Should East Asia's Currencies Be Pegged to the Yen? The Role of Invoice Currency

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Abstract

Growing concern that a dollar peg exposes East Asian economies to fluctuations in the dollar-yen exchange rate has stimulated research on currency basket regimes as alternatives for these economies. However, existing studies have mostly ignored an important characteristic of East Asia, i.e., most of its international trade is invoiced in the U.S. dollars. This paper investigates how the preponderance of dollar invoicing affects optimal currency basket regimes for East Asian economies. I develop a three-country center-periphery sticky-price dynamic stochastic general equilibrium model for the analysis. The model is solved numerically by taking second order approximations to the policy functions with the expected lifetime utility of households chosen as the welfare criterion. Contrary to the conjecture of existing literature, I show that predominance of dollar invoicing implies that the dollar should receive a smaller weight than suggested by bilateral trade shares between emerging markets in East Asia and the United States. The results hinge on the interaction of different degrees of pass-through implied by the choice of invoice currency and endogenous responses of monetary policies in the center countries.

Keywords: Optimal currency basket; East Asia; Dollar invoicing; Second order approximation; Center-periphery model

JEL Classifications: F33; F41

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1 Introduction

In recent years, currency basket regimes have received renewed interest as policy options for emerging markets, especially those in East Asia. At the center of this revival of interest is the observation that East Asian countries’ de facto peg to the U.S. dollar prior to the East Asian Financial Crisis exposed them to macroeconomic instability associated with fluctuations in the dollar-yen exchange rate. For instance, McKinnon and Schnabl (2003) document that East Asian countries tended to experience booms when the yen appreciated against the dollar and recessions when the yen depreciated against the dollar. This has led many studies (Ito et al., 1998; Williamson, 2000; Kawai and Takagi, 2000; Bird and Rajan, 2002; Kawai, 2002; Ogawa and Ito, 2002) to advocate currency basket regimes as alternatives for East Asian economies. Despite the differences in the details of their theoretical models, there seems to be a consensus among these studies that given the extensive trade linkages between emerging markets in East Asia and Japan (Table 1), the yen should receive significant weight in the proposed currency basket regimes for emerging markets in that region. However, in arriving at their conclusion, these studies have largely ignored an important characteristic of East Asia: most of its international trade is invoiced in the U.S. dollars.

How does the predominance of dollar invoicing affect optimal currency basket regimes in East Asia? McKinnon (2001) argues that it implies that the dollar should receive higher weights than suggested by simple bilateral trades between East Asian economies and the United States. Yet, his argument is informal and no rigorous theoretical model has ever been developed to study this topic\footnote{Lipschitz (1979) also discusses whether the currency denomination of international trade should affect optimal currency basket weight. However, he does not lay out a formal theoretical model to study this issue either.}.

This paper aims to fill this gap in the literature by developing the first formal theoretical model to study how the predominance of dollar invoicing in East Asia affects optimal currency basket regimes for emerging markets in that region. I show that contrary to McKinnon’s conjecture, the predominance of dollar invoicing actually implies that the dollar should receive less weight in an optimal currency basket regime. The results hinge on the interaction of different degrees of pass-through implied by the choice of invoice currency and endogenous responses of monetary policies.

A priori, there seems to be little distinction between the direction of trade and the
currency denomination of trade. It seems natural to think that trade between the U.S. and an East Asian country, say Korea, could be conducted in either the U.S. dollars or the Korean won, while trade between Japan and Korea could be conducted in either the Japanese yen or the won. In reality, there is a huge discrepancy between the direction of trade and the currency denomination of trade. Tables 2 to 4 show the fractions of trade invoiced in the U.S. dollars and the Japanese yen for Korea, Thailand and Japan from 1980-2000. As can be seen from Table 2, throughout the 1990s, almost 90% of Korean exports were invoiced in the U.S. dollars, even though only about 21% of Korean exports went to the United States. In contrast, while 14% of Korean exports went to Japan, less than 8% of Korean exports were invoiced in the yen. Similarly, close to 80% of Korean imports were invoiced in the dollars while less than 13% of Korean imports were invoiced in the yen, even though the shares of Korean imports from the United States and Japan were about the same (22% and 23% respectively). There is also a predominance of dollar invoicing in Thailand’s external trade. Throughout the 1990s, more than 90% of Thai exports and close to 80% of Thai imports were invoiced in the U.S. dollars (Table 3). Surprisingly, dollar invoicing is also prevalent in Japan’s external trade. More than 80% of Japanese exports to the U.S. and about 50% of Japanese exports to Asia were invoiced in the dollars throughout the 1990s (Table 4). The fraction of Japanese imports invoiced in the dollars was even higher: about 80% of Japanese imports from the U.S. and more than 70% of Japanese imports from Asia were invoiced in the dollars.

The model that I develop in this paper is a three-country sticky price dynamic stochastic general equilibrium model. It features utility maximizing households and profit maximizing firms. Prices are assumed to be adjusted in a staggered fashion. To study how the predominance of dollar invoicing affects optimal currency basket regimes in East Asia, I consider two price-setting specifications. In the "producer currency pricing" (PCP) version of the model, export prices are set in the currencies of the producers, as is commonly assumed in the literature. In the "dollar standard" (DS) version of the model, all exporters, regardless of which countries they are from, set their export prices in the dollars. The latter is meant to be an approximation of the predominance of dollar invoicing in East Asian trade. The dollar standard specification is first used by Devereux, Shi and Xu (2003) in a more stylized two-country model. They show that DS implies a very different prescription for optimal monetary policy compared with PCP in their two-country model. Figure 1 summarizes the differences between the two specifications in the assumptions about invoice currencies in various markets.
As mentioned above, I find that the preponderance of dollar invoicing actually implies that the dollar should receive less weight than suggested by the direction of trade. The mechanism that drives this result is the interaction of different degrees of pass-through implied by the dollar standard specification and endogenous responses of monetary policies in the center countries. Under DS, a negative productivity shock from the United States that causes the dollar to appreciate exerts upward pressure on the Japanese inflation rate as import prices are set in the dollars in Japan. This will prompt the Japanese monetary authority to tighten monetary policy to counter the inflationary pressure, which further depresses world demand. In contrast, a negative productivity shock from Japan that causes an appreciation of the yen has little effect on the American inflation rate since American import prices are set in the dollars. This means that the United States would not have to change its monetary policy as much. As a result, a productivity shock from Japan is less destabilizing than a productivity shock from the United States. An optimal currency basket regime has the feature that less weight should be put on the currency of the country that has the more destabilizing shock to minimize instability in the country that adopts the currency basket regime.

In addition to the basic question that it sets out to study, this paper differs from existing contributions in the currency basket literature in several important ways. First, it is the first paper in the currency basket literature to use a model that is neither linear nor linearized. Instead, the non-linear model in this paper is solved by taking second order approximations of the equilibrium conditions. One of the reasons why a second order approximation is used is purely technical: the expected lifetime utility of households is chosen as the welfare criterion in this paper. This by itself requires the model to be solved up to second order accuracy (Kim and Kim, 2003). The other reason is that it allows me to study how uncertainty affects the dynamics of the model. While almost all studies in the currency basket regime literature mention the negative effects of exchange rate uncertainty on trade as one of the arguments for a currency basket regime, none of them has been able to capture those effects in their model. This is because existing contributions use either linear or linearized models, which imply certainty equivalence. In contrast, I am able to consider the effects of uncertainty in this paper by solving the model up to second order accuracy.

Second, the model in this paper explicitly considers money and capital flows in a general equilibrium setting, whereas most existing contributions in the currency basket literature
use partial equilibrium real models\textsuperscript{2}. This distinction is important because in addition to expenditure switching effects that are stressed by real models, changes in the exchange rates have income and intertemporal substitution effects by affecting money balances and interest rates. Leaving out money and capital flows might lead to spurious conclusions.

The rest of the paper is organized as follows: Section 2 sets up the theoretical model. Section 3 derives the welfare measure, followed by Section 4, which discusses the solution method and calibration issues. Results are presented in Section 5. Section 6 concludes and discusses future research directions.

2 The model

A three-country dynamic stochastic general equilibrium model is developed for the theoretical analysis. The three countries, $A$, $J$, and $M$ (for concreteness, think of them as the United States, Japan and Malaysia) have $n_A$, $n_J$ and $n_M$ households respectively. $A$ and $J$ are assumed to be large, “center” countries while $M$ is a small, “periphery” country (i.e. $n_A, n_J \gg n_M$)\textsuperscript{3}.

Within each country, there is a continuum of monopolistically competitive firms. The measure of firms equals the number of households in each country. Each firm produces a brand of goods that is an imperfect substitute to goods produced by other firms. All goods are traded internationally. Firms are assumed to be able to price discriminate across markets. Prices are adjusted in a staggered fashion à la Calvo (1983). This setting introduces price rigidity into the model and allows monetary policy to have real effects.

As mentioned in the introduction, I consider two price-setting specifications in this paper. In addition to the usual producer currency pricing (PCP) specification where export prices are set in the currencies of the exporters, I also consider a specification called the dollar standard (DS), where all export prices are set in currency $A$ (the dollar). The latter specification will allow me to examine how the preponderance of dollar invoicing affects optimal currency basket regime in East Asia.

The financial markets are modeled as incomplete with only riskless nominal bonds

\textsuperscript{2}Slavov (2004) is the only other study that uses a dynamic stochastic general equilibrium model to study optimal currency basket regime. However, his focus is on how the currency denomination of external debt affects the optimal basket weights.

\textsuperscript{3}The total number of households in the model is normalized to 1, so $n_A + n_J + n_M = 1$.  

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denominated in the currencies of countries $A$ and $J$ being traded internationally. Table 5 summarizes the notations of variables used in this paper.

2.1 Households

The representative household in country $i$, $i = A, J, M$, maximizes its expected discounted lifetime utility (1), by choosing aggregate consumption ($C^i_t$), labor hours ($L^i_t$) and riskless nominal bonds ($B^i_{h,t+1}$) denominated in currency $h$, $h = A, J$, subject to the budget constraint (3):

$$E_0 \sum_{t=0}^{\infty} \beta^t U^i_t(C^i_t, L^i_t),$$

$$U^i_t = \left[ \kappa \frac{1}{\rho} (C^i_t) \frac{\mu-1}{\rho} + (1 - \kappa) \frac{1}{\rho} (1 - L^i_t) \frac{\mu-1}{\rho} \right]^{\frac{\mu}{\rho}},$$

$$\sum_{h \in \{A, J\}} S^i_{h,t} B^i_{h,t+1} + P^i_t C^i_t + \sum_{h \in \{A, J\}} \frac{\psi_B}{2} \frac{\left[ S^i_{h,t} B^i_{h,t+1} \right]^2}{N^i_{Y_t}}$$

$$= \sum_{h \in \{A, J\}} R^h_{t-1} S^i_{h,t} B^i_{h,t} + W^i_t L^i_t + \Psi^i_t,$$

where $S^i_{h,t}$ is the nominal exchange rate between country $i$ and country $h$, expressed as the price of currency $h$ in currency $i$; $R^h_t$ is the gross nominal interest rate on $h$ currency denominated bonds; $W^i_t$ is the nominal wage rate; $P^i_t$ and $N^i_{Y_t}$ are the consumer price index and the nominal GDP per capita respectively, to be defined formally below; $\Psi^i_t$ is the dividend that the representative household receives from owning all domestic firms; $\frac{\psi_B}{2} \frac{\left[ S^i_{h,t} B^i_{h,t+1} \right]^2}{N^i_{Y_t}}$ is a convex cost of bond adjustment, introduced to ensure stationarity of

\footnote{This assumption is meant to capture the inability of periphery countries to borrow in their own currencies as emphasized by Calvo and Reinhart (2002). However, since I abstract from balance sheet considerations in this paper, introducing bonds denominated in currency $M$ does not change the results of this paper.}

\footnote{An increase in $S^i_{h,t}$ is a depreciation of currency $i$ against currency $h$.}

\footnote{For simplicity, it is assumed that all profits are distributed back to shareholders as dividends in each period.}
bonds and consumption (Schmitt-Grohé and Uribe, 2003; Kollmann, 2003; Lubik, 2003). Total amount of time available is normalized to 1, so that the amount of leisure enjoyed by household is $1 - L_i^t$. The flow utility at period $t$ is specified as a constant elasticity of substitution (CES) function of consumption and leisure. This specification is more general than the usual specification used in the literature and it allows me to consider cases where exchange rate variability affects the amount of trade. In contrast, the more commonly used specification where consumption and leisure are separable in utility has the implication that the exchange rate variability has no effect on the amount of trade (Bacchetta and van Wincoop, 2000). The more general specification is used because the effects of exchange rate variability on trade have often been cited as arguments for currency basket regimes.

The first order conditions for the representative household’s maximization problem are:

$$\frac{\partial U_i^t}{\partial C_i^t} = \lambda_i^t P_i^t,$$

$$-\frac{\partial U_i^t}{\partial L_i^t} = \lambda_i^t W_i^t,$$

$$\lambda_i^t S_{h,t}^i + \psi_B \left( S_{h,t}^i \right)^2 \frac{S_{h,t+1}^i}{N Y_t} = \beta R_h^t E_t \left[ \lambda_{t+1} \right] , h = A, J, M,$$

where $\lambda_i^t$ is the Lagrange multiplier on the budget constraint. Equation (4) relates the Lagrange multiplier to the marginal utility of consumption. The marginal disutility of labor is equated with the utility value of the nominal wage in equation (5). Equation (6) is the Euler equation for bonds.

The preferences of the representative household in country $i$ across goods of different brands and origins are described by the following subutility functions$^7$:

$$C_i^t = \left[ \left( v_{A}^i \right)^{1 \over \sigma} (C_A^i)^{1 \over \sigma-1} + \left( v_{J}^i \right)^{1 \over \sigma} (C_J^i)^{1 \over \sigma-1} + \left( v_{M}^i \right)^{1 \over \sigma} (C_M^i)^{1 \over \sigma-1} \right]^{\sigma \over \sigma-1},$$

$$C_h^t = \left( \frac{1}{n_h} \right)^{1 \over \sigma} \int_0^{n_h} \left( C_h(z) \right)^{1 \over \sigma-1} dz \right]^{\frac{1}{\sigma-1}}, h = A, J, M,$$

$^7$Time subscripts are omitted because the subutility functions below are all static.
where $C_i^h(z)$ is the consumption of brand $z$ goods from country $h$ by the representative household in country $i$; $C_i^h$, $h = A, J, M$, is a constant elasticity of substitution composite of different brands of goods from country $h$, with $\phi$ being the elasticity of substitution parameter; the parameter $\theta$ is the intratemporal elasticity of substitution for goods of different origins; $v_i^h$’s, $h = A, J, M$, are parameters that determine the non-stochastic steady state shares of trade between countries.

Cost minimization by the representative household implies the following first order conditions:

$$C_i^h(z) = \frac{1}{n_h} \left( \frac{P_i^h(z)}{P_h} \right)^{-\phi} C_i^h, h = A, J, M,$$

$$C_i^h = v_i^h \left( \frac{P_i^h}{P_i} \right)^{-\theta} C_i^h, h = A, J, M,$$

where $P_i^h(z)$ is the price of brand $z$ goods from country $h$ in country $i$’s currency. $P_i$ and $P_h$ are the CPI index and the price index of goods from country $h$ respectively, as defined below:

$$P_i = \left[ v_A^i \left( P_A \right)^{1-\theta} + v_J^i \left( P_J \right)^{1-\theta} + v_M^i \left( P_M \right)^{1-\theta} \right]^{\frac{1}{1-\theta}},$$

$$P_h = \left[ \frac{1}{n_h} \int_0^{n_h} (P_h(z))^{1-\phi} \, dz \right]^{\frac{1}{1-\phi}}, h = A, J, M.$$

### 2.2 Firms

The technology for a monopolistically competitive firm, $z$, in country $i$ is:

$$Y_i^z(z) = F_i^z L_i^z(z),$$

where $Y_i^z(z)$ is the output of the firm in period $t$; $L_i^z(z)$ denotes labor hours employed by firm $z$ and $F_i^z$ is a country specific productivity shifter. The natural log of $F_i^z$ is assumed to follow a first order autoregressive process:

$$\ln F_i^z = \rho^F \ln F_{i-1}^z + \epsilon_i^z,$$
where $\varepsilon_t^i$ is an i.i.d. shock with zero mean and variance $\sigma_{\varepsilon_t^i}^2$.

Labor input is chosen to minimize the cost of production subject to the constraint that the supply of goods is no less than the demand, $Y^{i,d}_t(z)$:

$$\min W_t^i L_t^i(z), \quad \text{(15)}$$

$$s.t. \quad F_t^i L_t^i(z) \geq Y^{i,d}_t(z). \quad \text{(16)}$$

The first order condition for the cost minimization problem is:

$$MC_t^i(z) = \frac{W_t^i}{F_t^i}, \quad \text{(17)}$$

where $MC_t^i(z)$ is the Lagrange multiplier associated with the constraint, which can also be interpreted as the marginal cost.

In addition to choosing the amount of labor input, firms also set prices in their domestic markets, as well as for export. As mentioned in the introduction, the model will be analyzed under two price-setting specifications. In the PCP version of the model, export prices are set in the currencies of producers; in the DS version of the model, all export prices are set in currency $A$. Prices for sale in domestic markets are set in the home currencies of firms under both specifications.

Price adjustment is staggered, à la Calvo (1983). Firms are assumed to be able to reset their prices only if they receive a "price-change signal," which comes at a random rate of $1 - \alpha$, $\alpha \in [0, 1]$. If prices are not reset, they are automatically updated by the (deterministic) steady state growth factor of prices, $\bar{\Pi}$ (which is assumed to be the same across countries in this model)$^9$.

### 2.2.1 Optimal price-setting rules under dollar standard

Let $Q_{i,t-\tau}^{h}$, $\tau = 0, 1, 2, ..., \infty$, be the price, denominated in the invoice currency, that a firm which reset its price $\tau$ periods ago chooses$^{10}$. Under dollar standard, we have:

$$P_{i,t}^i(z) = \bar{\Pi}^{t-\tau}Q_{i,t-\tau}^{i}(z), \quad \text{(18)}$$

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$^9$The results of this paper remain unchanged for the case where the updating factor is the last period growth factor of prices.

$^{10}$Given the structure of the model, all firms that have the opportunity to reset their prices will choose the same price.
\[ P_{t,t}^h(z) = S_{A,t}^h \Pi^{t-\tau} Q_{t,t-\tau}^h(z). \]  

(19)

The optimization problem for a firm from country \( M \) can be described by:

\[
[Q_M^M; Q_A^A; Q_J^J] = \text{ArgMax}_{Q_M^M,Q_A^A,Q_J^J} \sum_{\tau=0}^{\infty} \alpha^\tau E_t \rho_{t,t+\tau}^M \pi_{t+\tau}^M (Q_M^M, Q_A^A, Q_J^J),
\]

where \( \pi_{t+\tau}^M() \) is the profit function in period \( t + \tau \); \( \rho_{t+\tau}^M \) is a pricing kernel\(^{11} \) that a firm uses to evaluate its profit stream in period \( t + \tau \); \( Y_{M,t}(z) \) is the total demand for country \( M \)'s brand \( z \) goods by all households in country \( h \); and \( TC_t^M \) is the total cost. It can be shown that the optimal price-setting rules for firms in country \( M \) are as follow:

\[
Q_M^M = \frac{\phi}{\phi - 1} \frac{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^M MC_{t+\tau}^M(z) Y_{M,t+\tau}^M(z)}{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^M \Pi^\tau Y_{M,t+\tau}^M(z)},
\]

(20)

\[
Q_A^A = \frac{\phi}{\phi - 1} \frac{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^A MC_{t+\tau}^A(z) Y_{A,t+\tau}^A(z)}{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^A \Pi^\tau Y_{A,t+\tau}^A(z)},
\]

(21)

\[
Q_J^J = \frac{\phi}{\phi - 1} \frac{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^J MC_{t+\tau}^J(z) Y_{J,t+\tau}^J(z)}{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^J \Pi^\tau Y_{J,t+\tau}^J(z)},
\]

(22)

The laws of motion for price indices, \( P_A^A, P_J^J \) and \( P_M^M \) can be shown to be:

\[
(P_A^A)^{1-\phi} = \alpha(\Pi P_A^A)^{1-\phi} + (1 - \alpha)(Q_A^A)^{1-\phi},
\]

(23)

\[
(P_J^J/S_{A,t})^{1-\phi} = \alpha(\Pi P_J^J)^{1-\phi} + (1 - \alpha)(Q_J^J)^{1-\phi},
\]

(24)

\[
(P_M^M)^{1-\phi} = \alpha(\Pi P_M^M)^{1-\phi} + (1 - \alpha)(Q_M^M)^{1-\phi}.
\]

(25)

The optimal pricing rules and the laws of motions for the price indices of countries \( A \) and \( J \) are given in the appendix.

Equations (21) to (22) show that optimal export prices chosen by firms from country

\(^{11}\)Following the literature, this pricing kernel is assumed to be the ratio of Lagrange multipliers in period \( t + \tau \) and period \( t \), i.e. \( \rho_{t,t+\tau}^M = \frac{\lambda_{t+\tau}^M}{\lambda_t^M} \).
M are weighted averages of future marginal costs and nominal exchange rates between currency M and currency A, weighted by anticipated demands and pricing kernels. The nominal exchange rate between currency M and currency A, \( S^M_A \), enters into the optimal pricing rules for export prices because firms have to set their export prices in currency A while they value profit in terms of their domestic currency. This stands in contrast to optimal export pricing rules for firms from country A (equations 42 and 43), which can set their export prices in their home currency.

### 2.2.2 Optimal pricing-rules under producer currency pricing

Under PCP, optimal pricing rules for goods sold in the home markets of producers are identical to the dollar standard case. For the export price, we have:

\[
P_{h,t}^h(z) = S_{i,t}^h \Pi_{t-\tau}^h Q_{i,t-\tau}^h(z).
\]

(26)

The optimization problem for a firm from country M is:

\[
[Q_{M,t}^M, Q_{M,t}^A, Q_{M,t}^J] = \underset{Q_{M,t}^M, Q_{M,t}^A, Q_{M,t}^J}{\text{Arg Max}} \sum_{\tau=0}^{\infty} \alpha^\tau E_t \rho_{t,t+\tau}^M \Pi_{t+\tau}^M (Q_{M,t}^M, Q_{M,t}^A, Q_{M,t}^J),
\]

\[
\Pi_{t+\tau}^M(Q_{M,t}^M, Q_{M,t}^A, Q_{M,t}^J) = \Pi^\tau Q_{M,t}^M Y_{M,t+\tau}^M(z) + \Pi^\tau Q_{M,t}^A Y_{A,t+\tau}^A(z) + \Pi^\tau Q_{M,t}^J Y_{J,t+\tau}^J(z) - TC_{t+\tau}^M.
\]

The optimal pricing rules for country M’s export prices and the laws of motions for its export price indices can be shown to be:

\[
Q_{M,t}^h = \frac{\phi}{\phi - 1} \frac{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^M [MC_{t+\tau}^M(z)Y_{M,t+\tau}^M(z)]}{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^M \Pi^\tau Y_{M,t+\tau}^M(z)}, h = A, J,
\]

(27)

\[
(P_{M,t}^h/S_{M,t}^h)^{1-\phi} = \alpha (P_{M,t-1}^h/S_{M,t-1}^h)^{1-\phi} + (1 - \alpha)(Q_{M,t}^h)^{1-\phi}, h = A, J.
\]

(28)

The optimal pricing rules and the laws of motions of price indices for countries A and J are symmetric to those of countries M and are therefore omitted.
2.3 Market clearing conditions

Market clearing requires that the demand and supply of goods to be equal:

\[ Y_t^i(z) = \sum_h n_h C_{i,t}^h(z) = \sum_h n_h \frac{1}{n_i} \left( \frac{P_{i,t}^h(z)}{P_{i,t}^h} \right)^{-\phi} C_{i,t}^h. \]  (29)

Market clearing for bonds requires bonds to be in zero net supply in the world:

\[ n_A B_{A,t}^A + n_J B_{J,t}^J + n_M B_{M,A,t}^M = 0, \]  (30)

\[ n_A B_{J,t}^A + n_J B_{J,t}^J + n_M B_{M,J,t}^M = 0. \]  (31)

2.4 Aggregation

The assumption that prices are adjusted in a staggered fashion implies that there is relative price dispersion across different brands of goods in this model. Since output is demand determined, the relative price dispersion translates into a dispersion of output across the continuum of monopolistically competitive firms in each country. This means that care must be taken in aggregating output across firms. Let \( Y_t^i \) be the aggregate output per capita in country \( i \):

\[ Y_t^i \equiv \frac{1}{n_i} \int_0^{n_i} Y_t^i(z) dz. \]  (32)

Then, equation (29) can be aggregated as:

\[
Y_t^i = \frac{1}{n_i} \int_0^{n_i} \left[ \sum_h n_h \frac{1}{n_i} \left( \frac{P_{i,t}^h(z)}{P_{i,t}^h} \right)^{-\phi} C_{i,t}^h \right] dz
\]

\[
= \frac{1}{n_i} \sum_h n_h \frac{1}{n_i} \int_0^{n_i} \left( \frac{P_{i,t}^h(z)}{P_{i,t}^h} \right)^{-\phi} dz C_{i,t}^h
\]

\[
= \frac{1}{n_i} \sum_h n_h \delta_{i,t}^h C_{i,t}^h, \]  (33)
where

\[ d_{i,t}^{h} = \frac{1}{n_i} \int_{0}^{n_i} \left( \frac{P_{i,t}^{h}(z)}{P_{i,t}^{h}} \right)^{-\phi} dz. \]  

(34)

The variable, \( d_{i,t}^{h} \), is an index of the cross-firm dispersion of prices of goods from country \( i \) in market \( h \). By definition, \( d_{i,t}^{h} \geq 1 \). As shown in Kollmann (2003), \( d_{i,t}^{h} \) is an increasing function of the degree of price stickiness, \( \alpha \), and of the variance of \( \Pi_{i,t}^{h} \), where \( \Pi_{i,t}^{h} = P_{i,t}^{h}/P_{i,t-1}^{h} \). In addition, one can take a second order approximation of (33) to get \( \hat{Y}_{i}^{t} = \sum_{h} \frac{n_{h}}{n_{i}} \nu_{i}^{h} \hat{C}_{i,t}^{h} + \hat{d}_{i}^{t} \), where a caret over a variable denotes the percentage deviation of that variable from its deterministic steady state. The term \( \hat{d}_{i}^{t} = \sum_{h} \frac{n_{h}}{n_{i}} \nu_{i}^{h} d_{i,t}^{h} \) is a measure of the total resource cost of price dispersion across firms in country \( i \).

Using the same method as above, equation (13) can be aggregated as:

\[ Y_{i}^{t} = \frac{1}{n_{i}} \int_{0}^{n_{i}} F_{i}^{i} L_{i}^{i}(z) dz = F_{i}^{i} \frac{1}{n_{i}} \int_{0}^{n_{i}} L_{i}^{i}(z) dz = F_{i}^{i} \frac{1}{n_{i}} n_{i} L_{i}^{i} = F_{i}^{i} L_{i}^{i}. \]  

(35)

The third line of equation (35) follows from the fact that the total demand of labor hours by all firms, \( \int_{0}^{n_{i}} L_{i}^{i}(z) dz \), must equal the total supply of labor hours by all households in the country, \( n_{i} L_{i}^{i} \).

It is useful to define some auxiliary variables to simplify exposition below. Nominal GDP per capita, \( NY_{i}^{t} \), is defined by integrating the revenue of all firms in country \( i \) and dividing it by the number of households:

\[ NY_{i}^{t} = \left[ \sum_{h} \int_{0}^{n_{i}} n_{h} S_{h,i}^{i} P_{i,t}^{h}(z) C_{i,t}^{h}(z) dz \right] / n^{i} \]  

\[ = \left[ \sum_{h} n_{h} S_{h,i}^{i} P_{i,t}^{h} C_{i,t}^{h} \right] / n^{i}. \]  

(36)

The current account of country \( i \), \( CA_{i}^{t} \), is defined as the increase in country \( i \)'s holding
of nominal bonds in period $t$:

$$CA^i_t = S^i_{A,t}(B^i_{A,t+1} - B^i_{A,t}) + S^i_{J,t}(B^i_{J,t+1} - B^i_{J,t}). \quad (37)$$

### 2.5 Monetary policy

Since the focus of this paper is on the monetary policy of country $M$, for simplicity, it is assumed that monetary authorities in countries $A$ and $J$ follow strict consumer inflation targeting, that is, they adjust their interest rates so that $P^A_t/P^A_{t-1}$ and $P^J_t/P^J_{t-1}$ always equal the steady state gross inflation rate$^{13}$. Country $M$, on the other hand, is assumed to adopt a currency basket regime, i.e., it sets a linear combination of the percentage changes of its exchange rates against currencies $A$ and $J$ to zero:

$$b \Delta \ln S^M_{A,t} + (1 - b) \Delta \ln S^M_{J,t} = 0, \quad (38)$$

where $\Delta$ is the first difference operator and $b \in [0, 1]$ is the weight on currency A. The values $b = 0$ and $b = 1$ correspond to the special cases where country $M$ pegs exclusively to currency $J$ and currency $A$ respectively. While it is theoretically possible for $b$ to be smaller than zero or larger than one as argued in Turnovsky (1982), I restrict $b$ to be between zero and one because this is more consistent with currency basket regimes that are implemented in practice.

### 3 The welfare measure

The welfare measure used to rank currency basket regimes of different weights in this paper, $V^M_0$, is the conditional expected lifetime utility of the representative household in country $M$ at time zero:

$$V^M_0 \equiv E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{1}{\rho} (C^i_t) ^{\frac{\mu-1}{\mu}} + (1 - \kappa) \frac{1}{\rho} (1 - L^i_t) ^{\frac{\mu-1}{\mu}} \right]^{\frac{\mu}{\mu-1}}. \quad (39)$$

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$^{13}$This assumption is made mainly to facilitate exposition. The results are robust when countries $A$ and $J$ follow interest rate rules like Taylor rules.
The conditional expectation of lifetime utility is used as the welfare measure instead of the unconditional expectation, because the latter ignores welfare effects during transition periods when the economy moves from the initial state to the stochastic steady state and may lead to paradoxical results (Kim et al., 2003). Following Schmitt-Grohé and Uribe (2004b), the expected lifetime utility is computed conditional on the initial state being the deterministic steady state, which is the same for all values of currency basket weight, $b$. This choice of initial state has the advantage of ensuring that the economy starts from the same initial point for all policy regimes considered.

To provide a clearer sense of the magnitudes of welfare differences across different values of $b$, I follow Lucas (1987) and report welfare as the percentage change, $\zeta$, in the deterministic steady state consumption that will give the same utility as the conditional expected lifetime utility $V_0^M$. $\zeta$ is given implicitly by:

$$\left[\frac{1}{\kappa^{\frac{1}{2}}} \left( \frac{\zeta}{100} \right) (1 + \frac{\zeta}{100}) \frac{C^M}{\pi} + (1 - \kappa)^{\frac{1}{2}} (1 - L^M) \frac{\mu}{\pi}\right]^{\frac{1}{1 - \beta}} \frac{\mu}{\beta - 1} = V_0^M,$$  

(40)

where a bar over a variable denotes the deterministic steady state of that variable. Higher values of $\zeta$ correspond to higher welfare.

4 Solution method and calibration

The model outlined above does not yield an analytical solution, hence it is solved using numerical methods. Since the paper uses the conditional expected lifetime utility as the welfare measure, the model needs to be solved up to second order accuracy to capture the effects of uncertainty on the expected values of the variables in the model (Kim and Kim, 2003). This is done by taking second order Taylor approximations of the structural equations around the deterministic steady state mentioned above. The system of equations is solved using a perturbation method described in Schmitt-Grohé and Uribe (2004a) and implemented by the Dynare toolbox (Collard and Juillard, 2000). For each experiment, I consider 11 values of $b$, ranging from 0 to 1, with an increment of 0.1. The optimal currency basket weight is the value of $b$ that delivers the highest $\zeta$.

To use the numerical approximation methods described above, the values of the structural parameters of the model need to be specified. The coefficient of risk aversion, $\sigma$, is set at 2 as is commonly assumed in the literature. $\kappa$ is chosen so that the steady state share
of time devoted to labor hours is 0.37. The elasticity of substitution between consumption and leisure, \( \mu \), is set at 3 in the benchmark parameterization. This makes consumption and leisure substitutes in utility, which has the implication that exchange rate volatility discourages trade. The model will also be simulated with alternative values of \( \mu \) to check for robustness. The discount factor \( \beta \) is calibrated at 0.99, so that the steady state annual real interest rate is 4%. Following Rotemberg and Woodford (1998), \( \phi \) is chosen to be 7.66, which implies a steady state markup of 15%. \( \alpha \) is set at 0.75, which implies an average price change duration of 4 quarters. The bond adjustment parameter, \( \psi_B \), is set at 0.0038 following Kollmann (2003). Following Chari, Kehoe and McGrattan (2002), the intratemporal elasticity of substitution parameter \( \theta \) is set at 1.5 for the benchmark case. \( n_A, n_J \) are both set at 0.45 while \( n_M \) is set at 0.1 to reflect the assumption that the economic size of country \( M \) is small compared to countries \( A \) and \( J \). The steady state (gross) inflation rate, \( \bar{\Pi} \), is set at 1.01, so that the annual steady state inflation rate is about 4%.

The parameters \( v_{ih} \)'s in the definition of the consumption aggregate determine how the steady state consumption expenditure is distributed across goods from different countries. In the literature, they are commonly specified to be identical to the economic sizes of the respective countries (e.g. Benigno and Benigno, 2003). This paper follows Sutherland (2002a) and allow for "home-biasedness." For instance, \( v^M_A \) and \( v^M_J \) are set at \( \gamma n_A \) and \( \gamma n_J \) respectively (\( v^M_M = 1 - v^M_A - v^M_J \)). Other \( v_{ih} \)'s are chosen in the same spirit. The parameter \( \gamma \) can be seen as the degree of openness (equivalently, \( 1 - \gamma \) is the degree of home-biasedness). When \( \gamma = 1 \), the share of expenditure going to a country’s goods is identical to that country’s economic size as is usually assumed in the literature. When \( \gamma = 0 \), there is no trade among the countries. \( \gamma \) is set at 0.5 in the benchmark, which implies that 45% of \( M \)'s expenditure goes to imports, while the equivalent figure is 27.5% for countries \( A \) and \( J \), given the assumed values for \( n_A, n_J \) and \( n_M \). The calibration \( n_A = n_J = 0.45 \) also implies that country \( M \)'s trade is split evenly between countries \( A \) and \( J \) in the steady state. The first order AR coefficient, \( \rho_F \), on productivity shifters is set at 0.9 while the standard deviations of productivity shocks, \( \sigma_{\varepsilon_A}, \sigma_{\varepsilon_J}, \sigma_{\varepsilon_M} \), are set at 0.01. For the benchmark case, I set the correlations of productivity shocks across countries, \( \rho(\varepsilon^i, \varepsilon^h), i \neq h \), to be zero. A summary of the benchmark parameterization can be found in Table 6.
5 Results

This section evaluates the welfare implications of currency basket regimes of different weights using the conditional expectation of lifetime utility as the welfare measure. For each experiment, the values of the welfare measure, $\zeta$, along with the conditional means and standard deviations of selected variables of interest are reported. Conditional instead of unconditional moments are reported because the expected lifetime utility of the representative household can be decomposed into a weighted sum of the conditional means and variances of consumption and labor hours and hence they provide more useful information than unconditional moments. All statistics are shown in terms of percentage deviations from their steady state values.

To make the results more intuitive, they are first reported for the three cases where the economy is subjected to productivity shocks from only one of the three countries in each case. Impulse response functions of selected variables of interest are also presented for polar values of currency basket weight, $b = 0$ (dotted lines) and $b = 1$ (solid lines), to further clarify the transmission mechanism of the model. These two polar cases are shown because they are useful for understanding the dynamic behavior of the model for intermediate values of $b$. After understanding the dynamics of the model for the cases where the economy is subjected to productivity shocks from each of the three countries separately, results are presented for the case where shocks from all three countries are considered together. Finally, a subsection on robustness check follows.

5.1 Productivity shock from country A

Figures 2A and 2B show the plots of $\zeta$ as well as the conditional means and standard deviations of selected variables of interest as $b$ varies for the cases of PCP and DS, respectively, when the economy is subjected to productivity shocks from country A only. As can be seen from the figures, the welfare of country M is decreasing in $b$ under both price-setting specifications. The conditional means of consumption and labor hours are also both decreasing in the values of $b$. While other things being equal, the high expected labor hours at low values of $b$ reduce welfare, welfare of country M seems to be dominated by the higher expected consumption and the lower standard deviations of consumption and labor hours at lower values of $b$. This makes the overall welfare of country M decreasing in $b$. To see the intuition more clearly, it is useful to look at the impulse response functions of selected variables of interest.
Figures 3 and 4 show the dynamic response patterns of a number of variables of interest to a -1% innovation to country A’s productivity for the cases of PCP and DS, respectively. A temporary decrease in country A’s productivity has both direct and indirect effects on country A. The direct effect is a reduction in the output produced from a given labor input. This reduces the supply of country A’s goods and makes them more expensive relative to goods from other countries. As a result, households tend to substitute goods from other countries for country A’s goods, thus reducing the income of country A’s households and hence their consumption.

The indirect effect on country A arises from the impact that the temporary productivity decline has on its nominal exchange rate and inflation rate and the endogenous response of country A’s monetary policy. The temporary decline in country A’s productivity affects country A’s inflation rate through two channels. First, it decreases the supply of country A’s goods, thereby exerting an upward pressure on their prices and consequently on country A’s inflation rate. Since the monetary authority in country A is assumed to always hold its CPI inflation rate constant, the upward pressure on its inflation rate will elicit an endogenous response from its monetary authority, which will be elaborated below. Second, the temporary decrease in productivity also worsens country A’s current account, CA_A, as households in country A borrow from abroad to smooth consumption. This worsening of country A’s current account (or equivalently its net foreign investment) reduces the supply of its currency in international market and leads to a nominal appreciation of currency A. If export prices are set in producer currencies, as is commonly assumed in the literature, the appreciation in currency A will translate into a decrease in country A’s import prices, similar to the case where prices are flexible. This is because even though the majority of the exporters will not be able to adjust their prices immediately, nominal appreciation of currency A is immediately passed through to country A’s import prices, since country A import prices in currency A are simply the product of the prices that exporters set in their home currencies and the appreciated nominal exchange rates between currency A and the currencies of exporters. For the benchmark parameterization, the supply effect on inflation dominates the nominal appreciation effect. Since country A is assumed to be following strict CPI inflation targeting, it will have to raise its nominal interest rate to combat the upward pressure on its inflation rate. In contrast, under dollar standard, country A’s

14Impulse response functions of current accounts shown in this section are relative to each country’s nominal GDP.
import prices are rigid in currency A. Most exporters to country A would not have the opportunity to adjust their prices immediately. Nominal appreciation of currency A thus has little immediate effect on its import prices. This means that under DS, the supply effect on the inflation rate is even more pronounced compared to the nominal appreciation effect, and country A will have to raise its nominal interest rate by more compared to under PCP. In either case, the increase in $R_t^A$ adds to the decline in country A’s consumption and output\(^\text{15}\) stemming from the direct effect.

The negative productivity shock from country A is propagated to countries J and M through four channels. First, the decline in country A’s income and consumption induced by the negative productivity shock reduces demand for goods from countries J and M. This is because goods from those two countries make up part of country A’s consumption basket. When country A’s overall consumption declines, its demand for goods from countries J and M will drop ceteris paribus. Second, the negative shock to $F_t^A$ increases relative prices of goods from country A and affects the demand for goods from the other two countries. The increase in the relative prices of country A’s goods arises from the decline in their supply and the appreciation of currency A induced by the negative shock to $F_t^A$. All else equal, this tends to increase the demand for goods from countries J and M. Third, as a flip side to the decline in the current account of country A, current accounts in countries J and M improve following the negative shock to $F_t^A$. This alters the intertemporal consumption profiles in those two countries.

The fourth channel through which a negative productivity shock is propagated to countries J and M is the endogenous responses of monetary authorities in those two countries. For country J, the appreciation of currency A exerts an upward pressure on its inflation rate as its import prices become more expensive. This pressure is larger under DS since all of country J’s import prices are set in currency A, as opposed to under PCP in which only imports from country A are set in currency A. Hence, while country J has to raise its nominal interest rate to stabilize its inflation rate in both cases, the increase in the interest rate is larger under DS. The increase in country J’s nominal interest rate further depresses country J’s output and consumption. Overall, country J’s output, consumption and labor hours all decline following the negative productivity shock from country A.

For country M, the quantitative effects of a negative productivity shock from country

\(^{15}\)Impulse response functions of some variables described in this section are not shown in the paper to conserve space. They are available from the author upon request.
A depend on the currency basket weights that it chooses. Despite the presence of portfolio adjustment costs in the bond Euler equations, (6), deviations from uncovered interest parity are small in this model. Therefore, country M has to set its nominal interest rate roughly equal the nominal interest rate of country A (J) if it pegs to currency A (J) alone. For intermediate values of the currency basket weight, b, country M’s nominal interest rate would have to roughly equal a linear combination of nominal interest rates in countries A and J, with weights identical to the basket weights. Since \( R_t^J \) increases by more than \( R_t^A \) following the negative productivity shock from country A, country M would have to raise its nominal interest rate by more if it pegs to currency J alone (\( b = 0 \)) than for other values of \( b \). Ceteris paribus, the larger increase in \( R_t^M \) for \( b = 0 \) would lead to larger declines in country M’s consumption, output and labor hours. However, the quantitative effects of different basket weights are dominated by the expenditure switching effects. Consider the PCP case. If country M pegs to currency J alone, its currency would depreciate against currency A. Since export prices are set in producer currencies under PCP, this would make country M’s goods cheaper for country A, which means that country A’s consumption of country M’s goods, \( C_{AM,t}^A \), would decline by less compared to the case where \( b = 1 \). Similarly, \( C_{JM,t}^J \) would decline by less for \( b = 0 \) than for \( b = 1 \) (in the latter case, currency M appreciates against currency J). In addition, \( C_{MM,t}^M \) would decline by less for \( b = 0 \) than for \( b = 1 \). This is because in the former case, imports from country A would become more expensive for country M, causing households in country M to consume more home goods; in the latter case, imports from country J would become cheaper for country M. In fact, since the amount by which currency M depreciates against currency A is decreasing in \( b \), the declines in \( C_{AM,t}^A \), \( C_{JM,t}^J \) and \( C_{MM,t}^M \) are increasing in the values of \( b \). All three expenditure effects described above imply that country M’s output (and hence labor hours) would decline less for \( b = 0 \) than for any other value of \( b \). The smaller decline in output for \( b = 0 \) implies a smaller decline in income and hence a smaller decline in consumption. Thus, pegging to currency J alone when the negative productivity shock originates in country A allows country M’s exchange rates to play a more effective role as shock absorbers.

Under dollar standard, the scope for country M’s exchange rates to act as shock absorbers is more limited. This is because under dollar standard, country A’s import prices in currency A are insulated from changes in exchange rates while country J’s import prices in currency J depend on the nominal exchange rate between currencies A and J, which is independent of the basket weight that country M chooses. Nonetheless, the choice of cur-
currency basket still matters since it affects the relative prices that households in country $M$ face. If country $M$ pegs to currency $J$, its currency would depreciate against currency $A$, making prices of imports from both countries $A$ and $J$ more expensive compared to home goods. As a result, households in country $M$ would consume more home goods when $b = 0$ than when $b = 1$ (in which case import prices do not change). Similar to the case of PCP, there is a negative correlation between $C_{M,t}^M$ and $b$. Therefore, country $M$’s output, labor hours and consequently its income and consumption would decline by the least amount for the case where $b = 0$.

The impulse response functions presented above show that for both price-setting specifications, the declines in country $M$’s consumption and labor hours are increasing in $b$ when the economy is subjected to a negative productivity shock from country $A$. By symmetry, the increases in country $M$’s consumption and labor hours are also increasing in $b$ when the economy is subjected to a positive productivity shock from country $A$. It follows that the standard deviations of those variables are increasing in $b$ when there are only productivity shocks from country $A$. As for the conditional means of country $M$’s consumption and labor hours, it is impossible to infer from the impulse response functions why they are decreasing in $b$. This is because up to second order approximation, the expected value of a variable is a function of all the variances and covariances of the model (Sutherland, 2002b). It is only possible to show how the expected value of a variable depends on the variances and covariances of the model when the model is simple enough to be solved analytically. Heuristically, a pattern that emerges from Figures 2A and 2B is that the conditional mean of a variable tends to be highest when its conditional standard deviation is lowest.

5.2 Productivity shock from country J

For the case of PCP, countries $A$ and $J$ are symmetric under the benchmark parameterization. Hence, the graphs (not shown to conserve space) for country $M$’s welfare, conditional means and standard deviations of consumption and labor hours are mirror images of the case of a productivity shock from country $A$. Country $M$’s welfare and conditional means of consumption and labor hours are highest for $b = 1$, and its conditional standard deviations of consumption and labor hours are lowest for $b = 1$.

For the case of DS, Figure 5A shows that country $M$’s welfare, conditional means of consumption and labor hours are also highest for $b = 1$. The conditional standard deviations of $C^M$ and $L^M$ are lowest for $b = 1$ as well. To gain some intuition behind
this result, Figure 6 shows the impulse response functions of some variables of interest to a -1% productivity shock from country $J$ for the case of DS. Similar to the effects of a temporary decline in $F_t^A$ on $CA_t^A$, a temporary decline in $F_t^J$ worsens country $J$’s current account, $CA_t^J$, as households in country $J$ borrow from abroad to smooth consumption intertemporally. This leads to an appreciation of currency $J$. Under dollar standard, prices of country $J$’s imports from both countries $A$ and $M$, which are rigid in currency $A$, become cheaper, which puts a downward pressure on country $J$’s inflation rate. Under the benchmark parameterization, this nominal appreciation effect dominates the supply effect in the impact period, causing country $J$ to lower its nominal interest rate in the impact period to keep its inflation rate constant. In subsequent periods, the supply effect dominates the nominal appreciation effect, inducing country $J$ to set its nominal interest rate above its long run value before the economy moves back to its steady state. $Y^J$ and $C^J$ decline during the transition periods.

As in the case of a temporary decline in $F_t^A$, for country $M$, the difference between currency basket regimes of different basket weights depends on their effects on the relative prices of country $M$’s exports and imports. Since in exact opposite to the case of a negative productivity shock from country $A$, currency $J$ appreciates against currency $A$ following the negative productivity shock from country $J$, the same reasoning as in the last subsection implies that country $M$’s consumption and labor hours will decline by less for $b = 1$ than for any other value of $b$. Thus, when the only shocks are productivity shocks from country $J$, pegging to currency $A$ alone minimizes the change in country $M$’s consumption and labor hours. This implies that conditional standard deviations of $C^M$ and $L^M$ are lowest for $b = 1$.

It is interesting to note that under dollar standard, the declines in country $M$’s consumption and labor hours are larger for the case of a temporary decline in $F_t^A$ than for the case of a temporary decline in $F_t^J$. This difference arises because an appreciation of currency $A$ has different implications for the model compared to an appreciation of currency $J$. Since all export prices are set in currency $A$ under dollar standard, when currency $J$ appreciates following a negative productivity shock from country $J$, it has little effect on country $A$’s inflation rate. In contrast, when currency $A$ appreciates following a negative productivity shock from country $A$, it generates an upward pressure on country $J$’s inflation rate, prompting country $J$ to tighten monetary policy to stabilize its inflation rate. The more aggressive response from country $J$ following a temporary decline in $F_t^A$ compared to the response of country $A$ following a temporary decline in $F_t^J$ leads to a larger decline
in worldwide demand for the case of a temporary decline in $F_t^A$. Therefore, the demand for country $M$'s goods, and hence country $M$'s output, consumption and labor hours also decline by more for the case of a negative productivity shock from country $A$.

5.3 Productivity shock from country $M$

Figure 5B show the results for the case of DS when there are only productivity shocks from country $M$. The results for the case of PCP are similar and hence are omitted here. The most striking result from Figure 5B is that welfare as well as the conditional means and standard deviations of the variables of interest are identical for all values of $b$! What is the intuition behind this? Figure 7 presents the impulse response functions of variables of interest to a -1% shock to country $M$'s productivity. The dynamic behavior of the model is identical for all values of $b$. This is because while country $M$'s current account still worsens following a temporary decline in its productivity, it has no effect on the nominal exchange rate between currency $A$ and currency $J$. As a result, it does not matter which currency or what combination of currencies country $M$ pegs to. Pegging to currency $A$ alone is identical to pegging to currency $J$ alone when the nominal exchange rate between $A$ and $J$ does not change. Moreover, since the two price-setting specifications, PCP and DS, differ only in which currency export prices are set in, the facts that the nominal exchange rate between $A$ and $J$ does not change and that country $M$ chooses a currency basket regime imply that the dynamics of the model are the same under both price-setting specifications when there are only productivity shocks from country $M$.

5.4 All shocks

Figure 8A shows the results for the case of PCP when all shocks are considered together. As can be seen from the figure, $\zeta$ is highest at $b = 0.5$, which is also the trade weight. Conditional means of consumption and labor hours are also highest at $b = 0.5$, while conditional standard deviations of the same variables are lowest at that optimal currency basket weight. This is not too surprising given that countries $A$ and $J$ are symmetric for the case of PCP under benchmark parameterization. Recall from the subsections above that conditional standard deviations of $C^M$ and $L^M$ are increasing in $b$ when there are only shocks from country $A$ and decreasing in $b$ in when there are only shocks from country $J$. Since countries $A$ and $J$ are symmetric, standard deviations of $C^M$ and $L^M$ are lowest at $b = 0.5$ due to Jensen’s inequality when shocks from both countries are considered together.
In contrast to the case of PCP, the optimal currency basket weight is 0.3 (Figure 8B) for the case of dollar standard, which is lower than the trade weight between country \( M \) and country \( A \). This results stands in stark contrast to McKinnon (2001), who conjectures that the preponderance of dollar invoicing in East Asia implies that the weight on the dollar in East Asian economies’ currency basket regime should be higher than suggested by bilateral trade weight between East Asia and the United States. What is the intuition behind this result? While the welfare of country \( M \) is still decreasing in \( b \) when there are only shocks from country \( A \) and increasing in \( b \) when there are only shocks from country \( J \), countries \( A \) and \( J \) are no longer symmetric for the case of dollar standard. Note from Figures 2B and 5A that the welfare of country \( M \) is lower when there are only shocks from country \( A \) than when there are only shocks from country \( J \). Conditional means of \( C^M \) and \( L^M \) are also lower and conditional standard deviations of the same variables higher when there are only shocks from country \( A \). This is consistent with the results in Figures 4 and 6 that productivity shocks from country \( A \) are more destabilizing than productivity shocks from country \( J \) for the case of DS. An optimal currency basket regime requires that less weight be placed on the currency of the country that has the more destabilizing shocks in order to minimize instability in the country that adopts the currency basket regime.

5.5 Sensitivity analysis

In this subsection, I consider various deviations from the benchmark model to assess the robustness of the results. The results reported are for the dollar standard specification. The results for the producer currency pricing specification are omitted since consistent with the pattern found above, optimal currency basket regimes for the case of PCP merely entail larger weights for currency \( A \) compared to the corresponding DS cases.

5.5.1 Demand shocks

While I only consider productivity shocks in the benchmark model, the results in this paper continue to hold for the case of demand shocks. This is because the mechanism that drives the results in this paper is the different degrees of pass-through implied by the choice of invoice currency, rather than the nature of the shocks. Consider for instance a positive government spending shock in country \( A \). It exerts an upward pressure on country \( A \)’s inflation rate and causes an appreciation in currency \( A \). This in turn creates an upward pressure on country \( J \)’s inflation rate since country \( J \)’s imports are all invoiced in currency
A for the case of dollar standard. As a result, country J has to tighten its monetary policy. In contrast, a government spending shock in country J that causes an appreciation in currency J has a smaller effect on country A’s monetary policy since its imports are all invoiced in its home currency. Therefore, like the case of productivity shocks, government spending shocks in country A are more destabilizing than government spending shocks in country J. Panel A of Figure 9 shows that when the model economy is subjected only to government spending shocks, the optimal currency basket weight for the case of dollar standard remains 0.3.

### 5.5.2 Introduction of capital

In the benchmark model, the production function takes a simple constant returns to labor specification. It is natural to ask whether the results would still hold if capital is introduced into the model. Panel B of Figure 9 considers the case where the production technology is the commonly used Cobb-Douglas function of capital and labor\(^{16}\). As can be seen from panel B, the optimal currency basket weight on currency A is identical to the benchmark case. The intuition behind this result is similar to the case of demand shocks. Different degrees of pass through implied by the choice of invoice currency drive the results in this paper while the nature of the production function plays an insignificant role.

### 5.5.3 Deviations from the benchmark parameterization

Panel C of Figure 9 considers the case where the elasticity of substitution between consumption and leisure is 0.1, so that consumption and leisure are complements. Bacchetta and van Wincoop (2000) show that in this case, exchange rate variability increases trade. As can be seen from panel E, the optimal currency basket weight is the same as under the benchmark parameterization. Next, I consider the case where the degree of openness is smaller. Specifically, I set \( \gamma = 0.1 \) in panel D of Figure 9. This makes exports less than 10% of country M’s output. The optimal currency basket weight is slightly larger than the benchmark case, which is not surprising since the difference between currency basket regimes of different weights depends on the terms of trade effects, which are more muted for a less open economy. Finally, I consider an intratemporal elasticity of substitution that is much larger compared to the one assumed in the benchmark parameterization in the last

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\(^{16}\)Details of how capital is introduced into the model are available from the author upon request.
panel of Figure 9. Specifically, I set $\theta = 5$ following Bergin and Tchakarov (2003). The optimal currency basket weight does not change.

6 Conclusion

This paper sets out to study how the preponderance of dollar invoicing in East Asia affects optimal currency basket regimes for East Asian emerging markets. I develop a three-country sticky price dynamic stochastic general equilibrium model for the theoretical analysis. The model is solved numerically by taking second order approximations to the policy functions. I show that contrary to the conjecture of the existing literature, the preponderance of dollar invoicing actually implies that the dollar should receive less weight in an optimal currency basket regime.

The results in this paper have important policy implications. They suggest that attention should be paid to the pricing behavior and currency denomination of trade in designing an optimal currency basket regime. This might be especially relevant for a country like China, which some recent studies suggest should move to a basket peg. It is also worth stressing that the results in this paper have implications beyond emerging markets in East Asia. For instance, emerging markets in Eastern Europe, which trade extensively with both the U.S. and Euroland, might face similar trade-offs. Some empirical studies into the currency denomination of trade in that region might be warranted.

The model in this paper can be extended in several ways. First, instead of assuming that the choice of invoice currency is exogenous, it would be interesting to see what price-setting behavior will prevail and how it would affect optimal currency basket regime in this three-country model, if the currency denomination of trade is endogenous. Devereux, Engel and Storgaard (2004) have made important contributions on the theme of endogenous choice of price-setting currencies in the context of a two-country model. Second, a second periphery country can be introduced into the model to study how the two periphery countries affect each other’s optimal currency basket weights. It can also be used to study issues such as whether joint pegging (where both countries choose the same basket weights) is optimal. Another interesting direction for future research is estimating instead of calibrating the parameters in the model using the recently developed Bayesian structural estimation method as in Lubik and Teo (2004).
7 Appendix

Following the same steps as in Section 2.2.1, optimal pricing rules and laws of motions for price indices for countries $A$ and $J$ under dollar standard can be shown to be:

\[
Q_{A,t}^t = \frac{\phi}{\phi - 1} \frac{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^A \left[ MC_{t+\tau}^A(z)Y_{A,t+\tau}^A(z) \right]}{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^A \Pi^t Y_{A,t+\tau}^A(z)},
\]

(41)

\[
Q_{J,t}^t = \frac{\phi}{\phi - 1} \frac{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^J \left[ MC_{t+\tau}^J(z)Y_{J,t+\tau}^J(z) \right]}{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^J \Pi^t S_{J,t+\tau}^J Y_{J,t+\tau}^J(z)},
\]

(42)

\[
Q_{M,t}^t = \frac{\phi}{\phi - 1} \frac{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^M \left[ MC_{t+\tau}^M(z)Y_{M,t+\tau}^M(z) \right]}{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^M \Pi^t S_{M,t+\tau}^M Y_{M,t+\tau}^M(z)},
\]

(43)

\[
Q_{A,t}^{A,t} = \frac{\phi}{\phi - 1} \frac{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^A \left[ MC_{t+\tau}^A(z)Y_{A,t+\tau}^A(z) \right]}{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^A \Pi^t Y_{A,t+\tau}^A(z)},
\]

(44)

\[
Q_{J,t}^{J,t} = \frac{\phi}{\phi - 1} \frac{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^J \left[ MC_{t+\tau}^J(z)Y_{J,t+\tau}^J(z) \right]}{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^J \Pi^t Y_{J,t+\tau}^J(z)},
\]

(45)

\[
Q_{M,t}^{M,t} = \frac{\phi}{\phi - 1} \frac{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^M \left[ MC_{t+\tau}^M(z)Y_{M,t+\tau}^M(z) \right]}{E_t \sum_{\tau=0}^{\infty} \alpha^\tau \rho_{t,t+\tau}^M \Pi^t Y_{M,t+\tau}^M(z)},
\]

(46)

\[
(P_{A,t}^A)^{1-\phi} = \alpha(\Pi P_{A,t-1}^A)^{1-\phi} + (1 - \alpha)(Q_{A,t}^A)^{1-\phi},
\]

(47)

\[
(P_{J,t}^J/S_{A,t}^J)^{1-\phi} = \alpha(\Pi P_{J,t-1}/S_{A,t-1}^J)^{1-\phi} + (1 - \alpha)(Q_{J,t}^J)^{1-\phi},
\]

(48)

\[
(P_{M,t}^M/S_{A,t}^M)^{1-\phi} = \alpha(\Pi P_{M,t-1}/S_{A,t-1}^M)^{1-\phi} + (1 - \alpha)(Q_{M,t}^M)^{1-\phi},
\]

(49)

\[
(P_{A,t}^A)^{1-\phi} = \alpha(\Pi P_{A,t-1}^A)^{1-\phi} + (1 - \alpha)(Q_{A,t}^A)^{1-\phi},
\]

(50)

\[
(P_{J,t}^J)^{1-\phi} = \alpha(\Pi P_{J,t-1})^{1-\phi} + (1 - \alpha)(Q_{J,t}^J)^{1-\phi},
\]

(51)

\[
(P_{M,t}^M/S_{A,t}^M)^{1-\phi} = \alpha(\Pi P_{M,t-1}/S_{A,t-1}^M)^{1-\phi} + (1 - \alpha)(Q_{M,t}^M)^{1-\phi}.
\]

(52)
References


Table 1: Average Shares of East Asian Emerging Markets’ Total Trade with the U.S. and Japan for 1990-1998 (percent)

<table>
<thead>
<tr>
<th></th>
<th>U.S.</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>13.5</td>
<td>18.1</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>15.0</td>
<td>10.6</td>
</tr>
<tr>
<td>Indonesia</td>
<td>13.0</td>
<td>26.0</td>
</tr>
<tr>
<td>Korea</td>
<td>21.7</td>
<td>18.6</td>
</tr>
<tr>
<td>Malaysia</td>
<td>17.9</td>
<td>19.0</td>
</tr>
<tr>
<td>Philippines</td>
<td>26.3</td>
<td>19.5</td>
</tr>
<tr>
<td>Singapore</td>
<td>17.9</td>
<td>14.1</td>
</tr>
<tr>
<td>Taiwan</td>
<td>24.2</td>
<td>19.2</td>
</tr>
<tr>
<td>Thailand</td>
<td>16.0</td>
<td>23.0</td>
</tr>
<tr>
<td>Average</td>
<td>18.4</td>
<td>18.7</td>
</tr>
</tbody>
</table>

Source: Excerpted from Kawai and Takagi (2000)

Table 2: Invoice Currencies in Korean Trade, 1980-2000 (percent)

<table>
<thead>
<tr>
<th></th>
<th>Exports (receipts)</th>
<th>Imports (payments)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$</td>
<td>¥</td>
</tr>
<tr>
<td>1980</td>
<td>96.1</td>
<td>1.2</td>
</tr>
<tr>
<td>1985</td>
<td>94.7</td>
<td>3.7</td>
</tr>
<tr>
<td>1990</td>
<td>88.0</td>
<td>7.8</td>
</tr>
<tr>
<td>1995</td>
<td>88.1</td>
<td>6.5</td>
</tr>
<tr>
<td>2000</td>
<td>84.8</td>
<td>5.4</td>
</tr>
</tbody>
</table>

Source: McKinnon and Schnabl (2004). Trade in services is not included.
Table 3: Invoice Currencies in Thai Trade, 1993-2000 (percent)

<table>
<thead>
<tr>
<th></th>
<th>Exports (receipts)</th>
<th></th>
<th>Imports (payments)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$</td>
<td>¥</td>
<td>$</td>
<td>¥</td>
</tr>
<tr>
<td>1993</td>
<td>91.8</td>
<td>3.9</td>
<td>74.3</td>
<td>11.8</td>
</tr>
<tr>
<td>1994</td>
<td>90.5</td>
<td>4.7</td>
<td>77.1</td>
<td>11.0</td>
</tr>
<tr>
<td>1995</td>
<td>91.0</td>
<td>4.1</td>
<td>80.7</td>
<td>9.4</td>
</tr>
<tr>
<td>1996</td>
<td>91.7</td>
<td>4.5</td>
<td>80.1</td>
<td>9.6</td>
</tr>
<tr>
<td>1997</td>
<td>92.0</td>
<td>3.3</td>
<td>80.4</td>
<td>9.0</td>
</tr>
<tr>
<td>1998</td>
<td>90.6</td>
<td>3.7</td>
<td>80.7</td>
<td>9.6</td>
</tr>
<tr>
<td>1999</td>
<td>87.6</td>
<td>5.2</td>
<td>79.2</td>
<td>11.9</td>
</tr>
<tr>
<td>2000</td>
<td>87.0</td>
<td>5.7</td>
<td>79.0</td>
<td>12.2</td>
</tr>
</tbody>
</table>

Source: Bank of Thailand, as cited in Cook and Devereux (2004).

Table 4: Invoice Currencies in Japanese Trade, 1980-2000 (percent)

<table>
<thead>
<tr>
<th></th>
<th>Exports to</th>
<th></th>
<th>Imports from</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>US</td>
<td>Asia</td>
<td>$</td>
</tr>
<tr>
<td>1987</td>
<td>84.9</td>
<td>15.0</td>
<td>56.5</td>
<td>41.1</td>
</tr>
<tr>
<td>1990</td>
<td>83.7</td>
<td>16.2</td>
<td>48.1</td>
<td>48.9</td>
</tr>
<tr>
<td>1995*</td>
<td>82.9</td>
<td>17.0</td>
<td>53.4</td>
<td>44.3</td>
</tr>
<tr>
<td>2000*</td>
<td>86.7</td>
<td>13.2</td>
<td>50.0</td>
<td>48.2</td>
</tr>
</tbody>
</table>

Table 5: Notations for Variables in the Paper

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_{h,t+1}^i$</td>
<td>Country $i$ holding of currency $h$ denominated nominal bonds</td>
</tr>
<tr>
<td>$C_i^t$</td>
<td>Aggregate consumption of country $i$’s representative household</td>
</tr>
<tr>
<td>$C_{h,t}^i$</td>
<td>Consumption of goods from country $h$ by country $i$’s representative household</td>
</tr>
<tr>
<td>$C_{h,t}^i(z)$</td>
<td>Consumption of brand $z$ good from country $h$ by country $i$’s representative household</td>
</tr>
<tr>
<td>$CA_{h}^t$</td>
<td>Current account in country $i$</td>
</tr>
<tr>
<td>$d^i$</td>
<td>A measure of total resource cost of price dispersion across firms in country $i$</td>
</tr>
<tr>
<td>$d_{i,t}^h$</td>
<td>Index of cross-firm dispersion of prices of goods from country $i$ in market $h$</td>
</tr>
<tr>
<td>$F_i^t$</td>
<td>Productivity shifter in country $i$</td>
</tr>
<tr>
<td>$L_i^t$</td>
<td>Labor hours in country $i$</td>
</tr>
<tr>
<td>$MC_i^t(z)$</td>
<td>Marginal cost for firm $z$ in country $i$</td>
</tr>
<tr>
<td>$NY_i^t$</td>
<td>Nominal GDP per capita in country $i$</td>
</tr>
<tr>
<td>$P_i^t$</td>
<td>Consumer price index in country $i$</td>
</tr>
<tr>
<td>$P_{h,t}^i$</td>
<td>Price index of goods from country $h$ in country $i$ denominated in country $i$ currency</td>
</tr>
<tr>
<td>$P_{h,t}^i(z)$</td>
<td>Price of country $h$ brand $z$ good in country $i$ denominated in country $i$ currency</td>
</tr>
<tr>
<td>$Q_{i,t}^h$</td>
<td>Price that firms from country $i$ that can reset their price in period $t$ set for market $h$</td>
</tr>
<tr>
<td>$R_i^t$</td>
<td>Gross nominal interest rate in country $i$</td>
</tr>
<tr>
<td>$S_{h,t}^i$</td>
<td>Nominal exchange rate between currency $i$ and currency $h$</td>
</tr>
<tr>
<td>$TC_i^t$</td>
<td>Total cost of production</td>
</tr>
<tr>
<td>$V_{M}^0$</td>
<td>Conditional expected lifetime utility of country $M$</td>
</tr>
<tr>
<td>$W_i^t$</td>
<td>Nominal wage rate in country $i$</td>
</tr>
<tr>
<td>$Y_i^t$</td>
<td>Aggregate output per capita in country $i$</td>
</tr>
<tr>
<td>$Y_i^t(z)$</td>
<td>Output of firm $z$ in country $i$</td>
</tr>
<tr>
<td>$Y_{h,t}^i(z)$</td>
<td>Total demand for brand $z$ good from country $i$ by country $h$</td>
</tr>
<tr>
<td>$\Psi_{i,t}^h$</td>
<td>Dividend in country $i$</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>Percentage change in steady state consumption that will give equivalent welfare as $V_{0}^M$</td>
</tr>
<tr>
<td>$\varepsilon_i^t$</td>
<td>Exogenous shock to $F_i^t$</td>
</tr>
</tbody>
</table>
Table 6: Benchmark Parameterization of the Model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma$</td>
<td>2</td>
<td>Coefficient of risk aversion</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.99</td>
<td>Discount factor</td>
</tr>
<tr>
<td>$\mu$</td>
<td>3</td>
<td>Elasticity of substitution between consumption and leisure</td>
</tr>
<tr>
<td>$\psi_B$</td>
<td>0.0038</td>
<td>Bond adjustment cost parameter</td>
</tr>
<tr>
<td>$\phi$</td>
<td>7.66</td>
<td>Elasticity of substitution between different brands of goods</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.75</td>
<td>Probability that prices remain unchanged</td>
</tr>
<tr>
<td>$\Pi$</td>
<td>1.01</td>
<td>Steady state gross inflation rate</td>
</tr>
<tr>
<td>$n_A$</td>
<td>0.45</td>
<td>Size of country A</td>
</tr>
<tr>
<td>$n_J$</td>
<td>0.45</td>
<td>Size of country J</td>
</tr>
<tr>
<td>$n_M$</td>
<td>0.1</td>
<td>Size of country M</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.5</td>
<td>Degree of openness</td>
</tr>
<tr>
<td>$\rho^F$</td>
<td>0.9</td>
<td>Autoregressive coefficient on productivity shifter</td>
</tr>
<tr>
<td>$\sigma_\varepsilon^2$</td>
<td>0.01^2</td>
<td>Variance of productivity shock</td>
</tr>
<tr>
<td>$\rho(\varepsilon^i, \varepsilon^h)$</td>
<td>0</td>
<td>Correlation of productivity shock across countries</td>
</tr>
<tr>
<td>$\theta$</td>
<td>1.5</td>
<td>Intratemporal elasticity of substitution</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>0.4718</td>
<td>Parameter in the utility function</td>
</tr>
<tr>
<td>$b$</td>
<td></td>
<td>Weight on currency $A$ in country $M$’s currency basket, chosen by country $M$’s monetary authority</td>
</tr>
</tbody>
</table>
A. Producer Currency Pricing

B. Dollar Standard

*Directions of arrows indicate directions of export.

Figure 1: Invoice Currencies under Producer Currency Pricing and Dollar Standard
Figure 2: Results for the Cases of Producer Currency Pricing and Dollar Standard When There Are Only Shocks from Country A.
*Solid lines: Pegging to currency A only; Dotted lines: Pegging to currency J only.

Figure 3: Impulse Responses of Selected Variables to a -1% Shock to Country A’s Productivity for the Case of Producer Currency Pricing
*Solid lines: Pegging to currency A only; Dotted lines: Pegging to currency J only.

Figure 4: Impulse Responses of Selected Variables to a -1% Shock to Country A’s Productivity for the Case of Dollar Standard
*Horizontal axes measure the weights on currency A.*

Figure 5: Results for the Case of Dollar Standard When There Are Only Shocks from Country J and When There Are Only Shocks from Country M
*Solid lines: Pegging to currency A only; Dotted lines: Pegging to currency J only.

Figure 6: Impulse Responses of Selected Variables to a -1% Shock to Country J’s Productivity for the Case of Dollar Standard
Figure 7: Dynamic Responses of Selected Variables to a -1% Shock to Country M’s Productivity for the Case of Dollar Standard.

*Solid lines: Pegging to currency A only; Dotted lines: Pegging to currency J only.*
Figure 8: Results for the Cases of Producer Currency Pricing and Dollar Standard When All Shocks Are Considered

*Horizontal axes measure the weights on currency A.
Figure 9: Country M’s Welfare under Different Variations from the Benchmark Model

*Horizontal axes measure the weights on currency A