Twin Dollarization and Exchange Rate Policy *

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Abstract

This paper develops a small open economy general equilibrium model with nominal rigidities to study twin dollarization in East Asian economies, a phenomenon where firms borrow in US dollars and also set export prices in US dollars. In this model, we endogenize both the currency of liability denomination and the currency of export pricing. We show that a key factor that affects firms' dollarization decisions is exchange rate policy. Twin dollarization is an optimal strategy for all firms when exchange rate flexibility is limited, which implies that a fixed exchange rate regime may lead to an equilibrium with twin dollarization. Furthermore, we find that twin dollarization can reduce the welfare loss caused by the fixed exchange rate regime, as it helps to cushion the economy against domestic nominal risk.

JEL classification: F3, F4

Keywords: Twin dollarization; Exchange rate flexibility; Optimal strategy; Welfare

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1 Introduction

This paper is motivated by a frequently observed phenomenon in East Asian economies. On the one hand, the vast majority of lending to these emerging markets is denominated in foreign currencies, especially US dollars. On the other hand, most export goods in these economies are priced in US dollars as well. For instance, in Thailand, approximately 76 billion dollars was recorded as raised by Thai firms on international debt markets between 1992 and mid-1997, while only 3.2 percent was denominated in Thai baht. Meanwhile, about 90 percent of Thai export goods were priced in US dollars.[1] This phenomenon indicates the coexistence of liability dollarization and export pricing dollarization, which we refer to as "twin dollarization".

While considerable attention has been paid to the macroeconomic implications of liability dollarization and of export pricing dollarization, there are few papers that connect them together and investigate if some common cause exists. In this paper, we analyze this "twin dollarization" phenomenon formally and answer the following questions: Why do firms want to borrow in dollars and set export prices in dollars at the same time? Furthermore, if twin dollarization can be rationalized as an optimal strategy for firms, what is the inducement? Finally, what are the welfare implications of twin dollarization?

To address these questions, we first examine a single export firm's currency choices of export pricing and liability denomination in a stochastic environment, taking as given the distribution of exchange rates, interest rates, foreign demand, and the behaviors of other firms. Export firms are assumed to be monopolistically competitive, using intermediates to produce differentiated goods to export to the world market. They can set export prices either in domestic currency (pesos) or in foreign currency (dollars). Whatever currency they choose, firms must set their export prices before the state of the world is realized, and the prices cannot be adjusted immediately. To finance their intermediate goods purchases, firms need to borrow from international lenders. It is also assumed that the firms can choose to borrow either in domestic currency or in foreign currency *ex ante*. In such a setting, there will be four feasible (pure) strategies for every export firm, and each strategy represents a combination of the firm's currency choices for export pricing and debt contracts. We establish simple rules for currency strategies of the firm, which show that its currency choices for export pricing and debt contracts are related to each other.

We then place the export firms in a small open economy stochastic general equilibrium model where the exchange rate is endogenously determined by the central bank's monetary policy. This economy is subject to a foreign demand shock. In the presence of the external shock, we find that exchange rate policy is a key factor in determining firms' currency choices. When the economy is

[1] See Choi and Cook (2004) and Cook and Devereux (2006).

under a regime with low exchange rate flexibility, twin dollarization is an optimal strategy for all firms. In other words, a fixed exchange rate may lead to an equilibrium with twin dollarization. We also find that, as exchange rate flexibility increases, the degree of dollarization decreases. That is, few firms choose to borrow in dollars and set export prices in dollars. As a result, a floating exchange rate may lead all firms to borrow in domestic currency and set export prices in domestic currency.[2]

The intuition behind these findings is simple. In a stochastic economy, exchange rate policy determines how the absorption of external shocks is divided into changes in the domestic nominal interest rate and the exchange rate. Therefore, when the exchange rate policy is pre-announced and committed, the export firm can anticipate future nominal risks and their distribution, and then it can choose the currency strategy for export pricing and debt contracts accordingly *ex ante* to reduce these risks and achieve maximized expected profit.

More specifically, endogenous currency choices will help the firm to stabilize both market demand and the marginal cost. When monetary policy allows for higher exchange rate flexibility, the exchange rate is volatile and the domestic interest rate is relatively stable. Thus, the export firm will choose to borrow in domestic currency to avoid exchange rate risk, as it implies a more stable marginal cost. Meanwhile, by setting prices in domestic currency, the firm can stabilize the demand for its export goods, since in this case relative prices of export goods can be adjusted by exchange rates changes in face of demand shocks. Therefore, the optimal strategy for all export firms is to borrow in domestic currency and set export prices in domestic currency when exchange rates are flexible. In the opposite case with low exchange rate flexibility, exchange rate volatility is low and the domestic interest rate volatility is high. Therefore, the export firm can stabilize its marginal cost and avoid the volatile domestic interest rate by borrowing in foreign currency (dollars). Regarding the currency of export pricing, due to the lack of exchange rate flexibility, domestic currency pricing can not help the firm stabilize the demand for its goods. Meanwhile, when the firm sets export prices in domestic currency, its demand is directly sensitive to exchange rate movements, which may result in an increase in the firm's expected marginal cost, *ceteris paribus*. Hence, given a low exchange rate flexibility, the firm should choose to set export prices in dollars. Therefore, under a fixed exchange rate regime, twin dollarization is an optimal strategy for all firms.

Although twin dollarization is optimal for export firms when exchange rates are fixed, is it a beneficial arrangement for the whole economy in terms of welfare? Following Schmitt-Grohe and Uribe (2004), we use a perturbation method to calculate welfare, which is measured by the

[2]We also discuss firms' optimal currency strategies and the property of equilibria under intermediate exchange rate regimes in Section 5.

representative household's lifetime expected utility. In our model, the equilibrium under a flexible exchange rate regime implies higher welfare than the one under a fixed exchange rate regime, hence there is always a welfare loss associated with a fixed exchange rate regime. Nevertheless, given the fixed exchange rate regime, twin dollarization can deliver higher welfare than other currency strategies by dampening the welfare loss caused by the fixed exchange rate arrangement. This is because the welfare costs of moving to a fixed exchange rate regime are smaller once the endogenous behavior of firms is taken into consideration. Intuitively, under a fixed exchange rate regime, the exchange rate cannot insulate the economy from external shocks, so the economy is subject to both real shocks and nominal risks. But in an equilibrium with twin dollarization, some domestic nominal risks can be avoided and thus social welfare is improved. Quantitatively, for a calibrated East Asian small open economy, the welfare gain is about 0.0723% steady state consumption.

Our paper provides a new angle to study the dollarization phenomenon in East Asian emerging market economies. We relate two aspects of dollarization together and study their common cause, while most of the recent literature focuses solely on the macroeconomic implication of liability dollarization. For example, see Calvo and Reinhart (2002), Aghion, Bachetta, and Bannerjee (2001), Calvo (2000), and Cespedes, Chang, and Velasco (2004). In this paper, we emphasize that the fixed exchange rate regime causes twin dollarization, instead of Calvo and Reinhart's suggestion (2002) that liability dollarization leads to "fear of floating". In this sense, we show a new linkage between exchange rate policy and dollarization.[3] We also show that there exists a welfare gain from twin dollarization under a fixed exchange rate regime, which is different from the welfare implications of liability dollarization in most financial crisis literature.

This paper is also closely related to two other lines of literatures. With respect to the endogenous currency of pricing, we follow the approach used by Devereux, Engel, and Storgaard (2004). They endogenize the currency of export pricing and show that exporters wish to set prices in the currency of the country with a relatively stable monetary policy.[4] Our paper differs from theirs in two key dimensions. First, we focus on a small open economy and study how exchange rate flexibility affects firms' currency of export pricing. Second, we illustrate a channel through which the currency of debt denomination can affect the firm's marginal cost and the currency choice of export pricing.

Another line of research that is related to this paper is the literature on endogenous liability

[3]Other papers have also found that fixed exchange rates can be conductive to liability dollarization. For example, Chang and Velasco (2006) presents a model in which causality runs both ways. However, they focus on liability dollarization while we emphasize twin dollarization.

[4]Engel (2006) discusses the parallels between the choice of invoicing when prices are sticky and the optimal degree of exchange rate pass-through when prices are flexible.

denomination.[5] Our work differs in several aspects. First, most papers in this literature argue that foreign currency debt exists because of market or institutional failure in emerging market economies; see, for example, Jeanne (2000, 2005), and Caballero and Krishnamuthy (2003). Instead, we show that dollarization can be the result of firms' optimization behavior and that exchange rate policy is a key factor affecting firms' decisions. Second, our general equilibrium model setting has a natural advantage over papers based on partial equilibrium or reduced form models, since it allows for welfare analysis.[6] Finally, we investigate the common cause of two aspects of dollarization, instead of analyzing liability dollarization in isolation.

This paper is organized as follows. Section 2 describes some stylized facts of twin dollarization in East Asian economies. Section 3 sets out the decision problem of a single export firm in a stochastic environment and establishes the rules for the determination of the currency of export pricing and liability denomination. Section 4 presents the general equilibrium model. Section 5 solves the model and shows how the firm's dollarization decisions can be affected by exchange rate policy. Section 6 discusses the welfare implications. Section 7 concludes the paper.

2 Stylized Facts

A frequently observed fact in East Asian economies is that firms borrow externally in foreign currency and set their export goods prices in foreign currency as well. Since the US dollar is the dominant foreign currency, we refer to this phenomenon as "twin dollarization". It reflects the fact that, in contrast to the practice of firms in developed countries, firms in emerging market economies seldom use their own currency in the goods and financial markets when trading with the rest of the world.

Evidence of "twin dollarization" is given in Tables 1 and 2. Table 1 reports the use of foreign currency in export pricing (invoicing currency) in selected countries.[7] For East Asian economies, we report data from Korea, Thailand, Malaysia, and Indonesia. The selected developed countries are the US, Germany, Japan, the UK, France, and Italy. The striking feature of Table 1 is that East Asian economies seldom use their domestic currency as the currency of export pricing. In particular, for Korea and Thailand, almost all of their export goods are priced in foreign currency,

[5] There is also a presumption in the literature that developing countries cannot borrow in local currency. Some call it the "original sin". Here, we make a different point: there are well-defined economic reasons for why firms in developing countries may not want to borrow in local currency even if they could.

[6] Chamon and Hausmann (2005) also argue that the central bank's preference may affect a firm's choice of liability denomination in a reduced form model.

[7] Data on invoicing currencies are not available for every country, so we focus on the available data set in selected countries. Nevertheless, we believe that these countries are representative of East Asian economies and developed economies.

mostly in US dollars. By contrast, the share of domestic currency invoicing is much higher in the developed countries. Even in Italy, about 40 percent of exports are priced in Italian lira.

Table 2 presents the currency composition of the external debts of the same set of countries. From Table 2, we can see that the external debts of the East Asian economies are mainly denominated in foreign currency, while in developed countries, the share of domestic currency denominated external debt is much higher. Although the data in Table 2 include both public debts and private debts, statistics show that the share of private debts to total external debts is quite high in East Asian economies. For example, data from the Japanese Ministry of Finance show that 81.3% of Thailand's external debts and 98.5% of Korea's external debts were private debts at the end of 1996. Therefore, it is reasonable to infer that most private debts raised by firms in East Asian economies are denominated in foreign currencies. This argument is also well supported by other observations in Thailand and Korea: of the approximately 76 billion dollars recorded as raised by Thai firms on international debt markets between 1992 and mid-1997 (according to the IFR Platinum database), about 3.2% was denominated in Thai baht. During the same period, less than 1% of the approximately 144 billion dollars recorded as raised by Korean firms was denominated in Korean Won (Choi and Cook 2004). We also report the detailed currency composition of the external debts of selected East Asian countries in 1997. The dominant use of the US dollar in emerging market debt denomination is clear.

From Table 1 and Table 2, it can be seen that firms in East Asian emerging market economies tend to follow both export pricing dollarization and liability dollarization, which contrasts with borrowing and export pricing behavior of firms in developed countries. Thus, the special role of the US dollar in the global economy could not solely account for the twin dollarization phenomenon. Some other common characteristics in East Asian economies are needed as the explanation.

Devereux, Engel, and Storgaard (2004) show that monetary policies affect the currency of export pricing in a two-country open economy framework. This implies that for a small open economy exchange rate policy may also affect firms' currency choices of export pricing and liability denomination. Meanwhile, empirical evidence shows that there exists a strong and extremely robust positive correlation between the ability to borrow in domestic currency and the degree of exchange rate flexibility in emerging market economies (Hausmann, Panizza, and Stein 2001, 2002). Therefore, a possible explanation for twin dollarization is exchange rate regimes in these economies. Before the 1997-98 Asian crisis, East Asian economies like Hong Kong, Indonesia, Korea, Malaysia, the Philippines, Singapore, Taiwan, and Thailand all pegged their exchange rates to the US dollar. The exchange rate regimes ranged from a currency board hard peg in Hong Kong to a sliding or crawling peg in Indonesia. Although these pegs were often not openly admitted or were disguised as currency baskets, the common adherence to the dollar was easy

to recognize. On the other hand, the developed countries discussed here all adopted a flexible exchange rate regime. The volatilities of East Asian currencies were usually much lower than those of the major currencies.

Can the low exchange rate flexibility in East Asian economies explain the twin dollarization phenomenon? If this were the case, then we would observe decreases in export pricing dollarization and liability dollarization in some Asian counties since they floated their exchange rates after the financial crisis. In other words, the share of domestic currency pricing and domestic currency debt would be expected to rise when the exchange rate flexibility increased in these counties.

Goldstein and Turner (2004) show that a substantial shift took place in the foreign banks' lending market in the Asia-Pacific from 1997 to 2002. The domestic currency lending increased by $70 billion, while foreign currency lending fell by $183 billion. Thus the share of local currency lending by foreign banks has increased significantly since 1997. The data regarding export pricing are quite limited, but Fukuda and Ono (2005) provide some evidence that supports this trend. In Korea and Thailand, the share of foreign currency pricing decreased by 4.2% and 1.8% from 1998-2000, respectively. Nevertheless, without long-term historical data, it is difficult to investigate further empirical correlation between exchange rate flexibility and the degree of dollarization, so we leave rigorous empirical analysis for future research. In the following discussion, we focus on the theoretical investigation. The currency choices for both export pricing and liability denomination are endogenized to explore how exchange rate flexibility affects firms' dollarization decisions.

3 The Decisions of an Export Firm

To establish an export firm's optimization problem clearly and explicitly, following Devereux, Engel, and Storgaard (2004), we first describe the decision problem of a single monopolistically competitive exporting firm in a partial equilibrium setting. We develop conditions on variables that are exogenous to the firm, under which the firm will choose the currency (the domestic currency is called peso and the foreign currency is called dollar) of export pricing and liability denomination. Then in the next section, we consider a general equilibrium small open economy model where export firms face precisely the same type of demand curve, exogenous shocks, and cost functions as does the firm in this section.

The export sector is monopolistically competitive and contains a unit interval [0,1] of firms indexed by i. Each firm i in this sector sells a differentiated good to the world market and faces a downward-sloping demand function,

$$Y_{xt}(P^*_{xt}(i)) = (\frac{P^*_{xt}(i)}{P^*_{xt}})^{-\lambda}\frac{X_t}{P^*_{x_t}}, \tag{3.1}$$

where $P^*_{xt}(i)$ is the price that the foreign consumer pays for the export good i in period t, and P^*_{xt} is the price index for all export goods sold in the world market. X_t is assumed to be a stochastic foreign demand shift term. Without loss of generality, let $P^*_{xt}(i)$ and P^*_{xt} be denominated in dollars. The demand structure implies that foreign demand for the aggregate domestic export good is unit elastic, and each firm's own elasticity of demand is λ, where $\lambda > 1$.

In the export sector, firms produces with both labor and domestically produced intermediate goods. The production technology for firm i is given by

$$Y_{xt}(i) = AL_{xt}(i)^{1-\omega} I_{xt}(i)^{\omega}, \tag{3.2}$$

where $A = \frac{1}{\omega^{\omega}(1-\omega)^{1-\omega}}$ is a constant productivity term, and $L_{xt}(i)$ and $I_{xt}(i)$ represent the labor and intermediate goods used in the production of good i, respectively. ω is the share of intermediate goods in the production of export goods.

Each export firm i sets export goods prices to exploit its monopoly power, and chooses the currency in which to set prices. Whatever currency is chosen, the firm must set its export price to maximize expected discounted profits before the state of the world is realized. In addition, following Devereux, Shi, and Xu (2007), we assume that the firm incurs a fixed nominal cost *ex post*, when the price facing consumers is adjusted. These costs might be thought of as menu-changing costs, or customer resistance costs, that require management services on the part of the firm. Hence, if the export firm sets the price in the local currency of the buyer, it will not face these costs, as the price to the buyer will be sticky in the short run. But if the price is set in the export firm's own currency, prices facing the foreign consumer will be dependent upon the exchange rate. Therefore, if the firm sets prices in pesos, then it faces a fixed nominal cost.[8]

It is also assumed that the export firm has to borrow externally to finance the purchases of intermediate goods. In addition, the currency of liability denomination must be chosen by the firm *ex ante* as well.

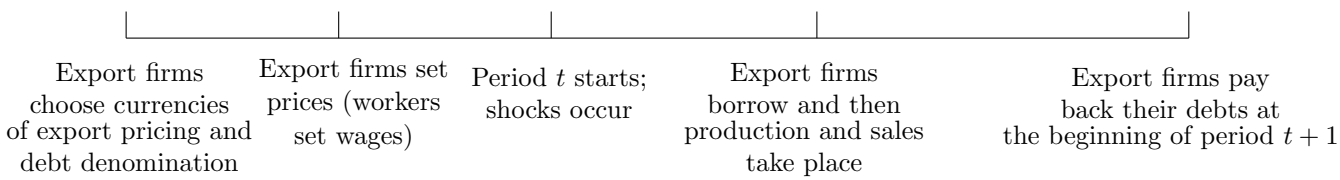
3.1 Timing

The timing of events is shown in Figure 1. Before the start of period t, export firms choose the currency in which to set their export good prices and the currency in which to contract their external debts. After that, they set prices to maximize expected discounted profits, based on the discount factor, and the anticipated market demand and marginal cost. When period t starts and

[8]The introduction of this fixed cost can make our result of twin dollarization more robust. In addition, it can solve the problem that when the exchange rate is completely fixed ($\sigma_s^2 = 0$), the firm is indifferent to the domestic currency pricing and foreign currency pricing. As shown in later analysis, only an extremely small fixed menu cost is needed. So the presence of the fixed cost is not essential to the export firm's currency choice.

external shocks occur, export firms will borrow to buy intermediate goods for production.[9] Then, production (and consumption) and sales take place. The debts are paid back to international lenders at the beginning of period $t+1$, but the payments depend on the debt contract the firm chose before.[10]

Figure 1: Timing of Events



In Figure 1, we can see that, in every period, any export firm's *ex ante* optimization problem is a simple two-stage decision problem. Before the start of period t, in Stage 1, the firm chooses the currency of export pricing and the currency of debt denomination to maximize the expected profit. In Stage 2, given the currency strategy chosen in Stage 1, the firm presets the optimal prices. The currency of debt denomination will affect the marginal cost of the export firm, and the currency of export pricing will affect the demand faced by the firm. Hence, before discussing optimal currency choices, we analyze the export firm's expected profits and show how currency choices affect the marginal cost, the demand, and the expected profit faced by the firm.

3.2 The Firm's Optimization Problem

In each period t, firm i's cash flow is given by

$$\Pi_{xt}(i) = P_{xt}(i)Y_{xt}(i) - W_t L_{xt}(i) - P_{It} I_{xt}(i) + D_t(i) - DP_t(i) - \varphi(i)\phi, \tag{3.3}$$

where P_{xt} is the price (in terms of domestic currency) of export goods i, W_t and P_{It} are nominal wage and domestic intermediate goods price faced by firms, respectively. $D_t(i) = P_{It} I_{xt}(i)$ is the loan that the firm borrows for the purchase of intermediate goods in period t, while $DP_t(i)$ is the payment for the loan the firm borrowed in period $t-1$, which depends on the debt contract that the firm chooses. ϕ is the nominal fixed cost firm i pays if it sets export price in pesos.[11] The dummy variable $\varphi(i) = 1$ if firm i chooses domestic currency pricing; $\varphi(i) = 0$ otherwise.

[9] In the general equilibrium model, workers preset their wages *ex ante*, before shocks occur. Then, in period t, they supply labor and choose their optimal consumption baskets and domestic bond holdings.

[10] Before period $t+1$ starts, the export firms also decide currency choices for debt contract and export pricing and set export prices for period $t+1$.

[11] The fixed cost is paid to foreign firms who provide management services when sales take place.

The firm chooses the currency of export pricing and debt denomination and presets prices *ex ante* to maximize its expected profits, $E_{t-1}\sum_{l=0}^{\infty}[\beta^{t+l}\frac{d_{t+l}}{d_{t-1}}\Pi_{xt+l}(i)]$, where d_t is the stochastic discount factor faced by firms in period t. Since the firm's currency choice decision is made period by period and it does not choose the optimal amount of loans, the firm's choice in each period is independent of previous choices. Therefore, the dynamic problem boils down to a sequence of one-period profit-maximization problem. Maximizing $E_{t-1}\sum_{l=0}^{\infty}[\beta^{t+l}\frac{d_{t+l}}{d_{t-1}}\Pi_{xt+l}(i)]$ is then equivalent to maximizing the following expected profit function

$$\max E_{t-1}[d_t Q_t(i)], \tag{3.4}$$

where $Q_t(i) = P_{xt}(i)Y_{xt}(i) - W_t L_{xt}(i) - \beta\frac{d_{t+1}}{d_t}DP_{t+1}(i)$.

Given the optimal currency strategy chosen *ex ante* and the preset prices, in period t, the firm also chooses labor and the amount of intermediate goods to maximize $E_t\sum_{l=0}^{\infty}[\beta^{t+l}\frac{d_{t+l}}{d_{t-1}}\Pi_{xt+l}(i)]$, which is equivalent to maximizing $E_t[d_t Q_t(i)]$.

3.3 The Currency of Debt Contracts and Marginal Cost

To finance the purchases of intermediate goods, the firm must borrow from the international capital market, represented by a continuum of international lenders. It is assumed that two types of debt contracts are provided by these lenders.[12] One type is contracted in pesos, and the other type is contracted in dollars. The export firm can borrow in either pesos or dollars, but the debt contract must be chosen *ex ante*. The presence of external shocks implies that the firm has to take some risk in financing and the risk is contingent on the debt contract. The amount of the loan (in terms of domestic currency) that firms need to borrow, D_t, is equal to the bill for intermediate goods purchase, $P_{It}I_{xt}$, where firms take P_{It} as given.

It is assumed that, if the firm borrows in pesos, the gross interest rate is $1 + i_{pt}$; if the firm borrows in dollars, the gross interest rate is $1 + i^*_{dt}$. Both $1 + i_{pt}$ and $1 + i^*_{dt}$ are contingent on the *ex post* domestic interest rate i_t and the world interest rate r^*_t between period t and $t + 1$. This assumption implies that one cannot write a peso or dollar contract in terms of a fixed interest rate. It captures the fact that borrowing through short-term debt makes the firm vulnerable to interest rate risks.[13] We further assume that the gross interest rate of the domestic currency debt is more

[12]The process of contract negotiation between international lenders and firms is not modeled, since our focus is to study how the firm chooses a debt contract, given the menu of contracts. We assume that contracts are exogenously posted by international lenders, and firms' choices in this small open economy have no effect on the design of contracts.

[13]McKinnon and Schnabl (2004) explain why firms in developing countries cannot borrow at a fixed interest rate. This is because these firms tend to be small and has no well-developed accounting systems. Therefore, even firms with longer term projects must roll over short-term bank loans, or, at best, borrow at the medium term with the

sensitive to the domestic interest rate than the world interest rate, while the gross interest rate of the foreign currency debt depends more on the world interest rate than the domestic interest rate. In particular, we assume the functional forms of $1 + i_{pt}$ and $1 + i^*_{dt}$ are respectively, as follows,

$$1 + i_{pt} = (1 + i_t)^{\alpha_p}(1 + r^*_t)^{1-\alpha_p} \tag{3.5}$$

$$1 + i^*_{dt} = (1 + i_t)^{\alpha_d}(1 + r^*_t)^{1-\alpha_d}, \tag{3.6}$$

where $\alpha_p > \frac{1}{2} > \alpha_d \geq 0$.[14] This also implies that $1 + i_{pt}$ is more sensitive to the domestic interest rate than $1 + i^*_{dt}$, while $1 + i^*_{dt}$ is more sensitive to the world interest rate than $1 + i_{pt}$.

Therefore, given these debt contracts, if the firm borrows in pesos, then the debt payment in period $t + 1$ in terms of pesos is given by

$$DP_{t+1}(i) = D_t(i)(1 + i_{pt}). \tag{3.7}$$

If the firm borrows in dollars, the export firm needs to borrow $\frac{D_t(i)}{S_t}$ to finance the purchase of intermediate goods. Since the debt is paid back at the beginning of period $t + 1$, the debt payment in terms of pesos is

$$DP_{t+1}(i) = \frac{D_t(i)}{S_t}(1 + i^*_{dt})S_{t+1}. \tag{3.8}$$

Given the export firm's production technology, the firm will choose labor and intermediate goods to minimize its expected costs (or maximize $E_t(d_t Q_t(i))$). This implies that the present value of the marginal cost at time t[15], MC_t, equals to $W_t^{1-\omega} q_t^{\omega}$, where q_t is the present value of the expected unit cost of intermediate goods and it depends on the way that the firm finances its purchase of intermediate goods. Since $D_t(i) = P_{It} I_{xt}(i)$, we have

$$q_t^{peso} = P_{It}(1 + i_{pt})E_t\left[\tilde{d}_{t+1}\right], \quad q_t^{dollar} = P_{It}(1 + i^*_{dt})E_t\left[\tilde{d}_{t+1}\frac{S_{t+1}}{S_t}\right], \tag{3.9}$$

variable interest rates tied to short rates.

[14] Equation 3.5 implies that the export firm may face different peso interest than the household. This assumption makes our model more general. It also makes the expression for the marginal cost under different debt contracts more intuitive.

[15] It should be noted that the export firm chooses the currency of export pricing and debt denomination and presets prices *ex ante* period by period to maximize its expected profits. Moreover, it does not choose the optimal amount of loans. Therefore, although the firm borrows intertemporally, its choice in each period is independent of previous choices. Hence, we can still use the methodology described in Devereux, Engel and Storgaard (2004) to determine the optimal currency strategies for export firms. Since now the firm borrows intertemporally, we use MC_t to denote the present value of the marginal cost of production at time t. Section 1.1 of the Technical Appendix gives the details of the derivation of MC_t.

where $\tilde{d}_{t+1} = \beta \frac{d_{t+1}}{d_t}$ is the stochastic discount factor between period t and period $t+1$. Therefore, the marginal cost under a peso contract and a dollar contract, respectively, can be derived as follows:

$$MC_t^{peso} = W_t^{1-\omega} \left(P_{It}(1+i_{pt}) E_t \left[\tilde{d}_{t+1} \right] \right)^{\omega}, \qquad MC_t^{dollar} = W_t^{1-\omega} \left(P_{It}(1+i_{dt}^*) E_t \left[\tilde{d}_{t+1} \frac{S_{t+1}}{S_t} \right] \right)^{\omega}. \tag{3.10}$$

Equation 3.10 shows that the firm's marginal cost depends critically on the currency of debt denomination. When the export firm finances intermediate goods purchases with peso debt, it will mainly take domestic interest rate risk; when it borrows in dollars, it will mainly be subject to exchange rate risk and world interest rate risk.[16]

3.4 The Currency of Export Pricing

The currency of export pricing will affect the demand faced by the export firm, thus affecting its expected profit, $E_{t-1}(d_t Q_t(i))$. Given the debt contract that the firm chooses, that is, given the marginal cost, if the export firm i sets its price in pesos, then its expected profit is

$$E\Pi^{peso}(i) = E_{t-1} \left\{ d_t \left[(P_{xt}^{peso}(i) - MC_{k,t}) (\frac{P_{xt}^{peso}(i)}{S_t P_{xt}^*})^{-\lambda} \frac{X_t}{P_{xt}^*} - \phi \right] \right\}, \tag{3.11}$$

where d_t is the discount factor, which is exogenous to the firm's decision; $MC_{k,t}$ is the marginal cost, where $k = peso$, $dollar$ is the index for the currency of debt denomination; $(\frac{P_{xt}^{peso}(i)}{S_t P_{xt}^*})^{-\lambda} \frac{X_t}{P_{xt}^*}$ is the demand for export good i when firm i sets prices in pesos. $P_{xt}^{peso}(i)$ is the price set by firm i in terms of pesos. Since firm i sets prices in pesos, a nominal fixed menu cost ϕ will occur.

If firm i sets its price in dollars, then the expected profit is

$$E\Pi^{dollar}(i) = E_{t-1} \left[d_t (S_t P^{*dollar}_{xt}(i) - MC_{k,t}) (\frac{P^{*dollar}_{xt}(i)}{P_{xt}^*})^{-\lambda} \frac{X_t}{P_{xt}^*} \right], \tag{3.12}$$

where $(\frac{P^{*dollar}_{xt}(i)}{P_{xt}^*})^{-\lambda} \frac{X_t}{P_{xt}^*}$ is the demand for export good i when the firm sets prices in dollars, and $P^{*dollar}_{xt}(i)$ is the price set by firm i in terms of dollars.

Equations (3.11) and (3.12) show that the firm's expected profits are affected by its currency choices for both export pricing and debt contracts. This leads us to a discussion about the firm's optimal currency choices.

[16] Note that when we say the peso contract is mainly subject to the domestic interest rate risk, it actually means that when the firm makes the decision of what currency to borrow *at time* $t-1$, the distribution of marginal cost under the peso debt contract will depend mainly on the distribution of $1+i_{pt}$. Similar interpretation applies to the dollar debt.

3.5 Optimal Currency Choices

As mentioned earlier, the firm's *ex ante* optimization problem is a two-stage decision problem. Before the realization of time t shocks, in Stage 1, the firm chooses the currency of export pricing and the currency of debt denomination. In Stage 2, given the currency strategy chosen in Stage 1, the firm presets its optimal prices.

We first define the set of feasible pure strategies for each export firm in Stage 1:

$$\Theta = [s_1, s_2, s_3, s_4] \equiv [(p,p),(p,d),(d,p),(d,d)], \tag{3.13}$$

where $p = peso$, $d = dollar$. For each strategy $s_l \in \Theta$, $l \in (1,2,3,4)$, the first letter represents the currency of export pricing, and the second represents the currency of debt denomination. The expected profit in period $t-1$ associated with strategy s_l is defined as $E\Pi(s_l)$.[17] Thus, the optimal currency strategy, s_l^*, for the firm can be determined by the following condition:

$$E\Pi(s_l^*) \geq E\Pi(s_l), \qquad \forall s_l \in \Theta. \tag{3.14}$$

Now we use backward induction to find out rules of the optimal currency strategies for the export firm. In Stage 2, given strategy s_l, the optimal price policies that maximize the expected profits can be derived from maximizing Equations (3.11) and (3.12):

$$P_{xt}^{p,p}(i) = \hat{\lambda}\frac{E_{t-1}(MC_{p,t}S_t^{\lambda}Z_t)}{E_{t-1}(S_t^{\lambda}Z_t)}, \qquad P_{xt}^{p,d}(i) = \hat{\lambda}\frac{E_{t-1}(MC_{d,t}S_t^{\lambda}Z_t)}{E_{t-1}(S_t^{\lambda}Z_t)}, \tag{3.15}$$

$$P^{*d,p}_{xt}(i) = \hat{\lambda}\frac{E_{t-1}(MC_{p,t}Z_t)}{E_{t-1}(S_tZ_t)}, \qquad P^{*d,d}_{xt}(i) = \hat{\lambda}\frac{E_{t-1}(MC_{d,t}Z_t)}{E_{t-1}(S_tZ_t)}, \tag{3.16}$$

where $\hat{\lambda} = \frac{\lambda}{\lambda-1}$ is the markup, and $Z_t = d_t {P^*_{xt}}^{\lambda-1}X_t$ represents a market demand factor.

By substituting the above optimal price schedules into Equations (3.11) and (3.12), the expected discounted profits associated with each strategy s_l are as follows:

$$E\Pi(p,p) = \widetilde{\lambda}[E_{t-1}(S_t^{\lambda}Z_t)]^{\lambda}[E_{t-1}(S_t^{\lambda}Z_tMC_{p,t})]^{1-\lambda} - E_{t-1}[d_t\phi], \tag{3.17}$$

$$E\Pi(p,d) = \widetilde{\lambda}[E_{t-1}(S_t^{\lambda}Z_t)]^{\lambda}[E_{t-1}(S_t^{\lambda}Z_tMC_{d,t})]^{1-\lambda} - E_{t-1}[d_t\phi], \tag{3.18}$$

$$E\Pi(d,p) = \widetilde{\lambda}[E_{t-1}(S_tZ_t)]^{\lambda}[E_{t-1}(Z_tMC_{p,t})]^{1-\lambda}, \tag{3.19}$$

$$E\Pi(d,d) = \widetilde{\lambda}[E_{t-1}(S_tZ_t)]^{\lambda}[E_{t-1}(Z_tMC_{d,t})]^{1-\lambda}, \tag{3.20}$$

where $\widetilde{\lambda} = \frac{1}{\lambda-1}(\frac{\lambda}{\lambda-1})^{-\lambda}$.

[17] From now on, lower-case letters denote the natural logs of their upper-case counterparts; that is, $x = \ln(X)$. Also, the time subscripts will be omitted in the approximation of expected profit functions. Without explicit statements, all the expectation and variance operators are conditional on the information set in period $t-1$.

Then in Stage 1, the firm can compare the expected profits associated with each strategy s_l to determine its optimal strategy. Following Devereux, Engel, and Storgaard (2004), we simplify the expected profit as a function of aggregate variables by using a second-order approximation approach. From (3.17)-(3.20), we establish the following Lemmas:

Lemma 1 *Given a debt contract, the firm will set export prices in pesos if and only if*

$$\frac{1}{2}\sigma_s^2 - cov(mc_k, s) > \frac{\xi}{\lambda(\lambda-1)}, \qquad k = p, d. \tag{3.21}$$

where $\xi = \frac{E_{t-1}[d_t\phi]}{\Pi}$ *is the ratio of expected discounted menu cost to the steady state expected profit* Π.

Proof: See Appendix A.

This optimal condition for export pricing is similar to the result in Devereux, Engle, and Storgaard (2004). The key difference is that, in our paper, the log of the marginal cost depends on the choice of the debt contract. In addition, the form of the optimal condition changes slightly. The export firm will set prices in its own currency if and only if the expected profit differential from doing so exceeds the expected menu cost.[18] The intuition behind Lemma 1 has already been illustrated clearly in Devereux, Engle, and Storgaard (2004), so we will not repeat it here. Note that, in this model, the covariance term between the marginal cost and the exchange rate varies with the debt contract. Thus, the export pricing currency decisions also depend on the choice of the debt contract.

Lemma 2 *When the firm sets export prices in pesos, it will borrow in pesos if and only if*

$$\frac{1}{2}\sigma_{mc_p}^2 + \lambda cov(mc_p, s) + cov(mc_p, z) < \frac{1}{2}\sigma_{mc_d}^2 + \lambda cov(mc_d, s) + cov(mc_d, z). \tag{3.22}$$

When the firm sets export prices in dollars, it will borrow in pesos if and only if

$$\frac{1}{2}\sigma_{mc_p}^2 + cov(mc_p, z) < \frac{1}{2}\sigma_{mc_d}^2 + cov(mc_d, z). \tag{3.23}$$

Proof: See Appendix A.

This condition says that given the currency choice of export pricing, it is optimal for a firm to choose the debt contract that has a smaller marginal cost effect on expected profits. This effect arises from the uncertainty of marginal cost and its covariance with other endogenous stochastic

[18] Nevertheless, since the fixed menu cost is extremely small, it will only affect the firm's currency choice when the expected profit differential between domestic currency pricing and foreign currency pricing is approximately zero. Hence, the introduction of the small menu cost just make our results more robust in the extreme case. For most cases, it will not affect the export firm's currency choice.

variables. Given the firm's currency choice of export pricing, the expected profit differential between peso debt and dollar debt depends mainly on the difference between marginal costs. Up to second order approximation, this differential is in turn decided by second moments associated with marginal costs, which we refer to as the marginal cost effect on expected profits. Since the marginal cost depends on the debt contract, this effect also varies with the choice of debt contract. The firm's expected profit is a function of the exchange rate, the marginal cost, and the market demand. Hence, besides the variance of marginal cost, the covariance between marginal cost and market demand or exchange rates will also affect the expect profit. Therefore, to maximize expected profits the firm should choose a debt contract that helps to reduce the total adverse effect caused by these second moments.

Furthermore, the composition of the marginal cost effect varies with currency choices of export pricing. When the firm sets export prices in pesos, the marginal cost effect is composed of three second moments: the variance of marginal costs; the covariance of marginal costs and exchange rates; and the covariance of marginal costs and the market demand. The first two terms are positive and reduce expected profits as they both increase the expected cost, while the effect of the third term on expected profits is ambiguous, as it varies with other firms' strategies and monetary policy regimes. When the firm sets export prices in dollars, the marginal cost effect only involves two terms, the variance of marginal cost and the covariance of marginal cost and the market demand. This is because the expected profits are linear in the exchange rate under dollar pricing, implying that no covariance term exists between the marginal cost and the exchange rate.

4 The General Equilibrium Model

The last section examined an export firm's decision regarding the currency of export pricing and debt denomination taking the distribution of exchange rates, wages, and market demand factors as given. In this section, we construct a general equilibrium small open economy model where these variables are determined endogenously. Besides the export firms, the model is similar to other small open economy models in the recent literature, so our description is kept brief. Where appropriate, foreign currency (dollar) prices are indicated with an asterisk.

4.1 Preference and Market Structure

The small open economy contains a unit interval [0,1] of households indexed by j. The expected utility of household j is given by

$$EU(j) = E_t \sum_{s=t}^{\infty} \beta^{s-t} [\frac{C_s(j)^{1-\rho}}{1-\rho} - \eta \frac{L_s(j)^{1+\psi}}{1+\psi}] \tag{4.24}$$

where $C = \frac{1}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} C_N^{1-\alpha} C_F^{\alpha}$ is a consumption index defined across homogenous domestic non-traded goods produced by a competitive sector, C_N, and imported consumption goods, C_F (α is the share of imported foreign goods in the total consumption expenditure); β is the discount factor; $\rho > 1$ is the inverse of the elasticity of intertemproal substitution; η is a scale parameter for the disutlity of labor and ψ is the inverse of the elasticity of labor supply. The consumer price index for domestic households then can be derived as $P_t = P_{Nt}^{1-\alpha} P_{Ft}^{\alpha}$, where P_N and P_F are prices of domestic non-traded goods and imported foreign goods, respectively.

Each household decides his consumption, domestic nominal bond holding, and labor supply every period. The household derives income from wages, profits from export firms, and returns on domestic bond holding. Household j's budget constraint can therefore be written as:

$$P_t C_t(j) + B_t(j) = W_t(j) L_t(j) + (1 + i_{t-1}) B_{t-1}(j) + \Pi_{Xt}, \tag{4.25}$$

where $B_t(j)$ represents household j's holding of domestic bonds, $W_t(j)$ is the nominal wage, and i_{t-1} is the domestic nominal interest rate between period $t-1$ and t. Π_{Xt} is the average profit from the export sector. It is assumed that households have no access to the international bond market. This assumption implies that the standard uncovered interest rate parity condition (UIRP) does not hold in our model since there are no arbitrage opportunities for households.[19]

There are two sectors in this economy, the export sector and the non-traded sector. As mentioned earlier, the export sector is monopolistically competitive and uses labor and domestically produced non-traded goods as intermediate goods to produce export goods. The non-traded sector is perfectly competitive and uses only labor as input with a linear production technology:

$$Y_{Nt} = L_{Nt}. \tag{4.26}$$

Each household, j, is assumed to supply, in a monopolistic fashion, a distinctive variety of labor service. The aggregate labor service hired by an export or non-traded goods firm, L_t, is given by $[\int_0^1 L_t(j)^{\frac{\theta-1}{\theta}} dj]^{\frac{\theta}{\theta-1}}$. Therefore, each household faces a downward-sloping labor demand curve with elasticity $\theta > 1$,

$$L_t(j) = [\frac{W_t(j)}{W_t}]^{-\theta} L_t, \tag{4.27}$$

where $W_t = [\int_0^1 W_t(j)^{1-\theta}]^{\frac{1}{1-\theta}}$ is the production-based wage index. We assume that the household

[19] This assumption captures the fact that households in emerging market economies can seldom smooth consumption by holding foreign assets. This imperfect financial market also implies that there might exist an interest rate differential between the domestic interest rate and the world interest rate even when exchange rates are fixed. For example, see Lahiri and Vegh (2003). Introducing a foreign bond market would likely lower the variability of domestic interest rates, thus reducing the cost of borrowing in the local currency. Nevertheless, this will only alter the threshold level of the policy parameter for twin dollarization, but it cannot affect the basic results of this paper.

sets nominal wages one period ahead (see Figure 1)[20] and, *ex post*, supplies the amount of labor that firms demand at the predetermined nominal wage. Hence, the marginal cost of non-traded firms is W_t, and the price of non-traded goods is $P_{Nt} = W_t$. This also implies that $P_{It} = W_t$. The export firms' marginal costs depend on the currency choice of the liability denomination, as shown by Equation (3.10). Besides choosing the currency of liability denomination and export pricing *ex ante*, export firms also preset their prices to maximize the expected discounted profits. Here, we assume that export firms are owned by domestic households. Therefore, the stochastic discounter factor firms face is given by $d_t = \frac{1}{P_t C_t^{\rho}}$.

The imported foreign consumption goods have a constant price of one in terms of dollars in the world market. Thus, the price of imported consumption goods in terms of domestic currency (pesos) is given by $P_{Ft} = S_t^{\varepsilon}$, where $0 \leq \varepsilon \leq 1$ is the degree of exchange rate pass-through to import prices. Therefore, the domestic consumer price index is $P_t = W_t^{1-\alpha} S_t^{\alpha\varepsilon}$.

4.2 Monetary Policy

The monetary authority is assumed to commit to a domestic interest rate targeting rule

$$1 + i_t = (1 + r)(\frac{S_t}{S_0})^{\gamma}, \qquad \gamma > 0, \tag{4.28}$$

where $r = \frac{1-\beta}{\beta}$ is the steady state interest rate. The parameter γ represents the degree of the exchange rate flexibility or the coefficient of exchange rate intervention. As long as $\gamma > 0$, there is a determinate equilibrium value for the nominal exchange rate. γ is exogenously given and it measures the preference of policy makers. The higher is γ, the closer the monetary rule approximates a fixed exchange rate regime, where the target for the exchange rate peg is S_0, the steady state exchange rate. When γ approaches zero, it represents a flexible exchange rate regime.[21]

4.3 External Shocks

This economy is subject to an external shock: the foreign demand shock. The foreign demand shock, X_t, is assumed to follow a log-normal distribution with mean zero and variance σ_x^2 in period

[20] There are two types of nominal rigidities in this model, the sticky price and the sticky wage. If prices are flexible, then the firm would be indifferent about the currency of export pricing, so the price stickiness is a crucial assumption. But the sticky wage assumption is just for the simplification of our analysis, and our results still hold under a flexible wage assumption.

[21] Note that as long as $\gamma > 0$, both the domestic interest rate and the exchange rate will absorb part of external shocks. This implies that even when γ is very close to zero, in the presence of external disturbances, domestic interest rate will not be constant and it is still different from the targeted interest rate.

t. To make our general equilibrium model as simple as possible, the world interest rate, r_t^*, is assumed to be constant and to equal to the steady state interest rate, r, over time.

4.4 Equilibrium

Table 3 gives the main equilibrium equations of the model. Given the stochastic processes of the external shock (X) and the exchange rate regime (γ), a symmetric equilibrium has the following properties: (i) Households preset wages and choose consumption and domestic bond holdings to maximize expected utility subject to their budget constraints (see Table 3a for details); (ii) Export firms choose the optimal currency strategy s_l^* to maximize their expected profits; (iii) Given optimal currency strategies, firms set prices to maximize their expected profits (see Table 3b for details); We denote the distribution of firms as $\Omega = (\mu_1, \mu_2, \mu_3, \mu_4)$, where $\mu_l \in [0, 1]$ is the endogenously determined number of firms who choose strategy $s_l \in \Theta$, and $\Sigma_{l=1}^4 \mu_l = 1$. Then, we may derive the export price index P_{xt}^*, as shown in Table 3c; (iv) Finally, labor, goods, and bond markets clear. Table 3d gives the details.

5 Model Solution

In this section, we analyze how monetary policy regime affects firms' decision. Since the export firm's expected profit is a function of second moments of endogenous aggregate variables (the exchange rate and other macroeconomic variables), to find optimal strategies for firms, we have to solve the general equilibrium model to get the endogenous aggregate variables. Besides the monetary policy, the determination of these variables also depends on the market structure - the distribution of firms who choose different optimal strategies. In other words, every export firm's payoff will be affected by other firms' optimal strategies. In equilibrium, the distribution of firms must be supported by each firm's optimal decision. Hence, to solve for the equilibrium, we first assume that there exists a distribution of firms with different optimal pure currency strategies, $\Omega = (\mu_1, \mu_2, \mu_2, \mu_4)$, and we derive the aggregate variables given the conjectured distribution. Then, every firm's optimal currency strategy can be determined. Finally, to find out if the conjectured distribution is an equilibrium, we must check if these strategies support that distribution.

We solve the model by log-linearizing around a non-stochastic, symmetric steady state, which is described in the Technical Appendix. The Technical Appendix also gives the complete solution of the model, so we will just outline the important and intuitive steps of the solutions here. Given the log-linearized system, the deviations of the exchange rate and other macroeconomic variables from their $t-1$ expectations are solved in terms of the external shock (X_t). From now on, $\hat{k}_t = log(K_t) - log(\bar{K})$, where $\bar{K}$ is the non-stochastic steady state value of variable K_t, and

$\tilde{k}_{t+j} = \hat{k}_{t+j} - E_{t-1}\hat{k}_{t+j}$, $j \geq 0$.

5.1 Endogenous Aggregate Variables

As shown in the Technical Appendix, we may derive consumption, the exchange rate, and the nominal interest rate as functions of the external shock, given Ω, the distribution of firms.[22]

$$\tilde{c}_t = \frac{-(\alpha\varepsilon + \gamma)}{\rho(\alpha\varepsilon - b) - (\alpha\varepsilon + \gamma)}\kappa\tilde{x}_t, \qquad \tilde{s}_t = \frac{\rho}{\rho(\alpha\varepsilon - b) - (\alpha\varepsilon + \gamma)}\kappa\tilde{x}_t, \tag{5.1}$$

$$\widetilde{1 + i}_t = \frac{\rho\gamma}{\rho(\alpha\varepsilon - b) - (\alpha\varepsilon + \gamma)}\kappa\tilde{x}_t \tag{5.2}$$

where b and κ are both functions of Ω, as shown in the Technical Appendix. Intuitively, b and κ measure the total effect of exchange rate changes and the effect of the foreign demand shock on the output of the export sector, respectively.

Although values of b and κ in equilibrium cannot be determined yet, from Equations (5.1) and (5.2), we can find that responses of aggregate variables to external shocks depend critically on the exchange rate policy parameter, γ, especially in two extreme cases of the exchange rate policy regime. When $\gamma \to 0$, as implied by Equation (5.2), the domestic interest rate is quite stable and external shocks are mainly absorbed by flexible exchange rates. Thus, the impact of external shocks on consumption is small. As $\gamma \to \infty$, Equation (5.1) suggests that the exchange rate is almost fixed and cannot insulate consumption from external shocks. In this case, the domestic interest rate will absorb external shocks. Nevertheless, without current account dynamics, households cannot spread the shocks over to future periods; therefore, current consumption becomes quite volatile.

5.2 Optimal Strategies

Given the above equations, we can calculate the conditional variance and covariance terms of the (log) exchange rate, consumption, marginal cost, and other variables. Then we can express the export firm's expected profit as a simple function of the second moment of foreign demand shock, σ_x^2, and find the firm's optimal strategies. (Please refer to the Technical Appendix for details.) Then we may establish the following proposition.

Proposition 1 *There always exist two critical values, γ_L and γ_H ($\gamma_L < \gamma_H$), such that for any $\gamma \in (0, \gamma_L)$, the optimal strategy for each export firm is (p, p). That is, all firms set export prices in pesos and borrow in pesos. The distribution of firms is $\Omega = [1, 0, 0, 0]$. Meanwhile, for any*

[22] Generally speaking, Ω is time variant. But the equilibrium in our model is stationary, so we can drop the time subscript of Ω.

$\gamma \in (\gamma_H, \infty)$, the optimal strategy for every export firm is (d, d). That is, all firms set export prices in dollars and borrow in dollars, and $\Omega = [0, 0, 0, 1]$.

Proof: See Appendix B.

The intuition behind this Proposition is as follows. First, consider the case where exchange rate flexibility is high (γ is low). The impact of exchange rate flexibility on the firms' choices of debt contract works through the borrowing cost channel. In our model, the borrowing cost of a peso contract is mainly subject to *ex post* domestic interest rate risk, while the borrowing cost of a dollar contract depends mainly on the world interest rate and the exchange rate risk. From Equations (5.1)-(5.2), we know that when γ is low, the exchange rate will absorb most foreign demand shock, so the domestic interest rate is stable and the exchange rate is volatile. Therefore, borrowing in pesos implies a more stable borrowing cost for firms than borrowing in dollars. As for the currency of price setting, with high exchange rate flexibility, setting export prices in pesos gives firms a higher expected profit. This is because, under domestic currency pricing, exchange rate changes can help to adjust the relative prices in face of demand shocks, and then firms can stabilize the demand for their export goods. Therefore, when exchange rate flexibility is high, firms will borrow in pesos and also set export prices in pesos.

When exchange rate flexibility is low (γ is high), domestic currency pricing can not help firms to stabilize the demand for their goods. Furthermore, under peso pricing, the demand is directly sensitive to exchange rate movements, which may result in an increase in firms' expected marginal costs, *ceteris paribus*. As a result, export firms will choose to set prices in dollars when the exchange rate flexibility is low. Why do firms want to borrow in dollars when exchange rate flexibility is low? As shown by equations (5.1) and (5.2), when exchange rate flexibility is low, the domestic interest rate will absorb the foreign demand shock, and thus it will become quite volatile. Because borrowing in dollars is subject to less domestic interest rate risk than borrowing in pesos, the peso debt contract implies a higher expected cost than the dollar debt contract when γ is high (the exchange rate risk is almost zero). Therefore, firms tend to borrow in dollars when exchange rate flexibility is low.

In the above discussion, we focus on optimal currency strategies for firms in two extreme cases, where $\gamma < \gamma_L$ and $\gamma > \gamma_H$. Now, we analyze optimal strategies for firms in the intermediate cases, where $\gamma_L < \gamma < \gamma_H$. As optimal strategies for firms in intermediate cases cannot be solved analytically, we resort to numerical solutions.

5.3 Numerical Results

Calibration Our model has only a few parameters that need to be calibrated (see Table 4). The discount factor, β, is calibrated at 0.96, so that the steady state annual interest rate is 4%. The coefficient of risk aversion, ρ, is set to 2, which implies the inter-temporal elasticity of substitution is about 0.5. The elasticity of substitution across individual export goods, λ, is chosen to be 11, which implies a steady state mark-up of 10%. This is the common value (e.g., Basu and Fernald 1997) used in the literature. Following Devereux and Poon (2004), we set the share of intermediate goods in production, ω, to 0.4, which is consistent with the estimates for intermediate goods as a fraction of GDP in Braggion, Christiano, and Roldos (2003). α is set to equal 0.3, which is slightly smaller than the value of 0.4 used for industrialized small open economies. This is because for Asian economies, the share of imported consumption in the consumption basket is relatively small. This is also close to the evidence cited by Schmitt-Grohe and Uribe (2000) for Mexico, and in Cook and Devereux (2001) for Malaysia and Thailand. We set the scale parameter of disutility of labor η to 1 and the inverse of the elasticity of labor supply ψ to 1. We also set $\theta = 11$ so that the wage mark-up is about 10%. For parameters regarding debt contracts, we simply set $\alpha_p = 0.95$ and $\alpha_d = 0.25$ to emphasize the difference in sensitivity of i_{pt} and i^*_{dt} to domestic interest rate. We also consider incomplete exchange rate pass-through to import prices and set $\varepsilon = 0.5$. We set the fixed cost $\phi = 0.000091$ so that ξ, the ratio of the fixed menu cost to the steady state expected profit, is only 0.1%. We set the standard deviation of (log) foreign demand shock, σ_x, to 4% so that the standard deviation of log GDP of this small open economies is about 2%, which is close to the average volatility of GDP of small open economies reported in Arena and Magud (2005).

Given the calibration of parameters, we can solve for the two critical values γ_L and γ_H. Table 5 lists the changes in Ω (the distribution of firms) when γ increases. Recall that μ_l is the number of firms who choose the strategy s_l. To highlight the extent of dollarization, we also report the degree of export pricing dollarization, e, and the degree of liability dollarization, v, separately in the last two rows of Table 5, where $e = \mu_3 + \mu_4$ is the number of firms that set export prices in dollars; and $v = \mu_2 + \mu_4$ is the number of firms that borrow in dollars. From Table 5, we can see that, as exchange rate flexibility decreases (γ increases), both e and v increase, implying that the degree of dollarization increases with γ. The intuition is straightforward. As exchange rate flexibility decreases, the benefits of peso currency pricing and peso debt decrease, which induce more firms to set prices in dollars or to borrow in dollars. This finding suggests that a policy that increases exchange rate flexibility may help to reduce the degree of dollarization in the economy.

We also find that for some intermediate values of γ, firms will be indifferent to certain strategies . As shown in Table 5, for $\gamma \in [132.501, 134.378]$, the firm will be indifferent to the strategy

(p, d) and (d, d). Hence, some firms choose the strategy (p, d), while others choose the strategy (d, d). Nevertheless, in these intermediate regions, given γ, the distribution of firms can still be determined. For example, when $\gamma = 134$, we have $\Omega = (0, 0.20, 0, 0.80)$, which implies that $e = 0.80, v = 1$. This is because under intermediate exchange rate regimes, one firm's currency strategy will be affected by the behaviors of other firms. Therefore, when the difference between the expected payoffs of firms' strategies is small, the interaction among firms will lead to such an equilibrium outcome.

In this section, we have shown that if the exchange rate intervention (γ) is sufficiently large, then twin dollarization will be an optimal strategy for all firms. In other words, a fixed exchange rate will cause twin dollarization. This finding is in contrast to the "fear of floating" literature, which argues that liability dollarization causes fear of floating. In our model, it is the fixed exchange rate itself that leads to both liability and export pricing dollarization. In this sense, our finding builds a new linkage between fixed exchange rate regimes and dollarization.[23]

Our findings imply that twin dollarization is optimal for firms under a fixed exchange rate regime, but is it a beneficial arrangement for the whole economy in terms of welfare? We will answer this question in the next section.

6 Welfare Implications

In this section, we discuss the welfare implications of firms' dollarization decisions for the economy. Following Schmitt-Grohe and Uribe (2004), the welfare measurement is the conditional expected lifetime utility of the representative household at time zero.[24] To measure the magnitude of the welfare differential across regimes, we define ζ_k as the percentage change in the deterministic steady state consumption that will give the same conditional expected utility under regime k,

[23] In our analysis, we assume that the central bank follows a fixed exchange rate regime and this regime is credible. Given this, we show that the twin dollarization is an equilibrium outcome. Nevertheless, in reality, governments sometimes abandon the fixed exchange rate regime if it implies raising domestic interest rates too high. If the exchange rate policy is not entirely credible, our result will be affected to some extent. For instance, suppose there is an upper bound on the domestic interest rate at which the government abandons the fixed exchange rate regime. This will reduce the volatility of domestic interest rate and make borrowing in domestic currency more attractive. However, this will just change the cutoff values of the policy parameter which induces twin dollarization and will not affect the main results of our paper.

[24] The expected lifetime utility is computed conditional on the initial state being the deterministic steady state. This choice of the initial state has the advantage of ensuring that the economy starts from the same initial point for all policy regimes considered.

which is conditional on given γ and Ω. That is, ζ_k is given implicitly by:

$$\frac{\frac{1}{1-\rho}[(1+\zeta_k)\bar{C}]^{1-\rho} - \eta\frac{\bar{L}^{1+\psi}}{1+\psi}}{1-\beta} = EU_k, \tag{6.1}$$

where a bar over a variable denotes the deterministic steady state of that variable. If $\zeta_k > 0 (< 0)$, the welfare under regime k is implied to be higher (lower) than that of the steady state case. Higher values of ζ_k correspond to higher welfare.

The welfare EU_k is computed by taking second-order Taylor approximations of the structural equations around the deterministic steady state. The system of equations is solved using a perturbation method described in Schmitt-Grohe and Uribe (2004). The values of structural parameters are those listed in Table 4.

To find out whether or not twin dollarization is beneficial for the whole economy, we report the welfare effect of firms' endogenous dollarization decisions in Table 6. We know from Proposition 1 that firms will choose to set prices in pesos and borrow in pesos under a flexible exchange rate regime and choose twin dollarization under a fixed exchange rate regime. Therefore, we focus on these two extreme exchange rate regimes, which are represented by $\gamma = 0.01$ and $\gamma = 900$, respectively.

From Table 6, we can see that given Ω, the distribution of firms, a flexible exchange rate regime is superior to a fixed exchange rate regime in terms of welfare. Therefore, if monetary policy is chosen *ex ante* endogenously to maximize the welfare of the economy, twin dollarization can never be an optimal strategy for firms in equilibrium. Under a fixed exchange rate regime, however, twin dollarization is not only optimal for firms, but also a beneficial outcome for the economy. We can consider an economy that is in an initial equilibrium where the exchange rate is floating and all firms choose the strategy (p, p). Suppose the government switches the the exchange rate regime from flexible to fixed, if the the firm's pricing and borrowing behaviors remain unchanged, then the welfare loss will be equivalent to about 0.2229% of steady state consumption. If, however, the export firms' endogenous behaviors are considered, then firms will choose to set export prices in dollars and borrow in dollars, and the welfare loss is about 0.1506% of steady state consumption. In other words, twin dollarization reduces the welfare cost of moving from a floating exchange rate regime to a fixed exchange rate regime. In this case, the gain is about 0.0723% of steady state consumption.

This implies that once firms' endogenous currency choices for export pricing and debt denomination are taken into consideration, the welfare cost of moving to a fixed exchange rate regime will be reduced. This welfare gain comes from the fact that firms can adjust their currency choices or dollarization decisions according to changes in the exchange rate regime. Table 7 compares the mean and variance of consumption, labor, and other variables for $\Omega = [1, 0, 0, 0]$

and $\Omega = [0, 0, 0, 1]$, under a fixed exchange rate regime. From Table 7, we can see that twin dollarization delivers higher expected consumption and lower consumption volatility than does the strategy (p, p) under a fixed exchange rate regime, which thus improves welfare for the whole economy. Intuitively, twin dollarization can help the economy to avoid some domestic interest rate risk. As a result, the mean of marginal costs tend to be lower, which generates higher and more stable profits for export firms. Since export firms are assumed to be owned by households, this implies higher expected consumption and lower consumption volatility.[25] Therefore, twin dollarization is not only an optimal strategy for firms, but it also delivers higher welfare to the whole economy.

Our results imply that twin dollarization can reduce welfare costs for the economy under some circumstances. This is in contrast to the welfare implications of liability dollarization in most of the financial crisis literature, which emphasizes the welfare losses caused by foreign currency debt.

7 Conclusion

This paper studies twin dollarization - liability dollarization and export pricing dollarization in East Asian economies. We develop a small open economy general equilibrium model with nominal rigidities, where both the currency of export pricing and the currency of liability denomination are endogenous. Our main findings are that firms' dollarization decisions depend critically on exchange rate flexibility, and twin dollarization will be an optimal strategy for all firms if exchange rate flexibility is limited. Hence, our paper builds a new linkage between fixed exchange rate regimes and dollarization. Furthermore, we find that twin dollarization can reduce the welfare loss caused by the fixed exchange rate regime. This contrasts with the welfare implications of liability dollarization in most financial crisis literature.

Our model can be extended in a number of ways. For example, it may be interesting to consider the optimal debt contract design in our model, so that we can explore the strategic interaction between firms' liability dollarization and export pricing dollarization. This interaction will be especially interesting if we allow the export output to be the collateral for external borrowing. And, once extended to incorporate the debt contract negotiation process, our model can also be used to analyze the effects of default risk and country spread on firms' dollarization decisions and the welfare of the economy.

[25] In the case with twin dollarization, the labor supply is also higher. Thus, higher consumption also can be attributed to changes in wage income. But the increase in wage income cannot be the main source of welfare improvement, since the higher labor supply leads to more disutility in labor, which decreases welfare.

Appendix

A Proof of Lemmas 1 and 2

As shown in the paper, the expected profits under domestic currency pricing are given by

$$E\Pi(p,k) = \widetilde{\lambda}[E(S^{\lambda}Z)]^{\lambda}[E(S^{\lambda}ZMC_k)]^{1-\lambda} - E[d\phi], \tag{A.1}$$

where $\widetilde{\lambda} = \frac{1}{\lambda-1}(\frac{\lambda}{\lambda-1})^{-\lambda}$, $Z = dP_x^{*\lambda-1}X$, $E[d\phi] = E_{t-1}[d_t\phi]$, MC_k depends on the debt contract. The first term on the RHS of Equation A.1 may be rewritten as:

$$\widetilde{\lambda}[E\exp(\ln Z)\exp(\lambda\ln S)]^{\lambda}[E\exp(\ln Z)\exp(\lambda\ln S)\exp(\ln MC_k)]^{1-\lambda}. \tag{A.2}$$

Now using the second order approximation, we have

$$E\exp(\ln Z)\exp(\lambda\ln S) \approx \exp(E\ln Z)\exp(\lambda E\ln S)\left\{1 + \frac{1}{2}var(\ln Z) + \frac{\lambda^2}{2}var(\ln S) + \lambda cov(\ln Z, \ln S)\right\}. \tag{A.3}$$

Similarly, using the same approximation for the expression $E\exp(\ln Z)\exp(\lambda\ln S)\exp(\ln MC_k)$, we get:

$$\begin{aligned} E\Pi(p,k) \quad &\approx \quad \Pi[1 + \frac{1}{2}var(\ln Z) + \frac{\lambda^2}{2}var(\ln S) + \lambda cov(\ln Z, \ln S)]^{\lambda} \\ &\times \quad [1 + \frac{1}{2}var(\ln Z) + \frac{\lambda^2}{2}var(\ln S) + \frac{1}{2}var(\ln MC_k) + \lambda cov(\ln Z, \ln S) \\ &\quad +cov(\ln Z, \ln MC_k) + \lambda cov(\ln S, \ln MC_k)]^{1-\lambda} - E[d\phi], \end{aligned} \tag{A.4}$$

where $\Pi = \tilde{\lambda}\exp[E(\ln Z)]\exp[\lambda E(\ln S)]\exp[(1-\lambda)E(\ln MC_k)]$ is the expected discounted profit in the steady state. Taking approximation, we have [1]

$$\begin{aligned} E\Pi(p,k) \approx \Pi\exp[&\frac{1}{2}var(\ln Z) + \frac{\lambda^2}{2}var(\ln S) + \frac{1-\lambda}{2}var(\ln MC_k) + \lambda cov(\ln Z, \ln S) \\ &+\lambda(1-\lambda)cov(\ln MC_k, \ln S) + (1-\lambda)cov(\ln Z, \ln MC_k)] - E[d\phi]. \end{aligned} \tag{A.5}$$

Let $\pi(p,k) = \frac{1}{2}var(\ln Z) + \frac{\lambda^2}{2}var(\ln S) + \frac{1-\lambda}{2}var(\ln MC_k) + \lambda cov(\ln Z, \ln S) + \lambda(1-\lambda)cov(\ln MC_k, \ln S) + (1-\lambda)cov(\ln Z, \ln MC_k)$, then after proximation, the above expression can be simplified as[2]

$$E\Pi(p,k) \approx \Pi[1 + \pi(p,k)] - E[d\phi] \tag{A.6}$$

Using the same method, we can express the expected profits under dollar pricing, $E\Pi(d,k)$, as below

$$E\Pi(d,k) \approx \Pi[1 + \pi(d,k)] \tag{A.7}$$

where $\pi(d,k) = \frac{1}{2}var(\ln Z) + \frac{\lambda}{2}var(\ln S) + \frac{1-\lambda}{2}var(\ln MC_k) + \lambda cov(\ln Z, \ln S) + (1-\lambda)cov(\ln Z, \ln MC_k)]$.

Let lower-case letters denote the natural logs of their upper-case counterparts, then

$$\pi(p,p) = \frac{\lambda^2}{2}\sigma_s^2 + \frac{1-\lambda}{2}\sigma_{mc_p}^2 + \lambda(1-\lambda)cov(mc_p, s) + (1-\lambda)cov(mc_p, z) + \frac{1}{2}\sigma_z^2 + \lambda cov(z, s), \tag{A.8}$$

[1] Here, we use the approximation $(1+x) \approx \exp(x)$ if x is small.

[2] $\pi(p,k)$ simply represents the log deviation of $E\Pi(p,k)$ from the steady state expected discounted profit Π.

$$\pi(p,d) = \frac{\lambda^2}{2}\sigma_s^2 + \frac{1-\lambda}{2}\sigma_{mc_d}^2 + \lambda(1-\lambda)cov(mc_d,s) + (1-\lambda)cov(mc_d,z) + \frac{1}{2}\sigma_z^2 + \lambda cov(z,s), \tag{A.9}$$

$$\pi(d,p) = \frac{\lambda}{2}\sigma_s^2 + \frac{1-\lambda}{2}\sigma_{mc_p}^2 + (1-\lambda)cov(mc_p,z) + \frac{1}{2}\sigma_z^2 + \lambda cov(z,s), \tag{A.10}$$

$$\pi(d,d) = \frac{\lambda}{2}\sigma_s^2 + \frac{1-\lambda}{2}\sigma_{mc_d}^2 + (1-\lambda)cov(mc_d,z) + \frac{1}{2}\sigma_z^2 + \lambda cov(z,s). \tag{A.11}$$

Given the debt contract, we can show that the firm will choose peso pricing if and only if

$$\pi(p,k) - \pi(d,k) > \xi, \qquad k = p,d \tag{A.12}$$

where $\xi = \frac{E_{t-1}[d_t\phi]}{\Pi}$ is the ratio of expected discounted menu cost to the steady state expected discounted profit.

Also, given the currency of export pricing, the firm will choose a peso debt if and only if

$$\pi(k,p) - \pi(k,d) > 0, \qquad k = p,d \tag{A.13}$$

Substituting $\pi(s_l)$ into Equations A.12 and A.13, we can prove Lemmas 1 and 2.

B The proof of Proposition 1

Given the model solution obtained in the Technical Appendix, we can express all conditional variance (covariance) terms associated with the (log) marginal cost (mc_p, mc_d) as follows,

$$\sigma_{mc_p}^2 = (\alpha_p - 1)^2\gamma^2\omega^2\sigma_s^2, \qquad cov(mc_p,s) = (\alpha_p-1)\gamma\omega\sigma_s^2, \qquad cov(mc_p,z) = (\alpha_p-1)\gamma\omega\sigma_{sz}, \tag{B.1}$$

$$\sigma_{mc_d}^2 = \omega^2((\alpha_d-1)\gamma-1)^2\sigma_s^2, \qquad cov(mc_d,s) = \omega((\alpha_d-1)\gamma-1)\sigma_s^2, \qquad cov(mc_d,z) = \omega((\alpha_d-1)\gamma-1)\sigma_{sz}, \tag{B.2}$$

where exchange rate volatility σ_s^2 can be derived as,

$$\sigma_s^2 = [\frac{\rho}{\rho(\alpha\varepsilon - b) - (\alpha\varepsilon+\gamma)}]^2\kappa^2\sigma_x^2. \tag{B.3}$$

In the general equilibrium model, we have $Z = dP_x^{*\lambda-1}X$, which implies that $\tilde{z} = [\gamma-(\lambda-1)(1-e)]\tilde{s}+\tilde{x}$. Therefore, we can solve for $cov(s,z)$,

$$\sigma_{sz} = [\gamma-(\lambda-1)(1-e)]\sigma_s^2 + \frac{\rho\kappa}{\rho(\alpha\varepsilon-b)-(\alpha\varepsilon+\gamma)}\sigma_x^2. \tag{B.4}$$

To prove Proposition 1, we use the following method. We conjecture that when γ is low (high) enough, $\Omega = [1,0,0,0](\Omega = [0,0,0,1])$ is the equilibrium distribution, then check if the optimal strategy for each firm supports this distribution.

We first consider the case when γ is low enough. Comparing $\pi(p,p)$ and $\pi(d,p)$, we have

$$\pi(p,p) - \pi(d,p) \propto \frac{1}{2}\sigma_s^2 - cov(mc_p,s) = (\frac{1}{2} - (\alpha_p-1)\gamma\omega)\sigma_s^2. \tag{B.5}$$

As ξ is very small, Equation B.5 implies that there exists a critical value γ_1, for any value $\gamma < \gamma_1$, we have $\pi(p,p) - \pi(d,p) > \xi$.

Given our conjecture that $\Omega = [1, 0, 0, 0]$ when γ is low enough, the number of firms who set prices in dollars $e = 0$ and the number of firms who borrow in dollars $v = 0$. Therefore, we will have $b = \kappa$ in equilibrium and $\sigma_{sz} < 0$. This yields

$$\sigma^2_{mc_p} < \sigma^2_{mc_d}, \quad cov(mc_p, s) > cov(mc_d, s), \quad cov(mc_p, z) < cov(mc_d, z). \tag{B.6}$$

Obviously, there exists a critical value of γ_2, for any $\gamma < \gamma_2$,

$$\frac{1}{2}\sigma^2_{mc_p} + cov(mc_p, z) < \frac{1}{2}\sigma^2_{mc_d} + cov(mc_d, z). \tag{B.7}$$

Hence, from Lemma 2, we have $\pi(d, p) > \pi(d, d)$. Meanwhile, to prove $\pi(p, p) > \pi(p, d)$, we need to show

$$\frac{1}{2}\sigma^2_{mc_p} + \lambda cov(mc_p, s) + cov(mc_p, z) < \frac{1}{2}\sigma^2_{mc_d} + \lambda cov(mc_d, s) + cov(mc_d, z). \tag{B.8}$$

When γ approaches zero, there exists a critical value γ_3 such that when $\gamma < \gamma_3$, the left side of the inequality is close to zero approximately, while the right side is positive for empirically plausible values of parameters λ, α, ρ, and κ. This implies the inequality B.8 holds. Therefore, there exist a critical value $\gamma_L = \min[\gamma_1, \gamma_2, \gamma_3]$, such that for any $\gamma < \gamma_L$, (p, p) is the optimal strategy for every export firm, which verifies our conjecture that $\Omega = [1, 0, 0, 0]$ is the equilibrium distribution.

Now, we turn to the case when γ is high enough, and conjecture that $\Omega = [0, 0, 0, 1]$ is the equilibrium distribution. Comparing $\pi(p, p)$ and $\pi(d, p)$, we have

$$\pi(p, p) - \pi(d, p) \propto \frac{1}{2}\sigma^2_s - cov(mc_p, s) = \frac{[\frac{1}{2} - (\alpha_p - 1)\gamma\omega)]\rho^2\kappa^2}{[\rho(\alpha\varepsilon - b) - (\alpha\varepsilon + \gamma)]^2}\sigma^2_x. \tag{B.9}$$

As γ increases, the above expected profit differential approaches zero. Hence, given a very small ξ, there always exists a critical value γ_4, for any $\gamma > \gamma_4$, $\pi(p, p) - \pi(d, p) < \xi$. We also have

$$\pi(p, d) - \pi(d, d) \propto \frac{1}{2}\sigma^2_s - cov(mc_d, s) = \frac{[\frac{1}{2} - \omega((\alpha_d - 1)\gamma - 1)]\rho^2\kappa^2}{[\rho(\alpha\varepsilon - b) - (\alpha\varepsilon + \gamma)]^2}\sigma^2_x. \tag{B.10}$$

Similarly, $\pi(p, d) - \pi(d, d)$ approaches zero when γ is large enough. So there exists a critical value γ_5, for any $\gamma > \gamma_5$, $\pi(p, d) - \pi(d, d) < \xi$.

When γ is big enough and it is greater than a critical value γ_6, from equations B.1 and B.2, and using the fact that $e = 1$ and $v = 1$ when $\Omega = [0, 0, 0, 1]$, we can approximately get

$$\sigma^2_{mc_p} \approx (\alpha_p - 1)^2\delta^2\sigma^2_x, \qquad \sigma^2_{mc_d} \approx (\alpha_d - 1)^2\delta^2\sigma^2_x, \tag{B.11}$$

$$cov(mc_p, z) \approx (\alpha_p - 1)\delta_1\sigma^2_x, \qquad cov(mc_d, z) \approx (\alpha_d - 1)\delta_1\sigma^2_x. \tag{B.12}$$

where $\delta = \frac{\omega\rho\kappa\lambda}{\lambda + \rho a\omega^2(\lambda - 1)(\alpha_d - 1)}$ and $\delta_1 = \delta(\frac{\delta}{\omega} - 1)$. By Lemma 2, we have

$$\begin{aligned} \pi(d, d) - \pi(d, p) \quad &\propto \quad [\frac{1}{2}\sigma^2_{mc_p} + cov(mc_p, z)] - [\frac{1}{2}\sigma^2_{mc_d} + cov(mc_d, z)] \\ &\approx \quad \delta(\alpha_p - \alpha_d)[\frac{1}{2}\delta(\alpha_p + \alpha_d) + \frac{\delta(1 - \omega)}{\omega} - 1]\sigma^2_x > 0. \end{aligned} \tag{B.13}$$

Because $\alpha_p > \alpha_d$, for empirically plausible values of parameters ρ, κ and ω, we can show that Equation B.13 is positive. This implies $\pi(d, d) > \pi(d, p)$ when γ is big enough. Therefore, there exists a critical value $\gamma_H = \max[\gamma_4, \gamma_5, \gamma_6]$, such that for any $\gamma > \gamma_H$, (d, d) is the optimal strategy for all firms. This proves our conjecture that $\Omega = [0, 0, 0, 1]$ is the equilibrium distribution when γ is big enough.

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Table 1: The Currency Denomination of Export Invoicing of Selected Countries (%)[a]

Countries	Observation year	Foreign Currency				Own currency
		Dollar	Yen	DM	Other	
Korea	1995	88.1	6.5	2.4	0.8	$< 2.2^*$
Thailand	1996	91.7	4.5	0.5	2	1.3
Malaysia	1996	66	6.8	–	–	$< 20^*$
Indonesia	1995	90	–	–	–	$< 10^*$
Countries	Observation year	US dollar				Own currency
United States	1996	98.0				98.0
Germany	1994	9.8				76.4
Japan	1995	52.7				35.7
United Kingdom	1992	22.0				62.0
France	1995	18.6				51.7
Italy	1994	23.0				40.0

[a] Source: The data for developed countries are from Tavlas (1995). The data for Korea and Thailand are from Cook and Devereux (2006) and McKinnon and Schnabl (2004). Malaysian data are from Goldberg and Tille (2005). Indonesia data are from the World Bank. '–' indicats that data for this particular currency are not available. Data with * are calculated by the authors using data from above resources.

Table 2: The Currency Denomination of External Debt of Selected Countries (%)[b]

Countries	Year	Currency Composition of External Debt			Year	Share of Foreign Currency Debt
		Dollar	Yen	DM		
Korea	1997	83.0	10.2	0.3	1993-1998	100
Thailand	1997	73.9	20.8	1.0	1993-1998	98
Malaysia	1997	55.8	26.5	0.5	1993-1998	99
Indonesia	1997	27.2	32.9	4.7	1993-1998	94
Countries	Year	Share of Foreign Currency Debt				
United States	1993-1998	65				
Germany	1993-1998	67				
Japan	1993-1998	25				
United Kingdom	1993-1998	26				
France	1993-1998	52				
Italy	1993-1998	65				

[b]Source: The data for the currency composition of Korea, Malaysia and Indonesia in 1997 is for the long-term external debt, from the Global Development Finance 1999 by the World Bank. The data for Thailand in 1997 is for external debt, from Bank of Thailand. The data for the share of foreign currency debt for selected countries are from OSIN2 ratios in Eichengreen, Hausmann and Panizza (2005).

Table 3: Equations of the Model

(a) Optimal conditions for consumers	
Euler Equation: $\frac{1}{1+i_t} = \beta E_t(\frac{P_t C_t^{\rho}}{P_{t+1} C_{t+1}^{\rho}})$	Wage setting: $W_t = \frac{\theta}{\theta-1} \frac{E_{t-1}(\eta L_t^{1+\psi})}{E_{t-1}(\frac{L_t}{P_t C_t^{\rho}})}$
(b) Optimal condition for firms	
Peso pricing, peso debt(s_1): $P_{xt}^{p,p} = \hat{\lambda} \frac{E_{t-1}(MC_{p,t} S_t^{\lambda} Z_t)}{E_{t-1}(S_t^{\lambda} Z_t)}$	Peso pricing, dollar debt(s_2): $P_{xt}^{p,d} = \hat{\lambda} \frac{E_{t-1}(MC_{d,t} S_t^{\lambda} Z_t)}{E_{t-1}(S_t^{\lambda} Z_t)}$
Dollar pricing, peso debt(s_3): $P^{*d,p}_{xt} = \hat{\lambda} \frac{E_{t-1}(MC_{p,t} Z_t)}{E_{t-1}(S_t Z_t)}$	Dollar pricing, dollar debt(s_4): $P^{*d,d}_{xt} = \hat{\lambda} \frac{E_{t-1}(MC_{d,t} Z_t)}{E_{t-1}(S_t Z_t)}$
where $MC_{p,t} = W_t^{1-\omega}(E_t[\tilde{d}_{t+1} P_{It}(1+i_{pt})])^{\omega}$, $MC_{d,t} = W_t^{1-\omega}(E_t[\tilde{d}_{t+1} P_{It}(1+i^*_{dt}) \frac{S_{t+1}}{S_t}])^{\omega}$, $\hat{\lambda} = \frac{\lambda}{\lambda-1}$, $Z_t = d_t P^{*}_{xt}{}^{\lambda-1} X_t$, $\tilde{d}_{t+1} = \beta \frac{P_t C_t^{\rho}}{P_{t+1} C_{t+1}^{\rho}}$.	
(c) Price Index	
CPI: $P_t = W_t^{1-\alpha} S_t^{\alpha\varepsilon}$	Export price index: $P^*_{xt} = [\mu_1(\frac{P^{p,p}_{xt}}{S_t})^{1-\lambda} + \mu_2(\frac{P^{p,d}_{xt}}{S_t})^{1-\lambda} + \mu_3(P^{*d,p}_{xt})^{1-\lambda} + \mu_4(P^{*d,d}_{xt})^{1-\lambda}]^{\frac{1}{1-\lambda}}$
(d) Market Clearing Conditions	
Non-traded goods: $Y_{Nt} = C_{Nt} + \int_0^1 I_{xt}(i)$	
Export goods (peso pricing, peso debt): $Y^{p,p}_{xt} = (\frac{P^{p,p}_{xt}}{S_t P^*_{xt}})^{-\lambda} \frac{X_t}{P^*_{xt}}$	Export goods (peso pricing, dollar debt): $Y^{p,d}_{xt} = (\frac{P^{p,d}_{xt}}{S_t P^*_{xt}})^{-\lambda} \frac{X_t}{P^*_{xt}}$
Export goods (dollar pricing, peso debt): $Y^{d,p}_{xt} = (\frac{P^{*d,p}_{xt}}{P^*_{xt}})^{-\lambda} \frac{X_t}{P^*_{xt}}$	Export goods (dollar pricing, dollar debt): $Y^{d,d}_{xt} = (\frac{P^{*d,d}_{xt}}{P^*_{xt}})^{-\lambda} \frac{X_t}{P^*_{xt}}$
Labor Market: $L_{Nt} + \int_0^1 L_{xt}(i) di = L_t$	Bond Market: $B_t = 0$
Budget Constraint: $P_t C_t = W_t L_t + \Pi_{xt}$, where $\Pi_{xt} = \int_0^1 \Pi_{xt}(i) di$ and $\Pi_{xt}(i) = P_{xt}(i) Y_{xt}(i) - W_t L_{xt}(i) - DP_t(i) - \varphi(i)\phi$	

Table 4: Calibration Parameters

Parameters	value	Parameters	value	Parameters	value
ρ	2	β	0.96	α	0.3
λ	11	ω	0.4	σ_x	4%
ψ	1	θ	11	ϕ	0.000091
ε	0.5	α_p	0.95	α_d	0.25

Table 5: The Impact of γ on the Distribution of Firms Ω [c]

γ	$(0, 0.301]$	[0.302,132.501]	[132.501,134.378]	[134.378,∞)
s(p,p)μ_1	1	0	0	0
s(p,d)μ_2	0	1	$\mu_2(\gamma)$	0
s(d,p)μ_3	0	0	0	0
s(d,d)μ_4	0	0	$1-\mu_2(\gamma)$	1
$e=\mu_3+\mu_4$	0	0	$1-\mu_2(\gamma)$	1
$v=\mu_2+\mu_4$	0	1	1	1

[c] $\mu_2(\gamma)$ is the number of firms which choose the strategy s_2=(p,d) when $\gamma \in [132.501, 134.378]$, and it is also a decreasing function of γ, which satisfies with $\mu_2(132.501) = 1$ and $\mu_2(134.378) = 0$.

Table 6: Welfare Comparison

ζ	$\gamma = 0.01$	$\gamma = 900$
(p,p) $\Omega = (1, 0, 0, 0)$	-0.0020%	-0.2249%
(d,d) $\Omega = (0, 0, 0, 1)$	-0.0199%	-0.1526%

Table 7: Variables Comparison($\gamma = 900$)[d]

Strategy and distribution	$\widetilde{C}$	σ_C^2	$\widetilde{L}$	σ_L^2	$\widetilde{MC}$	$\widetilde{P}$
(p,p) $\Omega = [1, 0, 0, 0]$	-0.0019	0.0049	-0.0031	0.0018	0.0235	0.0107
(d,d) $\Omega = [0, 0, 0, 1]$	-0.0014	0.0029	-0.0019	0.0012	0.0171	0.0056

[d] $\widetilde{X} = EX_t - \bar{X}$, where $\bar{X}$ is the steady state variable of X.