman, 1953). Obstfeld and Rogoff (1995, 1998, 2000a, 2002) made a similar argument in a dynamic stochastic general equilibrium (DSGE) framework featuring producer currency pricing (PCP). They showed that, when the monetary authorities respond only to domestic shocks, the flexible exchange rate regime can replicate the flexible price equilibrium, i.e., the optimal outcome. However, later papers showed that this result depends on the degree of exchange rate pass-through. In particular, Devereux and Engel (2003) showed that, under local currency pricing (LCP), there is no exchange rate pass-through, and hence little value in exchange rate flexibility. In their model, a fixed exchange rate regime is optimal.[6] Compared to these papers, we show that, when vertical trade is introduced, even a country subject to a high level of exchange rate pass-through may prefer a fixed exchange rate regime.

This paper is also closely related to the branch of international macroeconomics literature that emphasizes the vertical integration of production and trade. Huang and Liu (2004, 2005, 2006) extended their closed-economy DSGE model with sticky prices and multiple stages of production, which was introduced in Huang and Liu (2001) to study the cross-country correlation in consump-

[5] Corsetti and Pesenti (2007) provided a graphical representation of optimal monetary policy in open economy models.

[6] However, depending on the model setup and types of shocks, LCP does not always imply that a fixed exchange rate regime is strictly preferred, e.g., Devereux et al. (2006) and Tille (2002).

tion and in output, the welfare effect of different inflation targets, and the international transmission and the welfare impact of unilateral monetary expansion in a two-country model. Another article that features vertical production and trade is Shi and Xu (2007), which examines an optimal linear monetary policy rule in a model with vertical trade and both counties practicing PCP.

Although our paper is closely related to Shi and Xu (2007), it differs in important ways. In terms of model setup, we emphasize the role of a high degree of exchange rate pass-through for small open economies and focus on simple targeting rules that do not require the observation of fundamental shocks. Regarding results, although Shi and Xu (2007) showed that the optimal monetary policy implies lower exchange rate volatility than that of an economy without vertical trade, their results still implied that a flexible exchange rate regime is optimal. Instead, our paper finds that the fixed exchange rate regime is preferred by the country that faces a high level of exchange rate pass-through. Moreover, if a country faces a low degree of exchange rate pass-through (i.e., exchange rate changes have a limited effect on its relative prices), even if vertical trade is present, there is little room for exchange rate policy.

We contribute to the literature by showing that the interaction between vertical trade and the degree of exchange rate pass-through can alter the desirability of a flexible exchange rate regime versus a fixed exchange rate regime. When there is vertical trade, a small economy subject to a high level of exchange rate pass-through generally prefers a fixed exchange rate regime because vertical trade leads to costly distortions in relative prices under a flexible exchange rate regime. Meanwhile, a large economy subject to a low level of exchange rate pass-through is less affected by such distortions and, as a result, generally favors a flexible exchange rate regime.

The remainder of the paper proceeds as follows. Section 2 describes the structure of the model. Section 3 presents the method used to compute welfare. Section 4 compares alternative monetary policies for the home and foreign countries. Section 5 highlights the key driving forces of the results. Conclusions follow.

2 Model

In our model, the world has two countries, home and foreign. Each country is populated by households that are immobile across borders.[7] We normalize the world population to a measure of one. Home households reside on the interval $[0, n]$, and foreign households reside on the interval $(n, 1]$. Hence, the parameter n is the size of the home country. Households derive utility from aggregate consumption, real money balance, and leisure. In each country, there are two production stages, one for intermediate and one for final goods. As illustrated in Figure 1, the two countries trade intermediate goods, final goods, and assets but not labor. For simplicity, we abstract away from any dynamics by considering a single period model with uncertainty and with two sub-periods, one before and the other after the realization of productivity shocks.[8] Figure 2 explains the sequence of events within the period. First, households enter the period and trade in a complete set of state-contingent nominal bonds that specify payoffs in all possible future states. Next, monetary authorities announce monetary policy rules . Firms then set prices in advance, taking into account their expected demands, marginal costs, and discount factors. After shocks are realized, production and consumption take place, and the exchange rate is determined.

Below, we describe the detailed structure of the home economy. Unless indicated otherwise, the foreign economy has an identical structure. Where appropriate, variables of the foreign economy are denoted with an asterisk.

2.1 Household

The representative household in the home country, taking prices and wages as given, maximizes the following expected utility:

$$U = \mathbb{E}\left[ln(C) + \chi ln(\frac{M}{P}) - \eta L\right] \tag{1}$$

where C is the aggregate consumption comprised of all home and foreign final goods

$$C = \left[n^{\frac{1}{\theta}} C_H^{\frac{\theta-1}{\theta}} + (1-n)^{\frac{1}{\theta}} C_F^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{2}$$

The parameter θ ($\theta > 0$) is the elasticity of substitution between home and foreign final goods.

[7] As we will discuss in details in Section 5, introducing labor mobility is unlikely to affect our results because migration is unlikely to affect the presence of vertical trade, a critical feature necessary for our results.

[8] Our results will hold in an infinite horizon model because of complete risk-sharing and price stickiness.

The fraction $\frac{M}{P}$ denotes real money balances and L represents labor supply. The parameters χ and η are positive. There is a continuum of home goods and foreign goods of measure n and $1-n$, respectively. Indices of home and foreign final goods are defined as

$$C_H = \left[(\frac{1}{n})^{\frac{1}{\phi}} \int_0^n C_H(i)^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}} \tag{3}$$

$$C_F = \left[(\frac{1}{1-n})^{\frac{1}{\phi}} \int_n^1 C_F(j)^{\frac{\phi-1}{\phi}} dj \right]^{\frac{\phi}{\phi-1}} \tag{4}$$

where $C_H(i)$ denotes the home final goods of variety i and $C_F(j)$ is the foreign final goods of variety j. The parameter ϕ ($\phi > 1$) is the elasticity of substitution between varieties of goods within each country. The implied aggregate consumer price index (CPI) is then

$$P = \left[nP_H^{1-\theta} + (1-n)P_F^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{5}$$

where P_H (P_F) represents the price index for home (foreign) final goods sold in the home country,

$$P_H = \left[\frac{1}{n} \int_0^n P_H(i)^{1-\phi} di \right]^{\frac{1}{1-\phi}} \tag{6}$$

$$P_F = \left[\frac{1}{1-n} \int_n^1 P_F(j)^{1-\phi} dj \right]^{\frac{1}{1-\phi}}. \tag{7}$$

Home individual demand for home final goods i (foreign final goods j) is then given by

$$C_H(i) = \frac{1}{n} [\frac{P_H(i)}{P_H}]^{-\phi} C_H \tag{8}$$

$$C_F(j) = \frac{1}{1-n} [\frac{P_F(j)}{P_F}]^{-\phi} C_F \tag{9}$$

where C_H (C_F) refers to home individual demand for all home (foreign) final goods,

$$C_H = n(\frac{P_H}{P})^{-\theta} C \tag{10}$$

$$C_F = (1-n)(\frac{P_F}{P})^{-\theta} C. \tag{11}$$

Note that the total demand for home final goods is $Y^d = nC_H + (1-n)C_H^*$, and the total demand for foreign final goods is $Y^{d*} = nC_F + (1-n)C_F^*$. Moreover, the following identities always hold: $\int_0^n P_H(i)C_H(i)di = P_H C_H$, $\int_n^1 P_F(j)C_F(j)dj = P_F C_F$, and $P_H C_H + P_F C_F = PC$.

Residents of each country can purchase a full set of state-contingent nominal bonds; thus, the household budget constraint is

$$PC + M + \sum_{\xi} q(\xi)B(\xi) = WL + \Pi + B + M_0 + T \tag{12}$$

where $q(\xi)$ and $B(\xi)$ represent the price and the amount of a specific bond that pays one unit of home currency in state ξ and zero in other states. After shocks are realized, households choose the optimal level of consumption C, money holding M, and labor supply L, while households are financed by labor income WL, payoff from the state-contingent bonds B, profit from all domestic firms Π, initial money balance M_0, and net government transfer T. Notice that the net government transfer can be written as $T = T_1 - T_2$, where T_1 and T_2 represent a lump-sum government transfer and a lump-sum tax, respectively. We assume that the government repays any seigniorage income through the lump-sum transfer to households, that is, $T_1 = M - M_0$. Moreover, to eliminate the distortion associated with monopolistic competition, the government uses the lump-sum tax T_2 to finance the production subsidy paid to domestic firms. Details of this production subsidy are discussed below.

The trade in state-contingent nominal bonds will lead to the following risk-sharing condition

$$\frac{1}{PC} = \Gamma_0 \frac{1}{SP^*C^*} \tag{13}$$

where S is the nominal exchange rate defined as the price of foreign currency in terms of home currency. Γ_0 is state invariant and determined in the initial market for assets.[9] This paper focuses on the effect of vertical trade and exchange rate pass-through on the choice of exchange rate regimes. Hence, we simplify the role of financial markets by assuming that there is complete international consumption risk-sharing. This assumption is typical in much of the NOEM literature. Furthermore, we assume that the monetary rules are announced after the state-contingent bond markets have closed. We would obtain the same results if we made the reverse assumption because

[9]For detailed derivation of the risk-sharing condition, see Devereux and Engel (2003) and Chari et al. (2002).

our model is static. In a dynamic model, Γ_0 will become endogenous and depend on policy choices, as shown in Senay and Sutherland (2011). In that case, the timing of asset trade may be crucial for policy analysis but it is beyond the scope of this paper.

Households' other optimization conditions, namely, the money demand function and the implicit labor supply schedule, are

$$M = \chi PC \tag{14}$$

$$W = \eta PC. \tag{15}$$

As a result, the nominal wage is proportional to the money in circulation. In addition, the optimization conditions imply that the exchange rate is determined by the relative money supplies between home and foreign countries, $S = \Gamma_0 \frac{M}{M^*}$.

2.2 Final Goods Stage

Home final goods producer i has access to the following technology

$$Y(i) = A\left[n^{\frac{1}{\epsilon}} X_H(i)^{\frac{\epsilon-1}{\epsilon}} + (1-n)^{\frac{1}{\epsilon}} X_F(i)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}} \tag{16}$$

where A is the stochastic productivity shock at the final goods stage in the home country with $E(logA) = 0$ and $Var(logA) = \sigma_A^2$. The parameter ϵ ($\epsilon > 0$) is the elasticity of substitution between home and foreign intermediate goods. $X_H(i)$ is a basket of home intermediate goods used in the production of home final goods i. $X_F(i)$ is a basket of foreign intermediate goods used in the production of home final goods i. They are defined as

$$X_H(i) = \left[(\frac{1}{n})^{\frac{1}{\phi}} \int_0^n X_H(i,h)^{\frac{\phi-1}{\phi}} dh\right]^{\frac{\phi}{\phi-1}} \tag{17}$$

$$X_F(i) = \left[(\frac{1}{1-n})^{\frac{1}{\phi}} \int_n^1 X_F(i,f)^{\frac{\phi-1}{\phi}} df\right]^{\frac{\phi}{\phi-1}} \tag{18}$$

where h and f index the varieties of home and foreign intermediate goods. Solving the cost minimization problem of the final goods producer i, we obtain the unit cost of producing final goods i

$$\Lambda = \frac{1}{A}\left[n(\tilde{P}_H)^{1-\epsilon} + (1-n)(\tilde{P}_F)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{19}$$

where $\tilde{P}_H$ ($\tilde{P}_F$) is the price index of home (foreign) intermediate goods sold in the home country and denominated in home currency.

To capture the choice of invoicing currencies observed in the data, we assume that home final goods producers set prices in home currency in the home market and in foreign currency in the foreign market. Namely, the home final goods producers practice local currency pricing (LCP). In contrast, foreign final goods producers always set prices in foreign currency in both home and foreign markets. That is, they practice producer currency pricing (PCP). Under these pricing assumptions, we do not expect the law of one price or purchasing power parity (PPP) to hold in general. To abstract away from distortions associated with monopolistic competition in both final and intermediate goods, we assume that there exists in each stage of production a production subsidy, $\gamma = \frac{1}{\phi-1}$, such that the price markup in each stage equals zero (i.e., $\frac{\phi}{(\phi-1)(1+\gamma)} - 1 = 0$).[10] After introducing such subsidies, the only type of distortion left in the economy is nominal price rigidity.

Given the demand structure and the unit cost of final goods, home firm i chooses prices $P_H(i)$ and $P_H^*(i)$ to maximize its expected profit

$$\begin{aligned}\mathbb{E}\pi(i) = \mathbb{E}D\{&[(1+\gamma)P_H(i) - \Lambda]n[\frac{P_H(i)}{P_H}]^{-\phi}(\frac{P_H}{P})^{-\theta}C \\ &+[S(1+\gamma)P_H^*(i) - \Lambda](1-n)[\frac{P_H^*(i)}{P_H^*}]^{-\phi}(\frac{P_H^*}{P^*})^{-\theta}C^*\}\end{aligned}$$

where D is the discount factor, $D = \frac{1}{PC}$. The optimal pricing equation of the home final goods i

[10]Notice that although the price markup is the same for all goods produced at different stages and in different countries, PPP does not generally hold in our model because home firms practice LCP and set different prices in advance for home and foreign markets based on their expected demand in the corresponding market.

sold in the home market is

$$P_H(i) = \frac{\mathbb{E}\left[D\Lambda P_H^{\phi}(\frac{P_H}{P})^{-\theta}C\right]}{\mathbb{E}\left[DP_H^{\phi}(\frac{P_H}{P})^{-\theta}C\right]}. \tag{20}$$

Because all prices are pre-set, by applying symmetry in varieties of final goods, we obtain the optimal pricing equation for the home final goods sold in the home market

$$P_H = \frac{\mathbb{E}(D\Lambda P^{\theta}C)}{\mathbb{E}(DP^{\theta}C)}. \tag{21}$$

Similarly, we can derive the optimal pricing equation for the home final goods sold in the foreign market

$$P_H^* = \frac{\mathbb{E}[D\Lambda(P^*)^{\theta}C^*]}{\mathbb{E}[DS(P^*)^{\theta}C^*]}. \tag{22}$$

Regarding the foreign final goods producers, in addition to assuming they always set prices in their own currency, we assume that they do not price to market, that is, $P_F(j) = SP_F^*(j)$. Given that the foreign country is much larger than the home country, it is reasonable to assume that foreign goods producers may find it too costly (e.g., extra information, menu, operation costs) to set a separate price for the home market. Therefore, foreign firm j chooses price $P_F^*(j)$ to maximize its expected profit

$$\mathbb{E}\pi^*(j) = \mathbb{E}D\left\{[(1+\gamma)P_F^*(j) - \Lambda^*]\left[n(\frac{SP_F^*(j)}{P_F})^{-\phi}(\frac{P_F}{P})^{-\theta}C + (1-n)(\frac{P_F^*(j)}{P_F^*})^{-\phi}(\frac{P_F^*}{P^*})^{-\theta}C^*\right]\right\}$$

where $D^* = \frac{1}{P^*C^*}$. In a symmetric equilibrium, we have

$$P_F^* = \frac{\mathbb{E}\left\{D^*\Lambda^*[n(\frac{P}{S})^{\theta}C + (1-n)(P^*)^{\theta}C^*]\right\}}{\mathbb{E}\left\{D^*\left[n(\frac{P}{S})^{\theta}C + (1-n)(P^*)^{\theta}C^*\right]\right\}}. \tag{23}$$

2.3 Intermediate Goods Stage

Home intermediate goods producer h has the following technology[11]

$$X_H(h) = \tilde{A}L(h) \tag{24}$$

where $\tilde{A}$ is the productivity shock at the intermediate goods stage in the home country with $E(log\tilde{A}) = 0$ and $Var(log\tilde{A}) = \sigma^2_{\tilde{A}}$. From the cost minimization problems of final goods producers, we can obtain the total demands for intermediate goods h of all home final goods producers and all foreign final goods producers, $X_H(h)$ and $X^*_H(h)$, respectively,

$$X_H(h) = [\frac{\tilde{P}_H(h)}{\tilde{P}_H}]^{-\phi}(\frac{\tilde{P}_H}{\Lambda})^{-\epsilon}\frac{1}{A^{1-\epsilon}}Y \tag{25}$$

$$X^*_H(h) = [\frac{\tilde{P}^*_H(h)}{\tilde{P}^*_H}]^{-\phi}(\frac{\tilde{P}^*_H}{\Lambda^*})^{-\epsilon}\frac{1}{(A^*)^{1-\epsilon}}Y^* \tag{26}$$

where $\tilde{P}_H(h)$ ($\tilde{P}^*_H(h)$) is the home-currency (foreign-currency) price of intermediate goods h sold in the home (foreign) country, and $Y = \int_0^n Y(i)di$ ($Y^* = \int_n^1 Y^*(j)dj$) represents the total output of home (foreign) final goods.

As in the case of home final goods producers, we assume that home intermediate goods producers price in the currencies of the local markets (i.e., LCP). Note that the unit cost of producing intermediate goods is given by $W/\tilde{A}$. Home intermediate goods firm h chooses prices $P_H(h)$ and $P^*_H(h)$ to maximize its expected profit

$$\mathbb{E}D\{[(1+\gamma)\tilde{P}_H(h) - \frac{W}{\tilde{A}}][\frac{\tilde{P}_H(h)}{\tilde{P}_H}]^{-\phi}(\frac{\tilde{P}_H}{\Lambda})^{-\epsilon}\frac{1}{A^{1-\epsilon}}Y$$
$$+[S(1+\gamma)\tilde{P}^*_H(h) - \frac{W}{\tilde{A}}][\frac{\tilde{P}^*_H(h)}{\tilde{P}^*_H}]^{-\phi}(\frac{\tilde{P}^*_H}{\Lambda^*})^{-\epsilon}\frac{1}{(A^*)^{1-\epsilon}}Y^*\}.$$

Again, by exploiting that all prices are pre-set and applying symmetry across varieties, we obtain

[11] We have assumed that no capital is required in either stage of production. Because there is no saving-investment decision in a one-period model, capital would be given exogenously in our simple model. Although the initial level of capital stock may have some impact on welfare, this is not an interest of this paper.

the optimal prices of home intermediate goods in the home and foreign countries

$$\tilde{P}_H = \frac{\mathbb{E}\left\{D\frac{W}{\tilde{A}}(\Lambda)^{\epsilon}\frac{1}{A^{1-\epsilon}}Y\right\}}{\mathbb{E}\left\{D(\Lambda)^{\epsilon}\frac{1}{A^{1-\epsilon}}Y\right\}} \tag{27}$$

$$\tilde{P}_H^* = \frac{\mathbb{E}\left\{D\frac{W}{\tilde{A}}(\Lambda^*)^{\epsilon}\frac{1}{(A^*)^{1-\epsilon}}Y^*\right\}}{\mathbb{E}\left\{DS(\Lambda^*)^{\epsilon}\frac{1}{(A^*)^{1-\epsilon}}Y^*\right\}}. \tag{28}$$

As in the case of foreign final goods producers, we assume that foreign intermediate goods firms price in the foreign currency for both markets (i.e., PCP) and do not engage in pricing to market. Under these assumptions, we can solve for the price of foreign intermediate goods that applies to both home and foreign markets

$$\tilde{P}_F^* = \frac{\mathbb{E}\left\{D^*\frac{W^*}{\tilde{A}^*}\left[(\frac{\Lambda}{S})^{\epsilon}\frac{1}{A^{1-\epsilon}}Y + (\Lambda^*)^{\epsilon}\frac{1}{(A^*)^{1-\epsilon}}Y^*\right]\right\}}{\mathbb{E}\left\{D^*[(\frac{\Lambda}{S})^{\epsilon}\frac{1}{A^{1-\epsilon}}Y + (\Lambda^*)^{\epsilon}\frac{1}{(A^*)^{1-\epsilon}}Y^*]\right\}}. \tag{29}$$

2.4 Monetary policy

We model monetary policy as a simple money supply rule and analyze a range of simple targeting rules that are easy to implement in practice. In particular, the money supply is targeted on easily observable variables, such as the nominal exchange rate and/or certain price index. The home monetary rule can be written as

$$M = \bar{M}\left(\frac{S}{\bar{S}}\right)^{-\delta_s}\left(\frac{P^X}{\bar{P}}\right)^{-\delta_p} \tag{30}$$

where $\bar{S}$ is the target level of the exchange rate and $\bar{P}$ is the target level of the home price. δ_s and δ_p indicate the degree to which the home monetary authority attempts to control variations in the exchange rate and the price index, respectively. If the money supply rule targets a particular price index, it stabilizes this price index, eliminating the relative price distortion in the presence of nominal price rigidities. Because the exchange rate responds endogenously to home and foreign disturbances in this case, such policy represents a type of active flexible exchange rate regime. More precisely, a producer price index (PPI) targeting rule is defined as a rule that replicates the environment of fully flexible prices. Under a PPI targeting rule, although prices are one hundred percent pre-fixed by producers, they are set at a level that is optimal even after shocks are realized. That is to say, firms will stick to the prices they have chosen even when they have chances to readjust the prices after the state of the economy is revealed. In our model, a price index targeting rule is equivalent to an inflation targeting rule with a zero inflation rate target. The variable P^X in equation (30) represents the “flexible”home price, which is the price that would prevail when prices are flexible. For instance, if the home monetary authority targets the PPI of intermediate goods, then $P^X = \frac{W}{\tilde{A}}$. If the home monetary authority targets the PPI of final goods, then $P^X = \Lambda$.

It is well known in the NOEM literature that, in a typical complete market open economy environment without vertical trade, it is optimal to stabilize the PPI inflation rate rather than the CPI inflation rate. In this paper, we look at both final and intermediate goods PPI inflation targeting because, in the presence of vertical trade and production, it is not obvious which PPI should be the target. Our main findings hold under both types of price targeting rules. However, from the welfare point of view, targeting intermediate goods PPI is much more efficient than targeting final goods PPI. To save space, we focus on targeting intermediate goods PPI inflation in the main text and detail the case of targeting final goods PPI inflation in a technical appendix (available upon request).

In this paper, we analyze three combinations of monetary regimes that we name from the perspective of the home country. These regimes are (1) the “inflation targeting”regime, in which both home and foreign monetary authorities target the PPI of intermediate goods (i.e., $\delta_s = \delta_s^* = 0$ and $\delta_p = \delta_p^* \to \infty$); (2) the “unilateral peg”regime, in which the home country targets the exchange rate (i.e., $\delta_s \to \infty,\ \delta_p = 0$) while the foreign country targets the PPI of intermediate goods ($\delta_s^* = 0,\ \delta_p^* \to \infty$);[12] and (3) a coordinated monetary policy regime, the “monetary union”, in which the central bank of the monetary union, acting as a social planner, maximizes world welfare subject to an inflation targeting rule and the constraint that the exchange rate must be kept constant at all times. Specifically, the common central bank maximizes

$$nU + (1-n)U^* \tag{31}$$

[12]We ignore the reverse of case (2), which is that the foreign country pegs unilaterally to the home currency. This is because the foreign economy is much larger in size, and it would not be optimal for the foreign country to engage in a unilateral peg.

subject to

$$n[PC + M + \sum_{\xi} q(\xi)B(\xi)] + (1-n)[SP^*C^* + SM^* + \sum_{\xi} q(\xi)B^*(\xi)]$$

$$= n(WL + \Pi + B + M_0 + T] + (1-n)(SW^*L^* + S\Pi^* + B^* + SM_0^* + ST^*) \tag{32}$$

$$S \equiv 1 \tag{33}$$

$$M \equiv nM + (1-n)M^* \;=\; \bar{M}\left(\frac{P^X}{\bar{P}}\right)^{-\delta_p} \tag{34}$$

where the common central bank targets a weighted average of all the producer prices of intermediate goods; that is, the price target is $P^X = \left(\frac{W}{\tilde{A}}\right)^n \left(\frac{W^*}{\tilde{A}^*}\right)^{1-n}$ and the policy parameter on the price target δ_p approaches positive infinity.[13]

2.5 Market Clearing

The final goods market clearing conditions are

$$Y = \left[n^2\left(\frac{P_H}{P}\right)^{-\theta} C + n(1-n)\left(\frac{P_H^*}{P^*}\right)^{-\theta} C^*\right] \tag{35}$$

$$Y^* = \left[n(1-n)\left(\frac{P_F}{P}\right)^{-\theta} C + (1-n)^2\left(\frac{P_F^*}{P^*}\right)^{-\theta} C^*\right]. \tag{36}$$

The intermediate goods market clearing conditions are

$$\tilde{A}L = (\frac{\tilde{P}_H}{\Lambda})^{-\epsilon}\frac{1}{A^{1-\epsilon}}Y + (\frac{\tilde{P}_H^*}{\Lambda^*})^{-\epsilon}\frac{1}{(A^*)^{1-\epsilon}}Y^* \tag{37}$$

$$\tilde{A}^*L^* = (\frac{\tilde{P}_F}{\Lambda})^{-\epsilon}\frac{1}{A^{1-\epsilon}}Y + (\frac{\tilde{P}_F^*}{\Lambda^*})^{-\epsilon}\frac{1}{(A^*)^{1-\epsilon}}Y^*. \tag{38}$$

[13] Benigno (2004) showed that, if two regions in a currency union have the same degree of nominal rigidity, it is optimal for the central bank to target the average inflation rate weighted by the economic sizes of the two regions. In practice, the European Monetary Union targets the average CPI of member countries, weighted by their consumption shares.

Notice that the total amount of production subsidy paid to home firms is

$$\begin{aligned} SD &= \gamma\{n^2 P_H \left(\frac{P_H}{P}\right)^{-\theta} C + n(1-n) S P_H^* \left(\frac{P_H^*}{P^*}\right)^{-\theta} C^* \\ &\quad + \tilde{P}_H \left(\frac{\tilde{P}_H}{\Lambda}\right)^{-\epsilon} \frac{1}{A^{1-\epsilon}} Y + S\tilde{P}_H^* \left(\frac{\tilde{P}_H^*}{\Lambda^*}\right)^{-\epsilon} \frac{1}{(A)^{*1-\epsilon}} Y^*\}. \end{aligned}$$

Therefore, the government budget constraint can be written as

$$T_2 + M - M_0 = SD + T_1$$

or

$$T = T_1 - T_2 = M - M_0 - SD.$$

2.6 Equilibrium

The *equilibrium* is comprised of a set of prices $\{P, P^*, P_H, P_H^*, P_F^*, \tilde{P}_H, \tilde{P}_H^*, \tilde{P}_F^*, \Lambda, \Lambda^*, W, W^*, S\}$ and a set of quantities $\{C, C^*, L, L^*, Y, Y^*, M, M^*\}$, which solve a system of equations (5), (13)-(15), (19), (30) and their foreign counterparts as well as (21)-(23), (27)-(29), and (35)-(38), given the productivity shocks in each stage of production, A, A^*, $\tilde{A}$, and $\tilde{A}^*$.

3 Solving the Model

Because it is not possible to derive an exact analytical expression for welfare in this model, and a second-order accurate solution is required for welfare comparison,[14] we solve the model by computing the second-order approximation around the non-stochastic steady state.

The second-order approximation of the welfare measure is given by

$$\tilde{U} \quad = \quad E\left[\hat{C} - \eta\bar{L}\left(\hat{L} + \frac{1}{2}\hat{L}^2\right)\right] + O(\epsilon^3) \tag{39}$$

where $\tilde{U}$ is the deviation of welfare from the non-stochastic equilibrium. $\bar{L}$ is the steady-state value

[14] The need for a second-order accurate solution in welfare analysis has been well addressed in the literature. For example, see Collard and Juillard (2001), Kim and Kim (2003), and Schmitt-Grohe and Uribe (2004).

of labor supply, and $\eta\bar{L} = 1$. Hereafter, we use the Jonesian hats to denote the log-deviation of a variable x from its steady-state value $\bar{x}$, that is, $\hat{x} = log(x) - log(\bar{x})$. The term $O(\epsilon^n)$ represents residuals of an equation approximated to an order of $n-1$. Welfare is increasing in the expected level of consumption but decreasing in the expected level of labor and in the variance of labor.

The second-order approximations of the CPI in each country are given by

$$\hat{P} = n\hat{P}_H + (1-n)(\hat{P}_F^* + \hat{S}) + \lambda_P + O(\epsilon^3) \tag{40}$$

$$\hat{P}^* = n\hat{P}_H^* + (1-n)\hat{P}_F^* + \lambda_{P^*} + O(\epsilon^3) \tag{41}$$

where λ_P and λ_{P^*} collect the second-order terms

$$\lambda_P = \frac{n(1-n)(1-\theta)}{2}(\hat{P}_H - \hat{P}_F^* - \hat{S})^2 \tag{42}$$

$$\lambda_{P^*} = \frac{n(1-n)(1-\theta)}{2}(\hat{P}_H^* - \hat{P}_F^*)^2. \tag{43}$$

We define terms of trade as the price of exports in terms of imports. Therefore, $E(\lambda_P)$ ($E(\lambda_{P^*})$) represents the variance of final goods terms of trade for the home (foreign) country.

Similarly, the second-order approximations of the unit cost of final goods production in each country are

$$\hat{\Lambda} = -\hat{A} + n\hat{\hat{P}}_H + (1-n)(\hat{\hat{P}}_F^* + \hat{S}) + \lambda_\Lambda + O(\epsilon^3) \tag{44}$$

$$\hat{\Lambda}^* = -\hat{A}^* + n\hat{\hat{P}}_H^* + (1-n)\hat{\hat{P}}_F^* + \lambda_{\Lambda^*} + O(\epsilon^3) \tag{45}$$

where λ_Λ and λ_{Λ^*} summarize the second-order terms

$$\lambda_\Lambda = \frac{n(1-n)(1-\epsilon)}{2}(\hat{\hat{P}}_H - \hat{\hat{P}}_F^* - \hat{S})^2 \tag{46}$$

$$\lambda_{\Lambda^*} = \frac{n(1-n)(1-\epsilon)}{2}(\hat{\hat{P}}_H^* - \hat{\hat{P}}_F^*)^2 \tag{47}$$

and $E(\lambda_\Lambda)$ ($E(\lambda_{\Lambda^*})$) represents the variance of intermediate goods terms of trade for the home (foreign) country.

The second-order approximations of the optimal pricing equations are given by

$$\hat{P}_H = E(\hat{\Lambda}) + \lambda_{P_H} + O(\epsilon^3) \quad (48)$$

$$\hat{P}^*_H = E(\hat{\Lambda} - \hat{S}) + \lambda_{P^*_H} + O(\epsilon^3) \quad (49)$$

$$\hat{P}^*_F = E(\hat{\Lambda}^*) + \lambda_{P^*_F} + O(\epsilon^3) \quad (50)$$

$$\hat{\tilde{P}}_H = E(\hat{W} - \hat{\tilde{A}}) + \lambda_{\tilde{P}_H} + O(\epsilon^3) \quad (51)$$

$$\hat{\tilde{P}}^*_H = E(\hat{W} - \hat{\tilde{A}} - \hat{S}) + \lambda_{\tilde{P}^*_H} + O(\epsilon^3) \quad (52)$$

$$\hat{\tilde{P}}^*_F = E(\hat{W}^* - \hat{\tilde{A}}^*) + \lambda_{\tilde{P}^*_F} + O(\epsilon^3) \quad (53)$$

where λ_{P_H}, $\lambda_{P^*_H}$, $\lambda_{P^*_F}$, $\lambda_{\tilde{P}_H}$, $\lambda_{\tilde{P}^*_H}$, and $\lambda_{\tilde{P}^*_F}$ collect the second-order terms and represent the risk premium that firms build into their corresponding pricing decisions

$$\lambda_{P_H} = E[\frac{1}{2}\hat{\Lambda}^2 + \hat{\Lambda}(\theta - 1)\hat{P}] \quad (54)$$

$$\lambda_{P^*_H} = E[\frac{1}{2}(\hat{\Lambda} - \hat{S})^2 + (\hat{\Lambda} - \hat{S})(\theta - 1)\hat{P}^*] \quad (55)$$

$$\lambda_{P^*_F} = E\{\frac{1}{2}\hat{\Lambda}^{*2} + \hat{\Lambda}^*[n(\theta - 1)(\hat{P} - \hat{S}) + (1 - n)(\theta - 1)\hat{P}^*]\} \quad (56)$$

$$\begin{aligned} \lambda_{\tilde{P}_H} = {} & E\{\frac{1}{2}(\hat{W} - \hat{\tilde{A}})^2 + (\hat{W} - \hat{\tilde{A}})\{\epsilon\hat{\Lambda} - (1 - \epsilon)\hat{A} + n[-\theta\hat{P}_H + (\theta - 1)\hat{P}] \\ & + (1 - n)[-\theta\hat{P}^*_H + (\theta - 1)\hat{P}^* - \hat{S}]\}\} \end{aligned} \quad (57)$$

$$\begin{aligned} \lambda_{\tilde{P}^*_H} = {} & E\{\frac{1}{2}(\hat{W} - \hat{\tilde{A}})^2 - \frac{1}{2}\hat{S}^2 + (\hat{W} - \hat{\tilde{A}} - \hat{S})\{\epsilon\hat{\Lambda}^* - (1 - \epsilon)\hat{A}^* \\ & + n[-\theta\hat{P}_F + (\theta - 1)\hat{P}] + (1 - n)[-\theta\hat{P}^*_F + (\theta - 1)\hat{P}^* - \hat{S}]\}\} \end{aligned} \quad (58)$$

$$\begin{aligned} \lambda_{\tilde{P}^*_F} = {} & E\{\frac{1}{2}(\hat{W}^* - \hat{\tilde{A}}^*)^2 + (\hat{W}^* - \hat{\tilde{A}}^*)\{n[\epsilon(\hat{\Lambda} - \hat{S}) - (1 - \epsilon)\hat{A}] + n^2[-\theta\hat{P}_H + \hat{S} + (\theta - 1)\hat{P}] \\ & + n(1 - n)[-\theta\hat{P}^*_H + (\theta - 1)\hat{P}^*] + (1 - n)[\epsilon\hat{\Lambda}^* - (1 - \epsilon)\hat{A}^*] \\ & + n(1 - n)[-\theta\hat{P}_F + \hat{S} + (\theta - 1)\hat{P}] + (1 - n)^2[-\theta\hat{P}^*_F + (\theta - 1)\hat{P}^*]\}\} \end{aligned} \quad (59)$$

Eventually, we can express the approximated welfare function (39) in terms of the second moments of variables in the model and compute the second-order accurate second moments from the first-order solutions for the realized values of endogenous variables.[15]

[15] This solution technique has been employed in a series of papers, e.g., Sutherland (2004) and Senay and Sutherland (2005). The technical appendix (available upon request) documents the complete log-linearized system.

4 Results

To compute welfare, we set the size of the home country to be one-ninth of the foreign country, i.e., $n = 0.1$, to match the respective sizes of the Canadian economy and the American economy.[16] The standard deviation of all productivity shocks is 1% of their steady-state level, i.e., $\sigma_A^2 = \sigma_{A^*}^2 = \sigma_{\tilde{A}}^2 = \sigma_{\tilde{A}^*}^2 = 0.0001$, and all shocks are independent of each other. Because the elasticity of substitution between home and foreign intermediate goods (ϵ) and between home and foreign final goods (θ) are important for the transmission of productivity shocks across the border, we explore a number of parameter ranges and combinations.

As reviewed by Obstfeld and Rogoff (2000b), the literature of international economics offers a wide range of estimations for θ from 1.2 to 21.4. The number often used in macroeconomics studies is between 1 and 2, e.g., Backus et al. (1994) and Chari et al. (2002), while the literature on international trade provides much larger estimates of this parameter, often around 10.[17] A value smaller than unity is seldom used. Meanwhile, empirical evidence provided by Saito (2004) suggested that the international substitutability among intermediate goods tends to be much higher than that among final goods. Hence, we consider the relevant parameter range to be $\epsilon > \theta > 1$.

4.1 Home Welfare

Figures 3, 7, and 11 plot home welfare under three combinations of monetary regimes, i.e., inflation targeting, unilateral peg, and monetary union, against ϵ in the range of $[1, 10]$ while fixing θ at 1, 2, and 5, respectively. Similarly, Figures 15, 19, and 23 plot the home welfare under three combinations of monetary regimes against θ in the range of $[1, 25]$ while fixing ϵ at 1, 2, and 5, respectively.[18] In general, we find that for the home country the unilateral peg regime dominates both the inflation targeting regime and the monetary union. To understand this result, we compare the three regimes based on welfare, paying particular attention to the roles of the

[16] The size of the home country does not affect our main results. For all $n \leq 0.5$, the results are qualitatively the same and available upon request.

[17] Ruhl (2008) reconciled the difference by suggesting that in the international macroeconomics literature, the smaller values of θ correspond to the responses of quantities to transitory shocks, while the larger estimates in the trade literature often rely on responses of quantities to permanent changes in tariff and trade cost.

[18] The literature suggests the relevant range for ϵ is [1,25]. We plot welfare for ϵ in [1,10] because we want to illustrate clearly the welfare comparison at lower values of ϵ and because the welfare ranking of the three regimes for all ϵ in [10,25] is the same as that for $\epsilon = 10$.

elasticity of substitution between home and foreign final goods (θ) and between home and foreign intermediate goods (ϵ)

4.1.1 Unilateral Peg vs. Inflation Targeting

As indicated in Figures 3, 7, and 11, the home welfare under the unilateral peg increases with the elasticity of substitution between home and foreign intermediate goods (ϵ). This is because the pricing risks are always higher for home intermediate goods producers than for foreign intermediate goods producers, meaning that foreign intermediate goods are constantly cheaper than home intermediate goods in terms of price levels, although they are not always lower in terms of relative prices. In the case of a unilateral peg, while foreign intermediate goods prices are optimal because they replicate the flexible prices, home intermediate goods prices are much higher due to a complete absence of relative price adjustments. When the relative price of intermediate goods is fixed due to a fixed exchange rate and nominal price rigidity, the higher the substitutability between home and foreign intermediate goods (i.e., ϵ increases), the lower the expected demand for domestic intermediate goods, which reduces the expected level of labor. In other words, when home and foreign intermediate goods become more substitutable, final goods firms can produce the same amount of final goods using a more effective combination of home and foreign intermediate goods. On average, home households are expected to work less, which explains why the welfare of the unilateral peg is an increasing function of ϵ. This result can also be observed in Figures 15, 19, and 23. There, as ϵ rises, the welfare of the unilateral peg goes up for any given value of θ.

Under the inflation targeting regime, the home welfare has an interesting inverse U-shaped relationship with ϵ, which occurs mainly because there are two opposite effects at work. The first is the relative price effect. As home and foreign intermediate goods become more substitutable, the benefit of having an effective relative price adjustment at the intermediate goods stage increases, which raises the welfare of the inflation targeting regime. The second is a negative spillover effect associated with vertical production and trade. In this case, because the monetary authority targets PPI of intermediate goods, the exchange rate responds only to productivity shocks at the intermediate goods stage. Consequently, any movement in the exchange rate can cause an inefficient relative price adjustment for the final goods. For instance, suppose there is a positive productivity shock to the production of home intermediate goods, which causes the home currency to depreciate. Although prices are pre-fixed, the depreciation of home currency helps to improve efficiency by lowering the relative price of home intermediate goods. Nevertheless, this depreciation of home currency also makes home final goods cheaper. The world demand for final goods shifts toward those made in the home country, although there is no real fundamental change in the final goods sector. To meet the additional demand with the same technology, home final goods producers must use more intermediate goods, causing an excessive demand for the relatively less expensive home intermediate goods. To produce more home intermediate goods, home households must supply more labor, resulting in a decrease in their welfare. The negative spillover effect tends to dominate the relative price effect when home and foreign intermediate goods become more substitutable. Therefore, as ϵ increases, the welfare of the inflation targeting regime first rises then drops. Moreover, this inverse U-shaped relationship is robust to the value of θ.

There is a third effect—the pricing risk effect—that generates the inverse U-shaped relationship. Under inflation targeting, there is absolutely no pricing risk when home intermediate goods producers sell in the home market. There is also no pricing risk when foreign intermediate goods producers sell in both home and foreign markets because they practice PCP. Nevertheless, owing to LCP, there are still some pricing risks for home intermediate goods producers selling in the foreign market. As a result, home intermediate goods are more expensive than foreign intermediate goods in terms of price levels. Similar to the argument under unilateral peg, given the relative price of intermediate goods, the higher the substitutability between home and foreign intermediate goods, the higher the welfare of home households is because there is less demand for home intermediate goods, meaning less work for home households. Under the inflation targeting regime, however, this pricing risk effect has limited influence on welfare because, when the exchange rate is flexible, the relative price of intermediate goods varies with the underlying shocks in the economy.

From Figures 15, 19, and 23, we can see that home welfare under the unilateral peg is not affected by the elasticity of substitution between home and foreign final goods (θ) because a fixed exchange rate eliminates all relative price changes when prices are pre-fixed. Meanwhile, under inflation targeting, welfare decreases in θ. This is because targeting the producer price of intermediate goods in both countries allows for efficient relative price adjustments at the intermediate goods stage but not at the final goods stage. When home and foreign final goods become more substitutable (i.e., θ increases), the cost of lacking an efficient relative price adjustment at the final goods stage rises, making the flexible exchange rate regime less attractive.

These results show that, in general, for the home country, the unilateral peg dominates the inflation targeting regime, and this result is robust to the values of θ and ϵ. We can understand the results by focusing on the role of the nominal exchange rate in adjusting relative prices. In the face of external shocks, efficient production and consumption requires adjustment in multiple relative prices throughout the vertical chain of production and trade. However, with the nominal prices of intermediate and final goods pre-fixed, one exchange rate cannot simultaneously achieve efficient adjustments in multiple relative prices. Therefore, when prevalent nominal price rigidities and multiple relative prices exist, a flexible exchange rate regime coupled with inflation targeting has a limited ability to stabilize the entire economy.

4.1.2 Unilateral Peg vs. Monetary Union

The unilateral peg dominates the monetary union, except for cases where ϵ is close to 1 (see Figure 15). Because the exchange rate is fixed under both regimes, home welfare under the monetary union is also not affected by the elasticity of substitution between home and foreign final goods (θ), as shown in Figures 15, 19, and 23. Meanwhile, under the monetary union, the common central bank targets a weighted average of home and foreign intermediate goods. In this case, neither country's intermediate goods prices are optimal. Compared to the unilateral peg, pricing risks for the home (foreign) intermediate goods producers are smaller (larger) in the currency union. However, the reduction (increase) in the pricing risks for home (foreign) intermediate goods producers is very limited because the home country is much smaller than the foreign country. The common central bank gives a much higher weight to the foreign intermediate goods prices. As a result, home intermediate goods still cost more than their foreign counterparts in absolute terms under the monetary union. For the same reason as discussed in Section 4.1.1, home welfare under the monetary union is again positively related to the elasticity of substitution between home and foreign intermediate goods (ϵ), as shown in Figures 3, 7, and 11. Given the relative price of intermediate goods (i.e., due to single currency and nominal price rigidity), the higher the substitutability between home and foreign intermediate goods, the lower the weight for home intermediate goods in the optimal basket of all intermediate goods used to produce final goods. Therefore, home households are expected to work less, which leads to an improvement in their welfare. This result can also be found in Figures 15, 19, and 23. As ϵ rises, the welfare of the monetary union goes up for any given value of θ.

As previously discussed, the only difference between the monetary union and the unilateral peg is the risk premium included in the pricing of intermediate goods. From the unilateral peg to the monetary union, the pricing risks for home (foreign) intermediate goods producers fall (rise). Accordingly, home intermediate goods become relatively cheaper than foreign intermediate goods; that is, the positive gap between home and foreign intermediate goods prices decreases. As the world demand shifts from the foreign to the home intermediate goods, two contrasting effects are at work. On the one hand, as home income rises, home households consume more. On the other hand, home households have to work more, and this effect becomes stronger as home and foreign intermediate goods become more substitutable. From the home country's point of view, the unilateral peg regime tends to dominate the monetary union, especially for values of ϵ that are more empirically relevant, that is, $\epsilon > 1$.

Combining the results in Sections 4.1.1 and 4.1.2, we conclude that, for the home country, the unilateral peg regime generally ranks higher than both the inflation targeting regime and the monetary union.

4.2 Foreign Welfare

Figures 4, 8, 12, 16, 20, and 24 compare the foreign welfare under the three monetary regimes (i.e., inflation targeting, unilateral peg, and monetary union) for different values of ϵ and θ. For the same reasons discussed in Section 4.1, foreign welfare under the unilateral peg and the monetary union are not affected by θ, and the welfare under the inflation targeting is negatively related to θ. The relationships between welfare and θ in the foreign country mirror those in the home country. The foreign country differs in the relationship between ϵ and the welfare under various monetary regimes relative to the home country. With regard to the ranking of the three policy combinations, the foreign country's preference is exactly the opposite of that in the home country. For the foreign country, the inflation targeting regime ranks the highest and the monetary union ranks the second.

We already know that, regardless of which policy regime in place, foreign intermediate goods are always cheaper than home intermediate goods in terms of price levels. Given the relative price of intermediate goods, the higher the substitutability between home and foreign intermediate goods, the lower the welfare of foreign households is because they have to work more to meet the shift in demand. This echoes our previous findings with regard to home households. The negative effect of ϵ on foreign welfare (i.e., the price level effect), present in all three regimes, explains why foreign welfare under the unilateral peg and under the monetary union are decreasing functions of ϵ. It also accounts for the initial drop in foreign welfare under inflation targeting; in other words, the first part of the U-shaped between welfare and ϵ. Meanwhile, because the positive effects of exchange rate on the relative price adjustments between home and foreign intermediate goods (i.e., the relative price effect) increases with ϵ, as discussed in Section 4.1.1, foreign welfare under inflation targeting eventually increases with ϵ, explaining the second part of the U-shaped relationship. Note that there is no negative spillover effect for the foreign country due to LCP.

For the foreign country, the welfare ranking between the unilateral peg and the monetary union depends on the differences in the relative price between home and foreign intermediate goods. The larger the gap between home and foreign intermediate goods prices, the more labor the foreign households must supply. Consequently, the monetary union dominates the unilateral peg in the foreign country.

The ranking between the monetary union and the inflation targeting regime for the foreign country depends on both θ and ϵ. Intuitively, if home and foreign final goods are highly substitutable while the substitutability between home and foreign intermediate goods is poor (i.e., high θ but low ϵ), the benefit of having efficient relative price adjustments at the intermediate goods stage is limited. In this case, it is possible for the monetary union to outperform the inflation targeting regime, as illustrated in Figures 16, 20, and 24. Nevertheless, as discussed above, the most relevant range of the parameters is $\epsilon > \theta > 1$.

Overall, our results suggest that, for the foreign country, the inflation targeting regime tends to dominate both the unilateral peg and the monetary union.

5 Discussion

Our model finds that when a small open economy is subject to vertical trade and a high degree of exchange rate pass-through, it generally prefers to peg its currency to its large trade partner. The essence of our findings is a real tradeoff between the cost and benefit of a flexible exchange rate regime in an environment of vertical trade and high exchange rate pass-through. Specifically, the cost arises because shocks spill over across sectors in a system of vertical production and trade, making it difficult for a single flexible exchange rate to balance all international relative prices. We find that for small open economies in our model, this cost outweighs the benefit of having efficient relative price adjustments at the intermediate goods stage. Under these conditions, it is possible to make a case for the fixed exchange rate regime for these small open economies.

This result contrasts sharply with those in the NOEM literature, which often favor a flexible exchange rate regime. In this section, we argue that both vertical trade and a high degree of exchange rate pass-through are necessary for obtaining our result. Meanwhile, the asymmetry in pricing (i.e., the home country adopts LCP while the foreign country adopts PCP) is not crucial. Lastly, we argue that allowing for labor mobility across countries would not affect our main result.

To highlight the importance of the vertical trade channel, we conduct a simple experiment in which we shut down the productivity shocks to the final goods sector. To be specific, we set $\sigma_A^2 = \sigma_{A^*}^2 = 0$ and $\sigma_{\tilde{A}}^2 = \sigma_{\tilde{A}^*}^2 = 0.0001$. As a result, the only source of distortion left in the economy is the sluggish price adjustment at the intermediate goods stage. In this setup, with no shocks to the final goods production, one may expect the key findings of the standard models in the NOEM literature to hold, meaning that both countries would prefer to target the PPI of the intermediate goods. However, even with the shocks to the final goods neutralized, we find no qualitative change to our earlier results. To be precise, the home country still prefers a fixed exchange rate regime, while the foreign country mostly prefers an inflation targeting regime.[19]

Note that in this simple experiment, as in the benchmark results shown in section 3, only when the exchange rate pass-through is high will the vertical trade create substantial distortion to the relative prices of final goods in a flexible exchange rate regime. Once more, a combination of vertical trade and high exchange rate pass-through generates inefficient spillovers from the intermediate

[19] Detailed figures are in the technical appendix (available upon request).

goods sector to the final goods sector, even when intermediate goods prices are optimal and there are no shocks at the final goods stage to be mitigated. Specifically, similar to the discussion in Section 4.1, a flexible exchange rate responds to the intermediate goods sector's productivity shocks, creating changes in the relative prices of final goods for the home households who must buy foreign goods priced in the foreign (producer) currency. Such changes in the relative prices of final goods are undesirable because there are no shocks to the final goods sector. Meanwhile, because there is zero exchange rate pass-through to the foreign country, it is not affected by these negative spillovers and hence prefers a flexible exchange rate regime.

We emphasize that both features (vertical trade and high exchange rate pass-through) are necessary conditions for obtaining our results. To draw an analogy, the vertical trade structure creates the bridge for inefficient spillovers, but it is the vehicle of exchange rate that delivers these negative spillovers. If a country faces a high degree of exchange rate pass-through but no vertical trade, a flexible exchange rate regime is often optimal, as the standard NOEM literature states, because it is possible for the flexible exchange rate regime to achieve efficient adjustment in international relative prices in a single sector. If a country has a limited exchange rate pass-through, even if the bridge of vertical trade is there, no substantial spillovers will occur. This is exactly the case for the foreign country in our model.

In our model, the pricing behavior is asymmetric because the home country practices LCP while the foreign country practices PCP. To show that this setup is not driving our results, we also consider an alternative case in which the home country also adopts PCP. The corresponding results for the home country are reported in Figures 5, 9, 13, 17, 21, and 25, and the results for the foreign country in Figures 6, 10, 14, 18, 22, and 26. These figures clearly show that the home country still prefers the unilateral peg regime. As for the foreign country, when the home country practices PCP rather than LCP, the foreign country is subject to higher exchange rate pass-through. In this case, the value of a fixed exchange rate regime should be higher for the foreign country. This is confirmed by comparing Figures 6, 10, 14, 18, 22, and 26 to Figures 4, 8, 12, 16, 20, and 24, respectively. We can see that, when we assume PCP in the home country, for the foreign country the unilateral peg regime and the monetary union dominate the inflation targeting regime for a wider range of parameter values. In other words, for any given set of parameterization, it is more likely for the foreign country to prefer a fixed exchange rate regime when it faces a higher degree of exchange rate pass-through.

Our model assumes that labor is immobile across countries, while in reality labor is mobile, to different degrees, between large economies and their trade partners. Motivated by higher real wages and falling "mobility"costs, migration has increased substantially, especially from the South to the North (e.g., from Mexico to the United States and from CEECS to the developed countries in the EU). However, we argue that allowing for labor mobility in the model would not alter its key result because labor mobility is unlikely to eliminate the presence of vertical trade, an important feature for obtaining our results.[20]

In this paper, we posit the existence of vertical trade without modeling the underlying forces giving rise to vertical trade. As discussed in the trade literature, countries trade intermediate (and final) goods for reasons such as differences in endowments, disparities in technologies, and increasing returns to scale. In a standard Heckscher-Ohlin environment where trade is driven by differences in endowments, if factor movements are permitted, the production factor (being labor or capital) will seek a higher return and move from a country where it is relatively more abundant to a country where it is relatively scarce. In other words, migration has the potential to equalize endowments across countries, leading to a reduction in trade (Mundell, 1957). However, in more generalized setups where countries have different production technologies or there exist increasing returns to scale, imperfect competition, or other market distortions, migration can actually increase trade between countries, even if they begin with identical endowments (Markusen, 1983). Markusen (1983) showed that under a non-factor-proportions basis for trade, the relatively high-priced factor in each country is the one used intensively in the export good. Therefore, factor mobility fosters an inflow (outflow) of the factor used intensively in the exporting (importing) sector, and the resulting differences in factor endowments will lead to an increase in trade. More recent studies argued that migration and trade have a positive relationship due to the so-called information and network channel. Immigrants process valuable information about culture, market, law, and institution. Their presence contributes to the alleviation of information friction, facilitates communication and

[20] Another necessary feature is a high degree of exchange rate pass-through. Labor mobility is unlikely to change the choice of pricing currency, hence allowing for labor mobility would not affect the degree of exchange rate pass-through or our main results.

contract enforcement, and thus promotes trade by lowering the trade cost in general (Rauch, 1999, 2001; Rauch and Casella, 2003).

Obviously, trade theories do not provide a consensus answer to the relationship between migration and trade (including vertical trade). The related empirical literature, however, is much more consistent and generally confirms a protrade effect of migration mainly credited to the information and network channel discussed above (Bettin and Turco, 2012; Dunlevy and Hutchinson, 1999; Felbermayr and Toubal, 2012; Ghatak et al., 2009; Girma and Yu, 2002; Gould, 1994; Head and Ries, 1998; Peri and Requena-Silvente, 2010; Rauch and Trindade, 2002; Wagner et al., 2002). Although there is no direct evidence about the relationship between migration and the trade of intermediate goods, the empirical literature does suggest that a larger trade-creation effect is found for differentiated goods than homogeneous goods and for countries that are more culturally distant from each other, presumably because immigrants help to reduce the information cost in international trade the most under these circumstances. Furthermore, Peri and Requena-Silvente (2010) found that most of the increase in trade volume is due to an expansion of the extensive margin rather than the intensive margin.

Therefore, based on the relevant theory and empirical evidence, we believe that migration does not impair the presence of vertical trade, which is critical to our results.

6 Conclusion

In the literature regarding monetary policy for open economies, a flexible exchange rate regime is often considered optimal because the flexible exchange rate can facilitate efficient international relative price adjustments when prices are sticky. In this paper, we take into account two important features of many small open economies: vertical trade and the use of foreign currencies as pricing currencies. The first feature implies that there are multiple relative prices in international trade associated with different stages of production. The second feature implies that the level of exchange rate pass-through is high for these small open economies but low for their large trade partners. In this environment, it is difficult for a single exchange rate to adjust all relative prices efficiently at the same time, and the difference in exchange rate pass-through leads to different exposures to exchange rate risks. We show that the welfare comparison between flexible and fixed exchange rate regimes depends on the interactions between vertical trade and the degree of exchange rate pass-through. In particular, a small economy favors a fixed exchange rate regime over a flexible exchange rate regime, while its large trade partner generally favors a flexible exchange rate regime.

We should caution that the purpose of the paper is to highlight the important welfare effects of vertical trade and high exchange rate pass-through under different exchange rate regimes. Our results do not imply that small open economies with these features should unquestionably fix their exchange rates because the choice of monetary and exchange rate regimes should be based on a thorough consideration of various economic and political factors.

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Figure 1: Structure of the Model

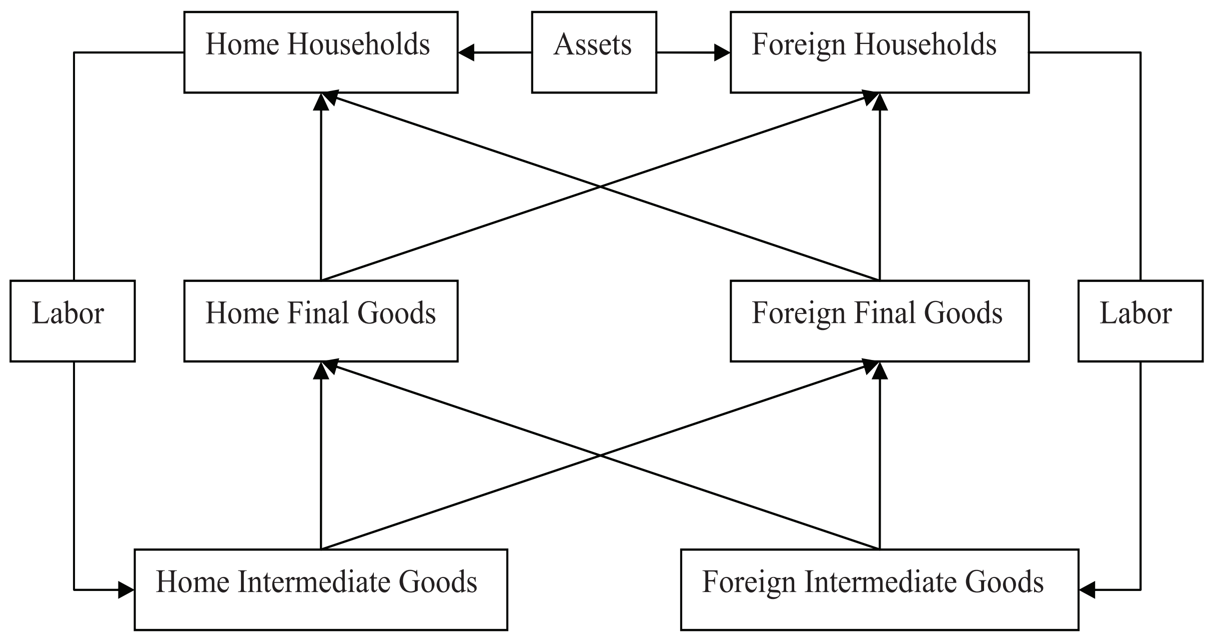

Figure 2: Timing of the Model

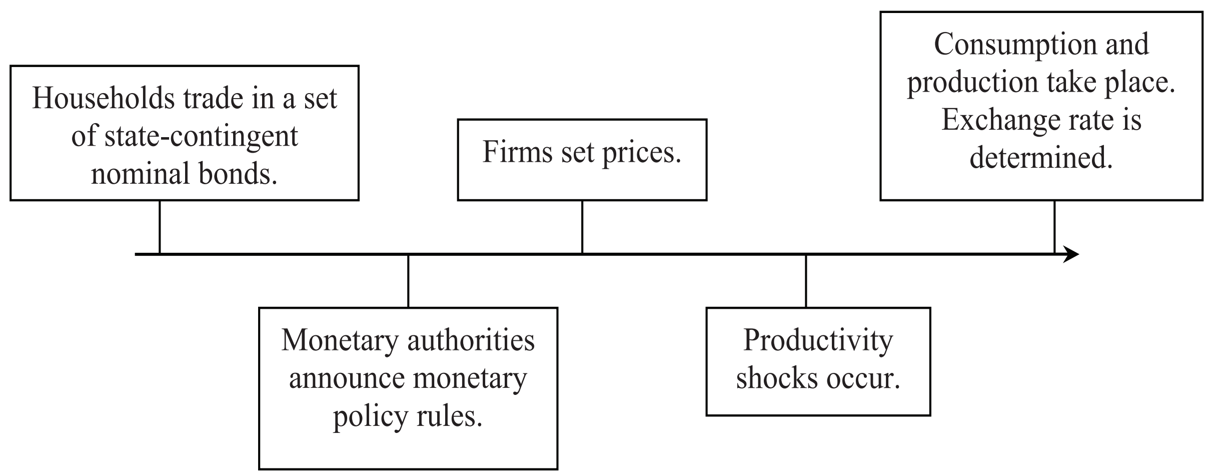

Figure 3: Home Welfare: LCP+PCP, $\theta = 1$, $\epsilon \in [1, 10]$

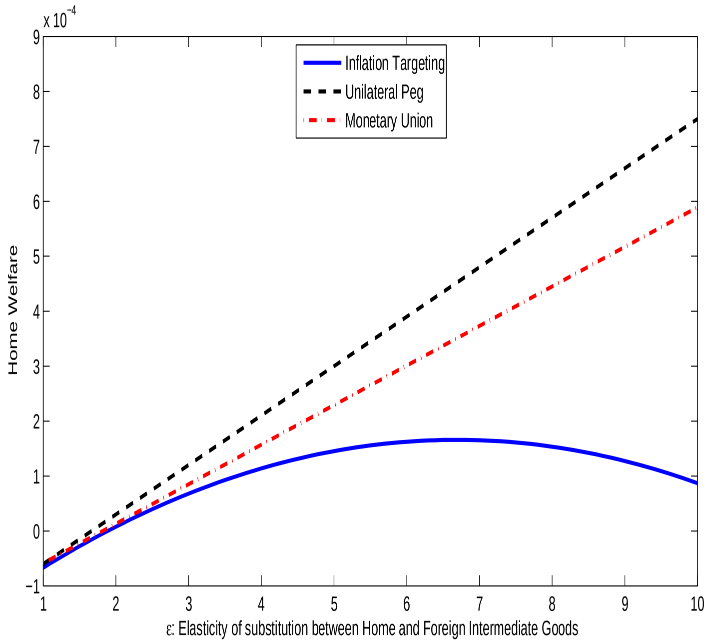

Figure 4: Foreign Welfare: LCP+PCP, $\theta = 1$, $\epsilon \in [1, 10]$

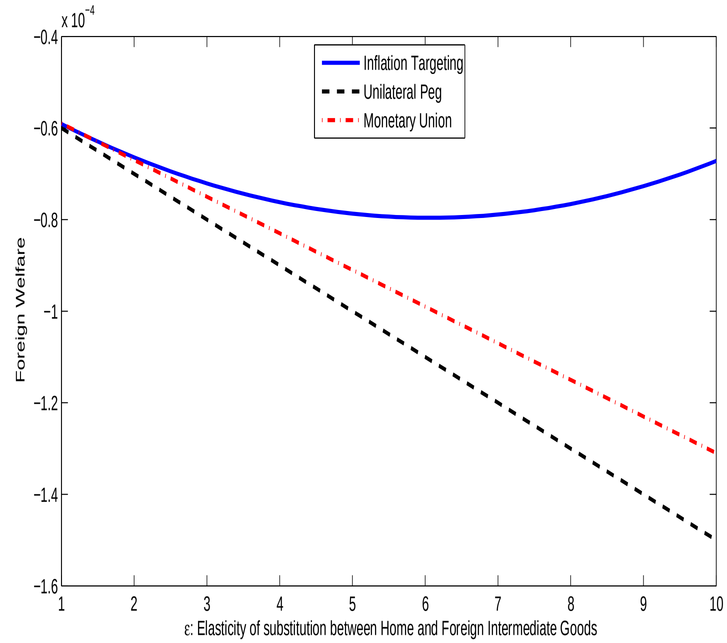

Figure 5: Home Welfare: PCP+PCP, $\theta = 1$, $\epsilon \in [1, 10]$

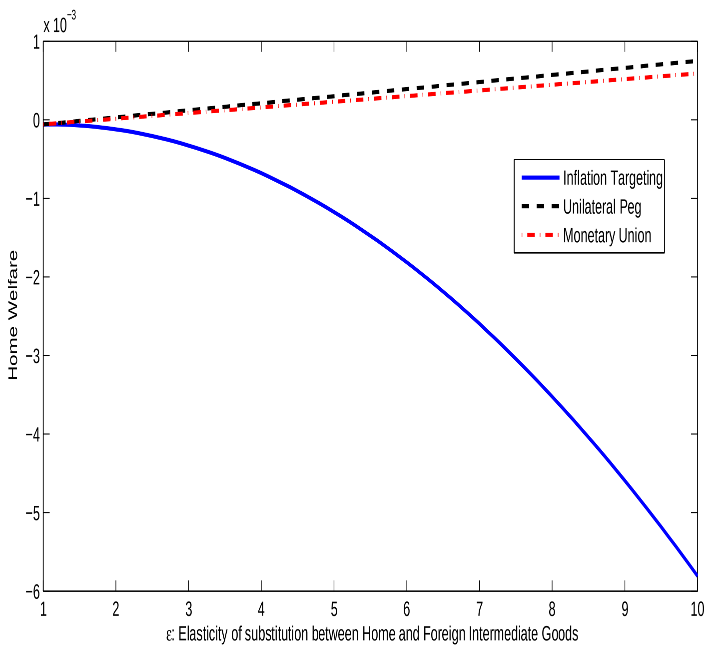

Figure 6: Foreign Welfare: PCP+PCP, $\theta = 1$, $\epsilon \in [1, 10]$

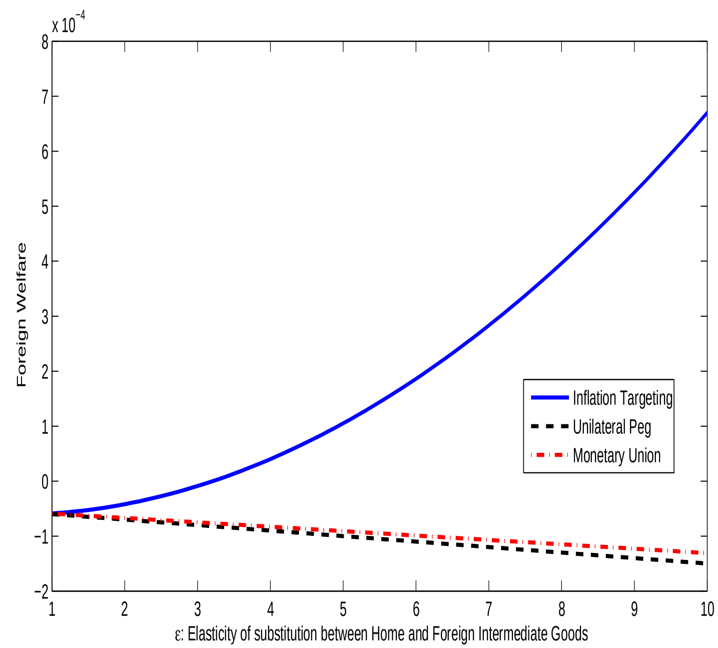

Figure 7: Home Welfare: LCP+PCP, $\theta = 2$, $\epsilon \in [1, 10]$

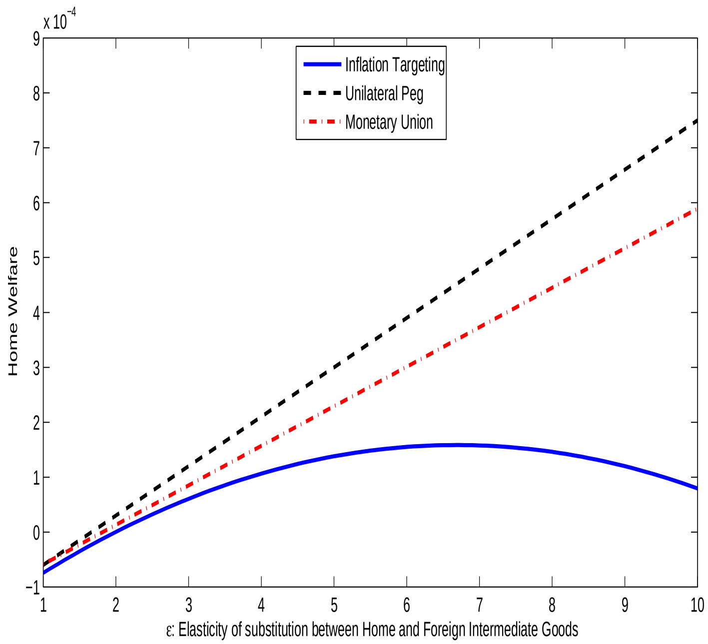

Figure 8: Foreign Welfare: LCP+PCP, $\theta = 2$, $\epsilon \in [1, 10]$

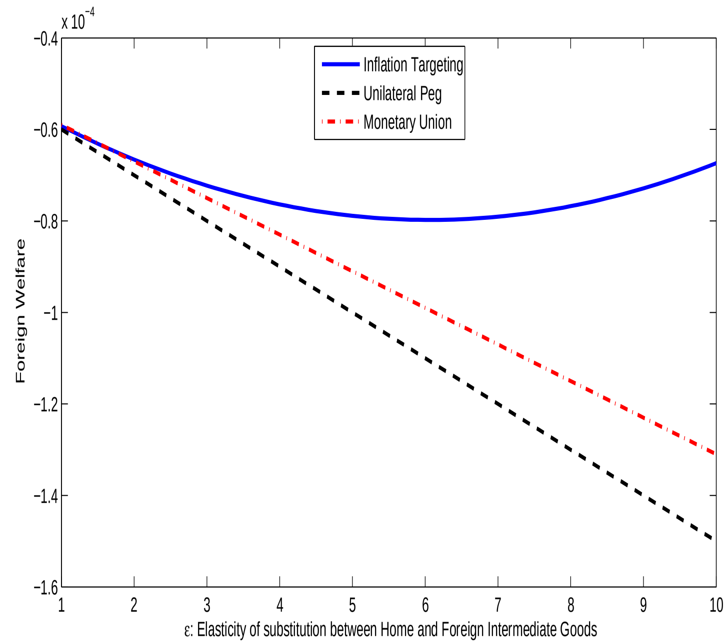

Figure 9: Home Welfare: PCP+PCP, $\theta = 2$, $\epsilon \in [1, 10]$

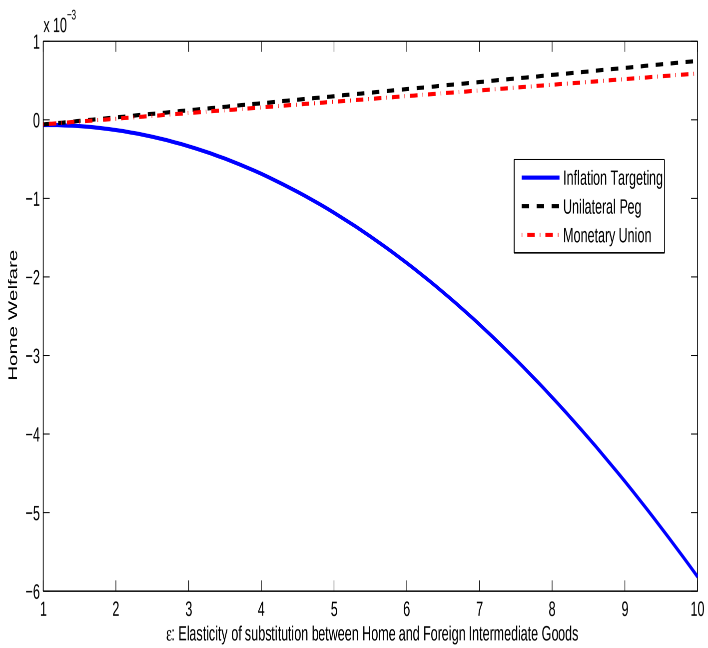

Figure 10: Foreign Welfare: PCP+PCP, $\theta = 2$, $\epsilon \in [1, 10]$

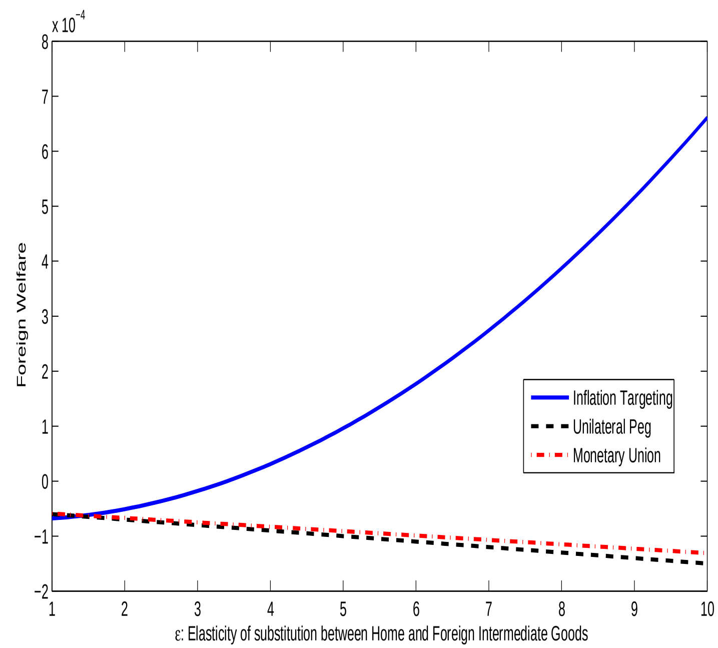

Figure 11: Home Welfare: LCP+PCP, $\theta = 5$, $\epsilon \in [1, 10]$

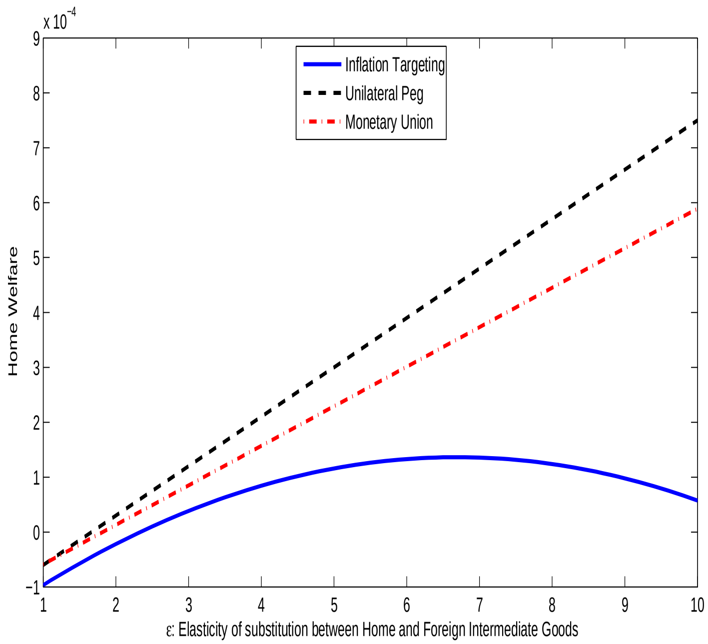

Figure 12: Foreign Welfare: LCP+PCP, $\theta = 5$, $\epsilon \in [1, 10]$

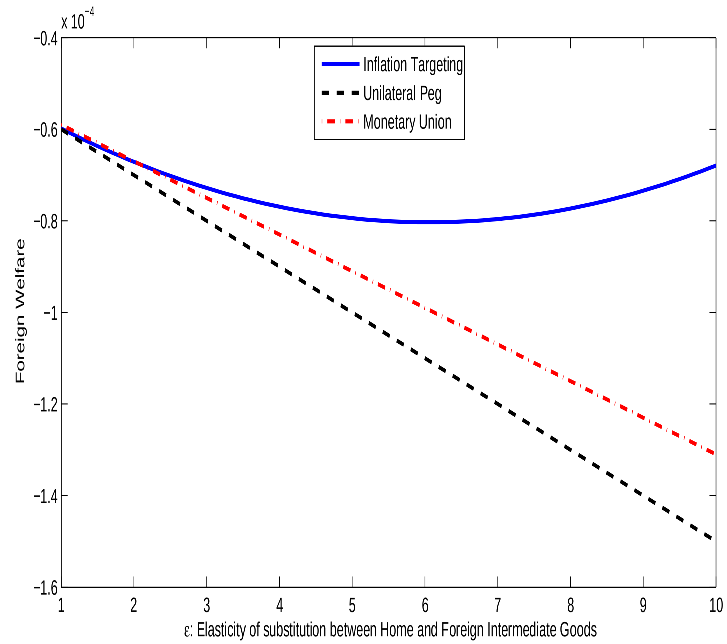

Figure 13: Home Welfare: PCP+PCP, $\theta = 5$, $\epsilon \in [1, 10]$

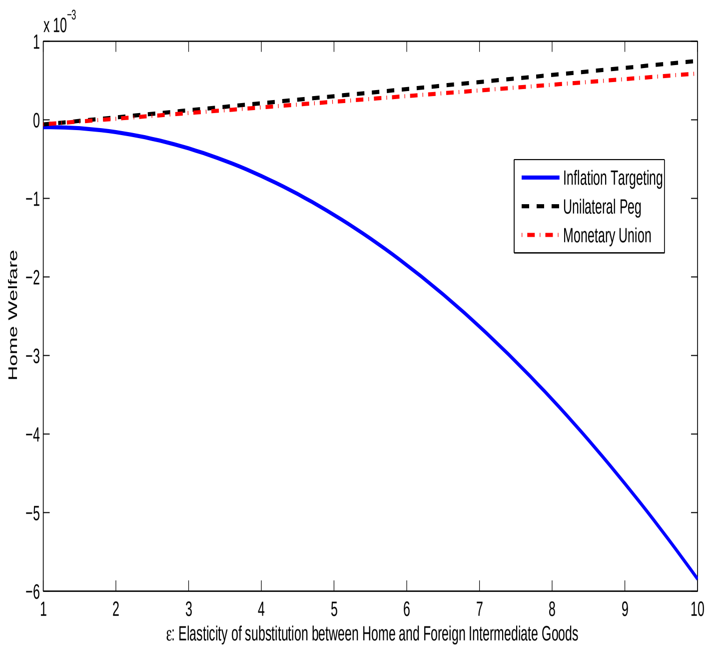

Figure 14: Foreign Welfare: PCP+PCP, $\theta = 5$, $\epsilon \in [1, 10]$

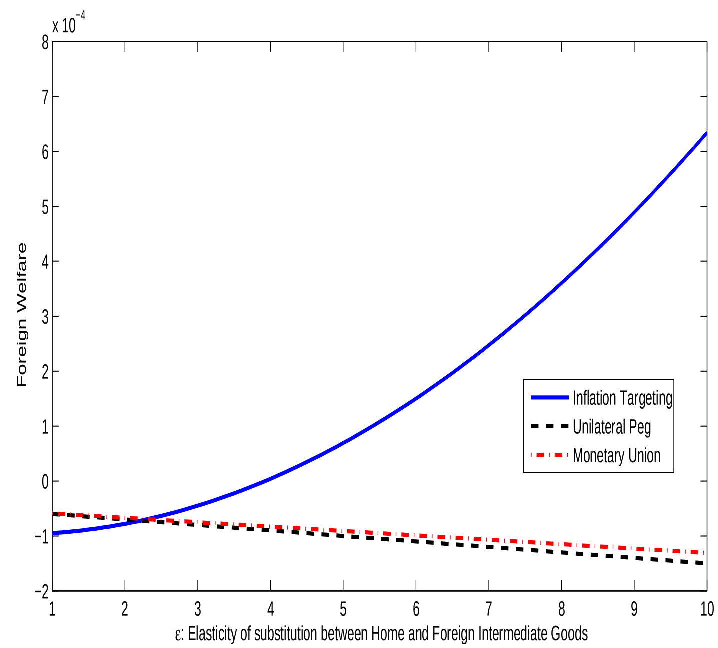

Figure 15: Home Welfare: LCP+PCP, $\epsilon = 1$, $\theta \in [1, 25]$

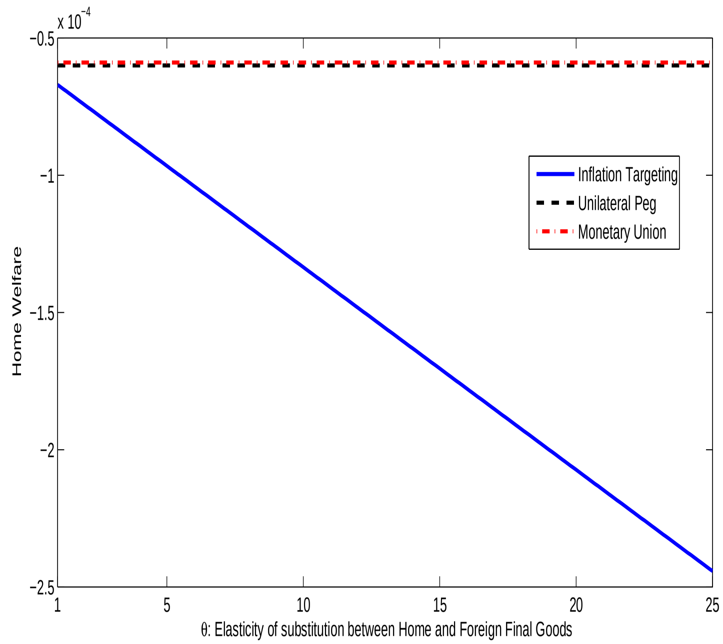

Figure 16: Foreign Welfare: LCP+PCP, $\epsilon = 1$, $\theta \in [1, 25]$

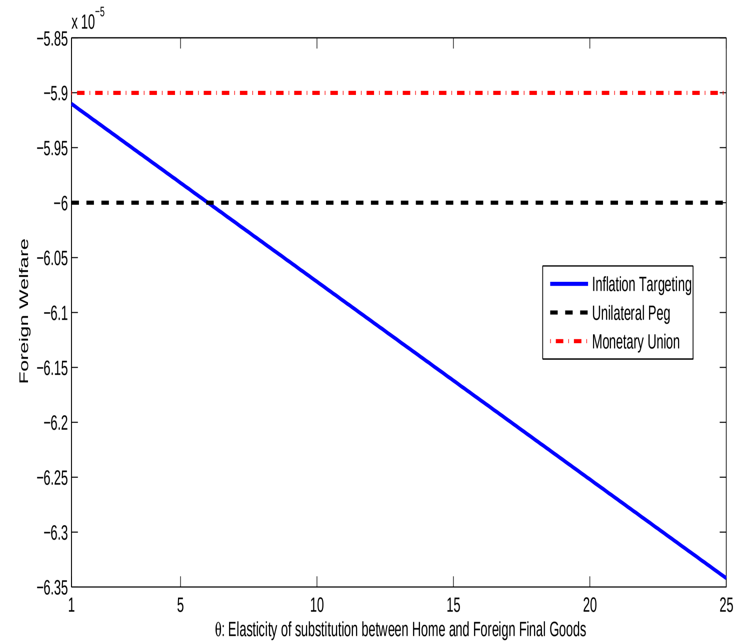

Figure 17: Home Welfare: PCP+PCP, $\epsilon = 1$, $\theta \in [1, 25]$

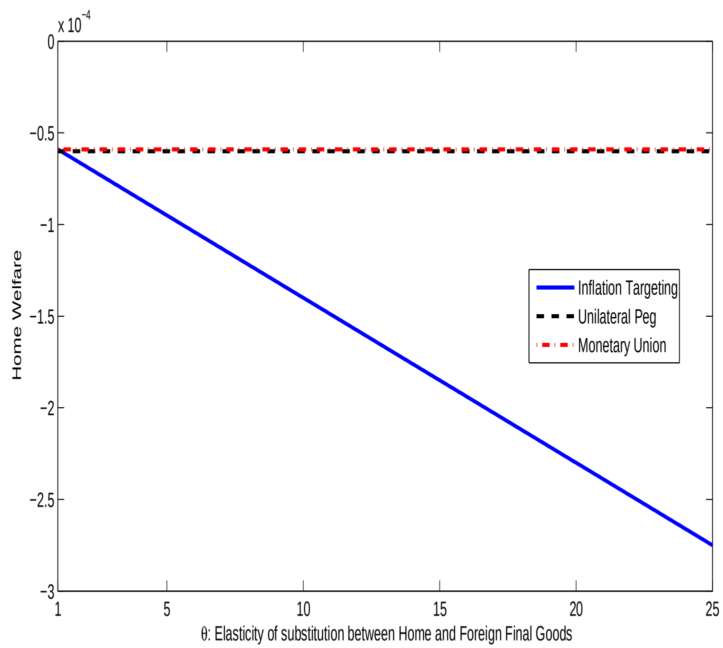

Figure 18: Foreign Welfare: PCP+PCP, $\epsilon = 1$, $\theta \in [1, 25]$

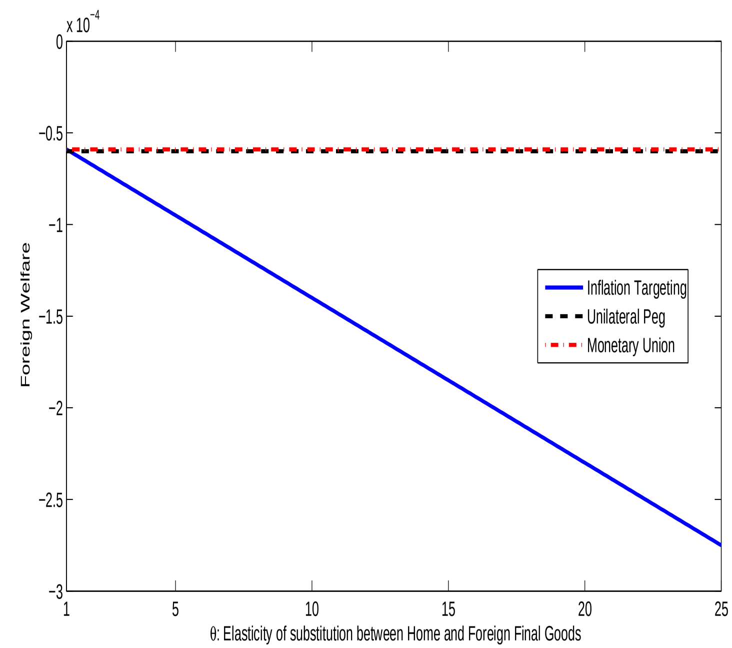

Figure 19: Home Welfare: LCP+PCP, $\epsilon = 2$, $\theta \in [1, 25]$

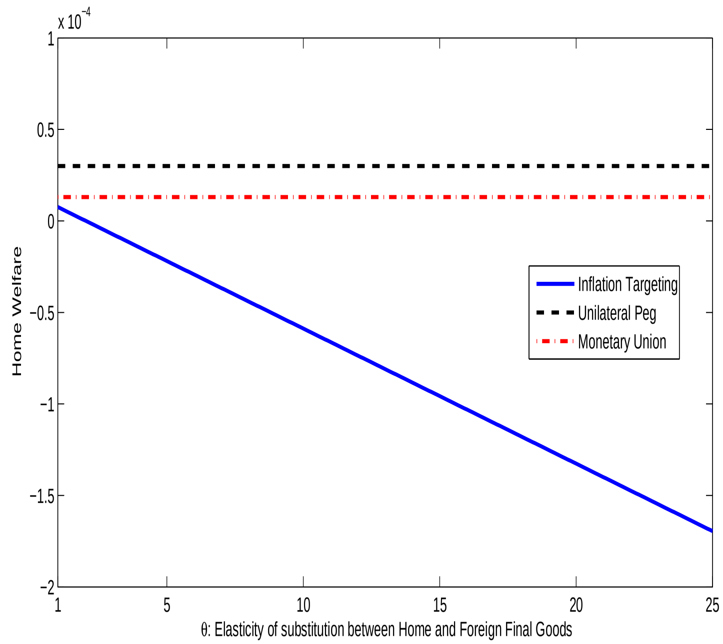

Figure 20: Foreign Welfare: LCP+PCP, $\epsilon = 2$, $\theta \in [1, 25]$

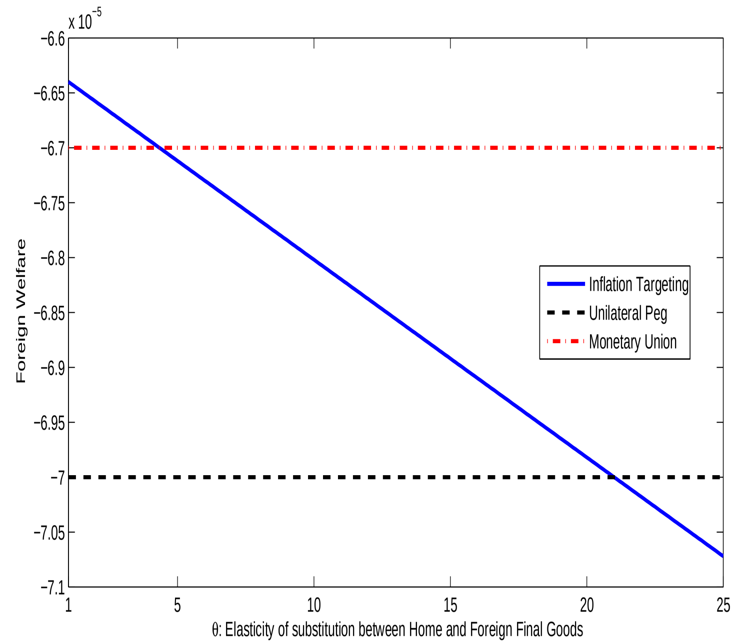

Figure 21: Home Welfare: PCP+PCP, $\epsilon = 2$, $\theta \in [1, 25]$

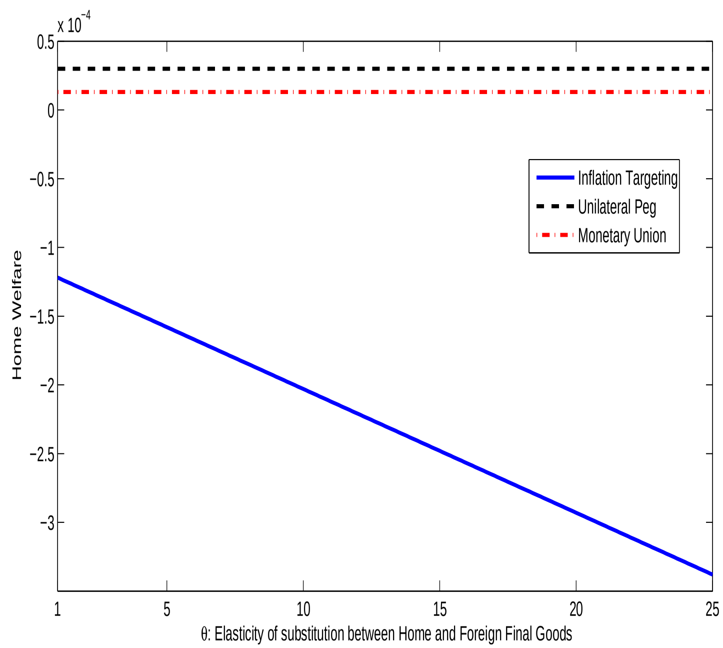

Figure 22: Foreign Welfare: PCP+PCP, $\epsilon = 2$, $\theta \in [1, 25]$

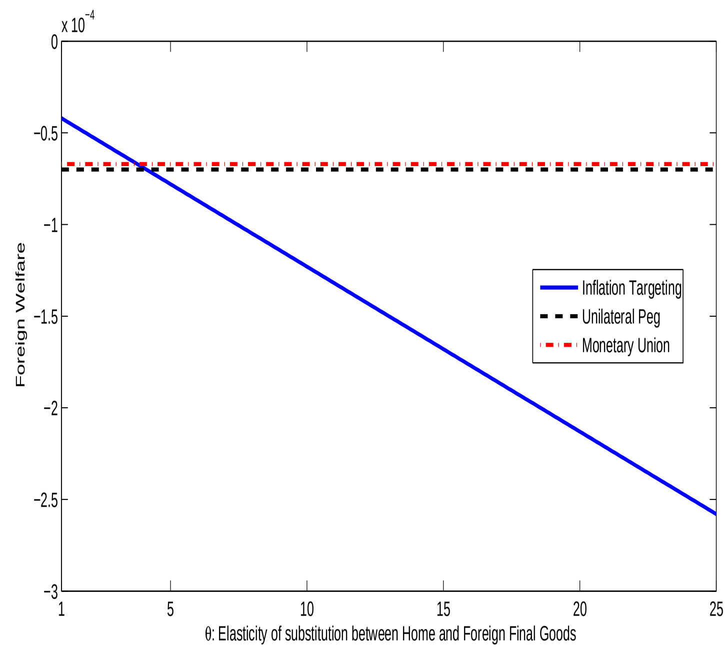

Figure 23: Home Welfare: LCP+PCP, $\epsilon = 5$, $\theta \in [1, 25]$

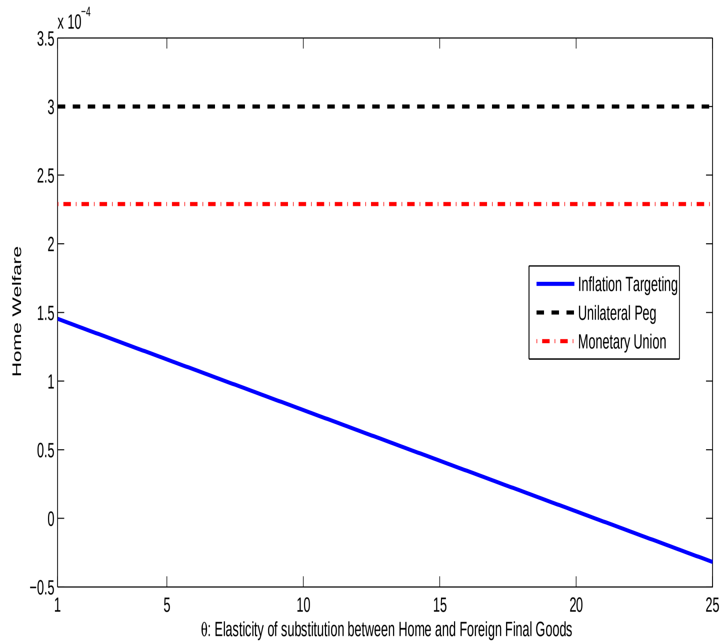

Figure 24: Foreign Welfare: LCP+PCP, $\epsilon = 5$, $\theta \in [1, 25]$

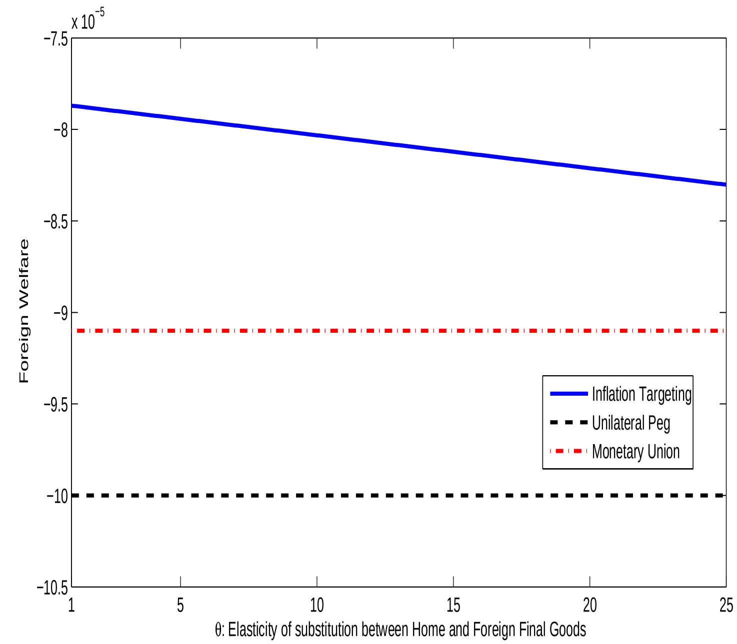

Figure 25: Home Welfare: PCP+PCP, $\epsilon = 5$, $\theta \in [1, 25]$

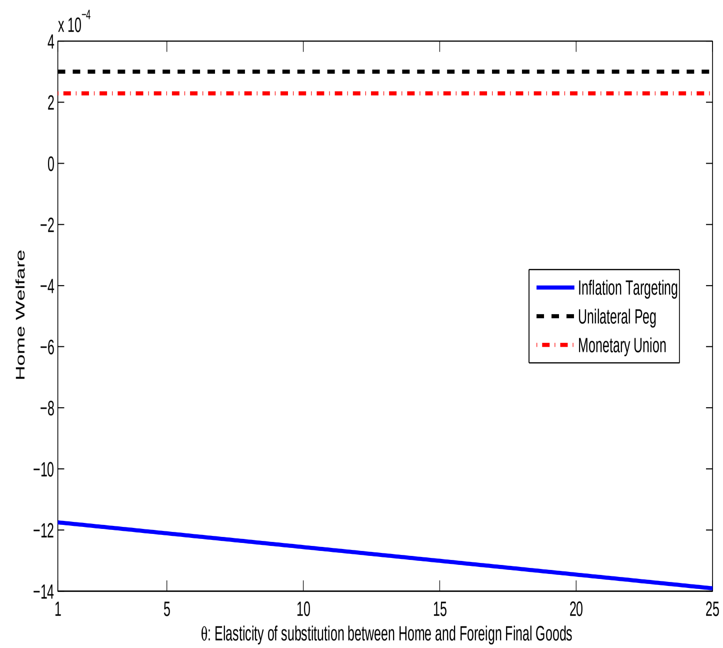

Figure 26: Foreign Welfare: PCP+PCP, $\epsilon = 5$, $\theta \in [1, 25]$