Exchange Rate Flexibility, Trade Openness and the Extensive Margin

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Abstract

For some countries, the number of exported products after a currency crisis is more volatile than before a currency crisis. But this pattern is not true for some other countries. This study constructs a general equilibrium model with dynamics of comparative advantage and sticky wages to explain the volatility of the number of exported products. In the presence of shocks on total factor productivity, the model predicts that the number of exported products under a fixed exchange rate regime is more volatile than under a flexible exchange rate regime. However, interest rate shocks yield the opposite prediction.

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1 Introduction

The recent literature on endogenous tradability has extensively incorporated business cycles fluctuations of the composition of exports and imports into macroeconomics. Majority of this line of work, including the seminal study by Ghironi and Melitz (2005) ignores the role of nominal exchange rate (NER). Subsequent work by Naknoi (2008), Bergin and Lin (2009), Alessandria, Kaboski and Midrigan (2010) and Rodriguez-Lopez (2011) has demonstrated that incorporating NER into models with endogenous movements of the composition of trade improves our understanding of the volatility of the real exchange rate (RER), the persistence of RER and the dynamics of trade flows.

This study contributes to the literature in three ways. First, we document stylized facts about the volatility of the number of exported products, or the extensive margin of exports, before and after episodes of currency crises, while the work by Alessandria, Kaboski and Midrigan (2010) focuses on the number of imported transactions in the period after currency crises. We use monthly US bilateral trade data filtered with a band-pass filter to study movements at the business cycle frequency. Due to the limitation of the data, we have a small set of five countries, namely Brazil, Indonesia, Korea, Russia and Thailand. We find that the extensive margin of exports from Russia to the US is more volatile before the Ruble crisis in August 1998 than after the crisis. In contrast, the extensive margin of exports from Brazil, Korea and Thailand becomes more volatile after the Real crisis in January 1999, the Won crisis and the Baht crisis in July 1998. There is no clear difference in the volatility of the extensive margin of exports from Indonesia before and after the Rupiah crisis in July 1998.

Next, we construct a two-country stochastic dynamic general equilibrium (SDGE) model with dynamics of comparative advantage and wage stickiness to explain these stylized facts. The model is built on Naknoi (2008) with modifications on both the demand side and the supply side. On the demand side, the elasticity of substitution among goods in the traded sector is the same as the elasticity of substitution between traded goods and non-traded goods. This assumption ensures that there is no bias towards traded goods or non-traded goods when households switch expenditure in response to movements of relative prices of
goods. On the supply side, this model introduces investment and capital accumulation as in Ghironi and Melitz (2005), while Naknoi (2008) and other studies on endogenous tradability assume that labor is the only factor of production. These modifications enable this model to replicate business cycles properties of important variables better than Naknoi (2008).

The benchmark model is calibrated to match the degree of trade openness of the two economies with the average degree of trade openness of these five sample countries and the US. We subject the world economy to shocks on total factor productivity (TFP) and shocks on the foreign interest rate, such that output volatility of the foreign economy under the flexible exchange rate system is close to that of the US. In the presence of TFP shocks, our model is capable of generating differences in the volatility of the extensive margin of exports, consistent with the case of Russia. In this case, the model predicts that currency depreciation coincides with a reduction of the number of exporters, because currency depreciation is caused by a fall in TFP. On the other hand, when shocks originate in the foreign interest rate, the model generates the opposite pattern, as in the case of Brazil, Korea and Thailand. In this case, the model predicts that currency depreciation increases the number of exporters.

Why do TFP shocks and monetary shocks give opposite predictions? As in all models with endogenous entry of exporters, negative TFP shocks reduce the number of exporters by causing low-productivity firms to quit exporting. The resulting rise of the export-sector productivity offsets the effect of TFP shocks on exits. This offsetting effect is increased by NER depreciation, which is caused by a fall in the domestic interest rate as the central bank attempts to stabilize output, because in the presence of wage stickiness the NER depreciation decreases the relative cost of production. Hence, a fixed NER reduces the number of exporters in response to falling TFP more than a floating NER. But when shocks are monetary, the volatility of the relative cost alone determines the number of exporters. With wage stickiness, the relative wage and the relative cost largely fall when currency depreciates following a rise in the foreign interest rate, hence the number of exporters increases. For this reason, foreign interest rate shocks cause currency depreciation to increase the number of exporters and the volatility of the extensive margin of exports.

Finally, having empirically and theoretically established that in the short run the extensive margin of exports behaves differently across exchange rate regimes, we explore the
impact of movements of the extensive margin of exports on the benefit of exchange rate flexibility. Our measure of welfare is the percentage increase of steady-state consumption that yields the same expected utility as the equilibrium allocation, as in Kollmann (2004) and Sutherland (2006). With TFP shocks, movements of the extensive margin of exports are found to increase the benefit of exchange rate flexibility. However, with foreign interest rate shocks, movements of the extensive margin of exports are found to decrease the benefit of exchange rate flexibility. Therefore, the predicted impacts of movements of the extensive margin of exports on the benefit of exchange rate flexibility reinforce the conventional wisdom first proposed by Friedman (1953), which is confirmed by recent quantitative studies by Kollmann (2004) and Sutherland (2006).

In addition, we demonstrate that the positive effect of endogenous specialization on the benefit of exchange rate flexibility in the presence of TFP shocks is increasing in the degree of trade openness and decreasing in the country size. Intuitively, a small country has a small size of labor and capital stock, hence a small country produces a small set of goods and imports a large set of goods. At the same time, a small country faces a large amount of capital inflows or outflows in response to TFP shocks, as pointed out by Crucini (1997). Hence, output volatility and consumption volatility for a small country is higher than a large country. For this reason, the role of NER and endogenous specialization in stabilizing consumption is more important for a small country than a large country.

It is important to emphasize that our focus is the short-run effects of exchange rate regimes on the extensive margin, and thus exchange rate regimes in our study are neutral in the long run, unlike the effects of exchange rate regimes on trade in Bacchetta and van Wincoop (2002). In particular, the long-run effects of exchange rate regimes on the extensive margin of trade have been studied by Bergin and Lin (2009).

The rest of the paper is organized as follows. The next section provides stylized facts about volatility the extensive margin of exports. Section 3 explains the model. The calibration and results are in Section 4. Section 5 concludes the paper.
2 Stylized Facts

This section presents evidence that the extensive margin of trade fluctuates at the business cycle frequency and its volatility depends on the exchange rate regime. The trade literature defines the extensive margin of trade in various ways, such as the number of exported products (Bergin and Glick, 2009), the number of exported products adjusted by the export share (Hummels and Klenow, 2005), and the number of transactions (Alessandria, Kaboski and Midrigan, 2010). Here, we define the extensive margin of trade as the number of exported products and denote it with $NX_t$. Let $RX_t$ denote the real value of exports. Then we can decompose the real value of exports into the following.

$$RX_t = NX_t VX_t,$$

where $VX_t$ is the average real value of exports per product, or the intensive margin of exports. Let lower cases denote natural logarithm. Thus, we can decompose the log of real value of exports as follows.

$$rx_t = nx_t + vx_t$$

To highlight the role of exchange rate regimes, we focus on the following set of five countries that experienced a currency crisis in the 1990s: Brazil, Indonesia, Korea, Russia and Thailand. The sample period is 48-60 months before and after each episode of currency crises: January 1999 in Brazil, and July 1997 in Indonesia, Korea and Thailand, and August 1998 in Russia. Our small sample of countries is restricted by the data availability. The series of $NX_t$ and the dollar value of exports to the US are from the bilateral monthly import data of the US from the US Census database. Products are classified by the 10-digit Harmonized System. $RX_t$ is calculated by deflating the dollar value of exports to the US with the US consumer price index series from the Bureau of Labor Statistics. Then we calculate $vx_t$ as the residual.

We filter the series $nx_t$, $vx_t$ and $rx_t$ with a band-pass filter, of which cyclical components last from 18 to 96 months and the length of leads and lags is 24 months. We report their
standard deviation in Table 1. For reference, we also report the standard deviation of absolute monthly percentage changes of the bilateral NER, defined as units of home currency per dollar. The NER series are denoted by $S_t$ and provided by the International Financial Statistics. Its absolute monthly percentage change is denoted by $|\Delta s_t|$. We do not filter the NER series with a band-pass filter, because the distinction between a fixed exchange rate regime and a flexible exchange rate is based on the statistics of monthly percentage changes of NER. There are two stylized facts as follows.

First, the volatility of the extensive margin of exports ranges from a quarter to twice the volatility of the intensive margin of exports. Hence, fluctuations of the extensive margin of exports account for a substantial part of fluctuations of the export value, although the volatility of the extensive margin of exports dominates the volatility of the intensive margin of exports for most countries. Brazil is the only country for which the extensive margin of exports is more volatile than the intensive margin of exports, regardless of the exchange rate regime. This stylized fact is in line with the findings by Alessandria, Kaboski and Midrigan (2010), who study movements of the extensive margin of imports after large devaluations.

Second, for four out of five countries the volatility of the extensive margin of exports is sensitive to the exchange rate regime. However, the cross-regime ranking of the volatility is not the same for every country. The extensive margin of exports is clearly more volatile in the post-crisis period than the pre-crisis period for Brazil, Korea and Thailand, but the opposite ranking holds for Russia. For Indonesia, the exchange rate regime does not make a difference in the volatility of the extensive margin of exports. The standard deviation of the absolute percentage change of NER in the last column of Table 1 confirms that NER in the post-crisis period is much more volatile than the pre-crisis period for all countries.

Our second finding is related to the recent work by Bergin and Lin (2009). They use annual data and find that a currency union raises trade through the extensive margin, but a fixed NER regime raises trade through the intensive margin. Although our sample countries do not belong to a currency union, all countries except for Russia satisfy their definition of a fixed NER regime prior to the crises and their definition of a flexible NER regime after the crises. To be specific, in their study a fixed NER regime requires that monthly NER
fluctuates within a 2-percent band for the entire year. Hence, our finding in the case of Brazil, Korea and Thailand serves as evidence that a fixed NER regime has an influence on the extensive margin of exports in the short run. However, our finding is not necessarily evidence against Bergin and Lin (2009), because their work is about low-frequency changes in the extensive margin of trade.

Having established that the volatility of the extensive margin of exports is sensitive to the exchange rate regime, we outline the model to explain this fact in the next section.

3 The Model

This section explains the SDGE model of comparative advantage with nominal rigidities. The specialization pattern is determined by comparative advantage, as in Naknoi (2008). However, the model is quite different from the structure in Naknoi (2008) on both the demand side and the supply side as follows. First, the elasticity of substitution between traded and non-traded goods is the same as that between import goods and export goods, while these two elasticities are different in Naknoi (2008). This modification implies that expenditure switching in the short run does not have a bias towards traded goods or non-traded goods. Second, the model here features investment and capital accumulation in order to highlight the role of supply shocks.

There are two countries: Home and Foreign. Residents in the two countries have identical preferences and consume a common set of goods indexed by \( z \in [0, 1] \). A continuum of competitive firms produce each good using labor and capital, and these firms take prices and wages as given when they decide to export or to sell domestically. We assume that nominal wages are sticky, in order to study the role of NER. This assumption is motivated by the evidence for wage stickiness in Castellanos, Garcia-Verdu and Kaplan (2004), Huang and Liu (2002), Kahn (1997) and Liu and Phaneuf (2007).

Since the key feature of the model is the endogenous exporting decision, we describe the model from the supply side.

\(^1\)In our dataset, the average of absolute monthly percentage changes of the Russian Ruble is 2.89 percent before the crisis, and 4.35 percent after the crisis.
3.1 Firms

A large number of homogeneous firms in industry \( z \) take price as given. Let \( X_t \) denote total factor productivity in the home country, and \( a_t(z) \) denote industry-specific productivity. The subscript \( t \) denotes the period. Goods prices are flexible, hence the invoice currency is irrelevant. Let producer price, \( p_p^t(z) \), be denominated in the seller’s currency. The representative firm in each industry produces output \( y_t(z) \) from labor input \( l_t(z) \) and capital stock \( k_t(z) \) with the following constant-return-to-scale technology.

\[
y_t(z) = X_t a_t(z) k_t(z)^{\alpha_k} l_t(z)^{(1-\alpha_k)},
\]

where \( 0 < \alpha_k < 1 \). Let \( W_t \) be unit labor cost, and \( R_{t,k} \) be rental rate of capital. Cost minimization gives the marginal-cost pricing.

\[
p_p^t(z) = \frac{H_t}{X_t a_t(z)},
\]

where \( H_t = R_{t,k}^\alpha W_t^{1-\alpha_k} / (\alpha_k (1-\alpha_k)^{1-\alpha_k}) \). \( H_t \) is the unit cost of composite factor \( k_t(z)^{\alpha_k} l_t(z)^{1-\alpha_k} \). Similar equations hold for the foreign firms.

3.2 Pattern of Specialization

Let \( \Phi_{t,a}(z) \) denote the cost of beginning to export. This entry cost helps us match the number of exporters to the estimate in Hummels and Klenow (2005). It is assumed to be an iceberg cost, which proportionally reduces productivity such that \( a_t(z) = (1 - \Phi_{t,a}(z)) \bar{a}(z) \), where the superscript \(-\) denotes the steady state. Let the superscript \( \star \) denote the foreign variables. Define the industry-specific relative productivity as \( A_t(z) = a_t(z) / a_t^\star(z) \), the set of new home export goods as \( Z_t^n \), and the set of disappearing home export goods as \( Z_t^d \). Let \( z_t^l \) and \( z_t^h \) denote the endogenously-determined least-competitive export industry in the home country and the foreign country, respectively. Assume that \( \phi_a \) is a parameter and \( \phi_a > 0 \).
The entry cost for the home producers is given by:

\[
\Phi_{t,a}(z) = \begin{cases} 
\phi_a \left( \bar{A}(z_{l-1}) \bar{A}(z_l) - 1 \right) & \text{for } z \in Z^n_t \cup Z^d_t \\
0 & \text{otherwise}
\end{cases}
\]

This functional form implies that the entry cost is time-variant and increasing in deviations of long-run productivity of the previously least-competitive export industry in the home country from that of the current one. A similar cost function applies to the foreign producers.

International trade is subject to iceberg trade costs, which melt a fraction \(\tau\) of goods in transit, where \(0 < \tau < 1\). Define relative unit cost as \(\omega_t = H_t/S_t H^*_t\), where \(S_t\) is the NER, defined as units of home currency per unit of foreign currency. Define relative TFP as \(\chi_t = X_t/X^*_t\). Dornbusch, Fischer and Samuelson (1977) show that if \(\partial A_t/\partial z < 0\) and \(0 < \tau < 1\), then for any given relative unit cost \(\omega_t\) there is a unique solution for \(z^l_t\) and \(z^h_t\) such that \(0 < z^l_t < z^h_t < 1\) and

\[
A_t(z^l_t)\chi_t(1-\tau) = \omega_t = A_t(z^h_t)\chi_t/(1-\tau).
\]

Specifically, the marginal exporters equate relative unit cost with relative productivity adjusted by trade costs faced by the two countries. The endogenous specialization pattern is as follows. The home economy produces the goods \(z \in [0, z^h_t]\) and exports the goods \(z \in [0, z^l_t]\). The foreign economy produces the goods \(z \in (z^l_t, 1]\) and exports the goods \(z \in (z^h_t, 1]\). Both countries produce the non-traded goods \(z \in (z^l_t, z^h_t)\) for domestic consumption.

In the steady state, \(\Phi_{t,a} = 0\) for all \(z\). When new home exporters emerge in the short run, \(z^l_t > z^l_{t-1}\), \(Z^d_t = \emptyset\), and \(\Phi_{t,a} > 0\) for \(z \in Z^n_t\). When some home exporters quit, \(z^l_t < z^l_{t-1}\), \(Z^n_t = \emptyset\) and \(\Phi_{t,a} < 0\) for \(z \in Z^d_t\). This implies that there are exit benefits, such as recoverable value. This can be found in the industrial organization literature (Ericson and Pakes, 1995). Hence, the entry cost raises the slope of the relative productivity schedule, and productivity of the exporters relative to non-exporters at the margin. The entry cost reduces the range of switching industries by pushing those about to enter exporting back into the non-traded sector and by throwing those about to quit back into exporting. Since the entry cost is not a fixed cost, it does not remove switching even with small shocks. It creates discontinuity in
the relative productivity schedule, but retains monotonicity along each segment.

The gist of the model is that the exporters at the margin change in response to exogenous shocks, including relative TFP shocks, which shift both the relative productivity schedule and relative unit cost.

\[
\frac{dz_l}{d\chi_t} = \frac{\partial z_l}{\partial \chi_t} + \frac{\partial z_l}{\partial \omega_t} \frac{\partial \omega_t}{\partial \chi_t} \tag{2}
\]

\[
\frac{dz_h}{d\chi_t} = \frac{\partial z_h}{\partial \chi_t} + \frac{\partial z_h}{\partial \omega_t} \frac{\partial \omega_t}{\partial \chi_t} \tag{3}
\]

We can obtain the partial derivative of the marginal exporters with respect to relative unit cost and relative TFP in (2) and (3) from (1).

**Proposition 1** Suppose \( A_t'(z_l) < 0 \). Then \( \frac{\partial z_l}{\partial \omega_t} < 0 \) and \( \frac{\partial z_h}{\partial \omega_t} < 0 \) for all \( t \).

**Proof.** From (1), \( \partial A_t(z_l)/\partial \omega_t = (\partial A_t(z_l)/\partial z_l)(\partial z_l/\partial \omega_t) = 1/((1-\tau)\bar{\chi}) > 0 \). Since \( A_t'(z_l) < 0 \), then \( \frac{\partial A_t(z_l)}{\partial \omega_t} < 0 \). Hence, \( \frac{\partial z_l}{\partial \omega_t} < 0 \). Likewise, \( \partial A_t(z_h)/\partial \omega_t = (\partial A_t(z_h)/\partial z_h)(\partial z_h/\partial \omega_t) = (1-\tau)/\bar{\chi} > 0 \). Since \( A_t'(z_h) < 0 \), then \( \frac{\partial A_t(z_h)}{\partial \omega_t} < 0 \). Hence, \( \frac{\partial z_h}{\partial \omega_t} < 0 \). \( \blacksquare \)

According to Proposition 1, a rise in the relative unit cost causes the marginal home exporters to exit as they lose comparative advantage, all else equal. At the same time, the foreign non-traded-goods producers at the margin begin to export. Therefore, a rise in the relative unit cost shrinks the range of home export goods but expands the range of home import goods.

**Proposition 2** Suppose \( A_t'(z_l) < 0 \). Then \( \frac{\partial z_l}{\partial \chi_t} > 0 \) and \( \frac{\partial z_h}{\partial \chi_t} > 0 \) for all \( t \).

**Proof.** From (1), \( \partial A_t(z_l)/\partial \chi_t = (\partial A_t(z_l)/\partial z_l)(\partial z_l/\partial \chi_t) = -\bar{\omega}/((1-\tau)\bar{\chi}) < 0 \). Since \( A_t'(z_l) < 0 \), then \( \frac{\partial A_t(z_l)}{\partial \chi_t} > 0 \). Similarly, \( \partial A_t(z_h)/\partial \chi_t = (\partial A_t(z_h)/\partial z_h)(\partial z_h/\partial \chi_t) = -\bar{\omega}(1-\tau)/\bar{\chi} < 0 \). Since \( A_t'(z_h) < 0 \), then \( \frac{\partial A_t(z_h)}{\partial \chi_t} > 0 \). \( \blacksquare \)

In Proposition 2, an increase in relative TFP, all else equal, causes the home non-traded-goods producers at the margin to begin exporting, and the foreign exporters at the margin to exit. The reason is that, for any level of relative unit cost, an increase in relative TFP improves the comparative advantage of the home country. As a result, an increase in relative TFP expands the range of home export goods but shrinks the range of home import goods.
From Propositions 1 and 2, $\partial z_t^l/\partial \chi_t > 0$ and $\partial z_t^l/\partial \omega_t < 0$. Thus, the sign of $dz_t^l/d\chi_t$ in (2) will be ambiguous if $\partial \omega_t/\partial \chi_t > 0$ or if relative unit cost rises in response to positive shocks on relative TFP. A similar property holds for $dz_t^h/d\chi_t$ in (3).

### 3.3 Consumer Prices

From the home residents’ perspective, we classify sectors into the import, export and non-traded sectors, and denote them by $i \in \{F, H, N\}$, respectively. Define $Z_{t,F} = [z_t^h, 1]$, $Z_{t,H} = [0, z_t^l]$, and $Z_{t,N} = (z_t^l, z_t^h)$. The consumer prices in each location are given by marginal cost adjusted by iceberg-type trade costs:

$$p_t(z) = \begin{cases} S_t H_t^* / (X_t^* a_t(z)(1 - \tau)) & \text{for } z \in Z_{t,F} \\ H_t / (X_t a_t(z)) & \text{for } z \in Z_{t,H} \cup Z_{t,N} \end{cases}$$

$$p_t^*(z) = \begin{cases} H_t^* / (X_t^* a_t(z)) & \text{for } z \in Z_{t,F} \cup Z_{t,N} \\ H_t / (S_t X_t a_t(z) (1 - \tau)) & \text{for } z \in Z_{t,H} \end{cases}$$

If $\tau = 0$, then $Z_{t,N} = \emptyset$ and $p_t(z) = S_t p_t(z)^*$. Hence, the presence of trade costs creates both the non-traded sector and deviations from the law of one price.

### 3.4 Price Indices

A large number of wholesalers in each sector $i \in \{F, H, N\}$ bundle goods into the constant-elasticity-of-substitution (CES) composites, $C_{t,i} = \left[ \left( \frac{1}{\delta_{t,i}} \right)^{\frac{1}{\theta}} \int_{Z_{t,i}} c_t(z)^{\frac{\theta - 1}{\theta}} dz \right]^{\frac{1}{\theta - 1}}$, where $\delta_{t,i} = sup(Z_{t,i}) - inf(Z_{t,i})$. The parameter $\delta_{t,i}$ measures the size of the range of goods in the sector $i$. Demand for good $z$ is given by $c_t(z)$. $\theta$ is the intratemporal elasticity of substitution, where $\theta > 1$. The CES aggregation is often used in models of monopolistic competition with differentiated products, but the aggregation here is over different industries. Cost minimization gives the unit cost of the consumption bundle as $P_{t,i} = \left[ \frac{1}{\delta_{t,i}} \int_{Z_{t,i}} p_t(z)^{1-\theta} dz \right]^{\frac{1}{1-\theta}}$. Hence, endogenous specialization behaves in the same way as taste shocks, which change the unit cost of each consumption composite.

At first it may appear that our definition of consumption composites requires the statisticians who compute price indices to change the definition of consumption composites every period. In practice, although statistical agencies such as the Bureau of Labor Statistics do
not frequently revise their definition of consumption composites, they employ a methodology to correct for changes in the quality of goods (Bils and Klenow 2001). In theory, changes in the quality of goods can be formulated as taste shocks in the SDGE model (Stockman and Tesar, 1995). For this reason, our approach does not necessarily contradict the principle behind the calculation of price index.

Next, we define sectoral productivity such that sectoral output is monotonically increasing in the product of sectoral productivity, TFP and an input composite.\(^2\)

\[
A_{t,i} = \left[ \frac{1}{\delta_{t,i}} \int_{Z_{t,i}} a_t(z)^{\theta-1} dz \right]^{\frac{1}{\theta-1}}, i = H, N
\]

Since only relative productivity matters for the central results, for simplicity, henceforth we assume that \(a^*_t(z) = 1\) and thus \(A_t(z) = a_t(z)\). Since we assume that \(A'_t(z) < 0\), then the definition of \(A_{t,i}\) implies that \(\partial A_{t,i}/\partial z^i_t < 0, i = H, N\). In other words, the export-sector productivity rises when the range of home export goods falls. The reason is that quitting exporters have lower productivity than remaining ones. At the same time, quitting exporters are more productive than the existing firms in the non-traded sector, therefore productivity in the non-traded sector rises. For this reason, sectoral productivity in both sectors is negatively correlated with the range of home export goods.

According to Propositions 1 and 2, the range of export goods is endogenous to relative unit cost and aggregate shocks. Therefore, aggregate shocks trigger fluctuations of productivity in each sector.

**Proposition 3** Suppose \(A'_t(z) < 0\). Then \(\partial A_{t,i}/\partial \omega_t > 0, i = H, N\).

**Proof.** From the definition of \(A_{t,H}\) and \(A_{t,N}\), \(\partial A_{t,H}/\partial \omega_t = (\partial A_{t,H}/\partial z^i_t)(\partial z^i_t/\partial \omega_t)\), and \(\partial A_{t,N}/\partial \omega_t = (\partial A_{t,N}/\partial z^i_t)(\partial z^i_t/\partial \omega_t)+(\partial A_{t,N}/\partial z^h_t)(\partial z^h_t/\partial \omega_t)\). Since \(A'_t(z) < 0\), then \(\partial A_{t,i}/\partial z^i_t < 0\). Let \(Y_{t,H}\) denote sectoral output in Sector \(H\). Let \(l_{t,H}\) denote labor input in Sector \(H\). Let \(k_{t,H}\) denote labor input in Sector \(H\) and let \(Q_t\) denote real exchange rate. It can be shown that \(Y_{t,H} = \delta_{t,H}^{\frac{1}{\theta}} \left( X_{t,H}^{1-\alpha} k_{t,H}^{\alpha \theta} \right)^{\frac{2}{\theta+1}} C_t^{\frac{\theta+1}{2}}\) where \(Y_{t,H} = P_t^{-1} \int_{z_{t,H}^*} p_t(z)y_t(z)dz\) and \(C_t = \alpha C_t + (1 - \alpha)(1 - \tau)^{\theta-1} C_t Q_t^{\frac{\theta}{2}}\). Likewise, sectoral output in Sector \(N\) satisfies the following: \(Y_{t,N} = \delta_{t,N}^{\frac{1}{\theta}} \left( X_{t,N}^{1-\alpha} k_{t,N}^{\alpha \theta} \right)^{\frac{2}{\theta+1}} C_t^{\frac{\theta+1}{2}}\) where \(Y_{t,N} = P_t^{-1} \int_{z_{t,N}^*} p_t(z)y_t(z)dz\).
0, \ i = H, N and \ \partial A_{t,N}/\partial z^h_t < 0. According to Proposition 1, \ \partial z^l_t/\partial \omega_t < 0 and \ \partial z^h_t/\partial \omega_t < 0. Hence, \ \partial A_{t,H}/\partial \omega_t > 0 and \ \partial A_{t,N}/\partial \omega_t > 0. □

According to Proposition 3, the sector-level productivity falls in both export sector and non-traded sector when relative unit cost rises, all else equal. This results from relatively high-productivity firms quitting exporting and selling only in the domestic market following a rise in relative unit cost, as predicted by Proposition 1.

**Proposition 4** Suppose \( A'_t(z) < 0 \). \ \partial A_{t,i}/\partial \chi_t < 0, \ i = H, N

**Proof.** From the definition of \( A_{t,H} \) and \( A_{t,N} \), \ \partial A_{t,H}/\partial \chi_t = (\partial A_{t,H}/\partial z^l_t)(\partial z^l_t/\partial \chi_t) \), and \ \partial A_{t,N}/\partial \chi_t = (\partial A_{t,N}/\partial z^l_t)(\partial z^l_t/\partial \chi_t) + (\partial A_{t,N}/\partial z^h_t)(\partial z^h_t/\partial \chi_t). Since \( A'_t(z) < 0 \), then \ \partial A_{t,i}/\partial z^l_t < 0, \ i = H, N \) and \ \partial A_{t,N}/\partial z^h_t < 0. According to Proposition 2, \ \partial z^l_t/\partial \chi_t > 0 \) and \ \partial z^h_t/\partial \chi_t > 0. Hence, \ \partial A_{t,H}/\partial \chi_t < 0 \) and \ \partial A_{t,N}/\partial \chi_t < 0. □

According to Proposition 4, the sector-level productivity rises in both the export sector and the non-traded sector when relative TFP rises, all else equal. This results from relatively low-productivity firms beginning to export following an improvement in comparative advantage, as predicted by Proposition 2. However, in general equilibrium models, relative unit cost is correlated with shocks on relative TFP. Thus, the overall effect of shocks on TFP on the sector-level productivity is as follows.

\[
\frac{dA_{t,i}}{d\chi_t} = \frac{\partial A_{t,i}}{\partial \chi_t} + \frac{\partial A_{t,i}}{\partial \omega_t} \frac{\partial \omega_t}{\partial \chi_t} \tag{4}
\]

Propositions 3 and 4 imply that the sign of \( dA_{t,i}/d\chi_t \) is ambiguous and depends on the correlation between relative unit cost and relative TFP. If relative unit cost is positively correlated with relative TFP, the negative effect of TFP on sectoral productivity will be weakened by the positive effect of relative unit cost on sectoral productivity.

To obtain equilibrium price indices, we substitute consumer prices of goods in Section
2.3 into the definition of unit cost.

\[ \begin{align*}
P_{t,F} &= \frac{H^*_s s_t}{X^*_t(1 - \tau)} \quad (5) \\
P_{t,H} &= \frac{H_t}{X_t A_{t,H}} \quad (6) \\
P_{t,N} &= \frac{H_t}{X_t A_{t,N}} \quad (7)
\end{align*} \]

We assume that these three baskets are bundled into a final consumption basket by a large number of sellers. They do this in two steps. First, they bundle the export and import baskets into the following CES traded basket.

\[ C_{t,T} = \left[ \left( \frac{z^l}{1 - z^h + z^l} \right)^{\frac{1}{\theta}} C_{t,H}^{\frac{\theta - 1}{\theta}} + \left( \frac{1 - z^h}{1 - z^h + z^l} \right)^{\frac{1}{\theta}} C_{t,F}^{\frac{\theta - 1}{\theta}} \right]^{\frac{\theta}{\theta - 1}} \]

This assumption is motivated by the evidence that the elasticity of substitution between imports and domestic varieties is greater than 1 (Hummels, 2001; Anderson and van Wincoop, 2004). Note that the weight assigned to each basket is time-invariant, to prevent endogenous specialization from becoming taste shocks and change the bias toward exports or imports.

Next, some sellers bundle the traded and non-traded baskets into the following CES final consumption basket.

\[ C_t = \left[ s_T C_{t,T}^{\frac{\theta - 1}{\theta}} + s_N C_{t,N}^{\frac{\theta - 1}{\theta}} \right]^{\frac{\theta}{\theta - 1}} \]

where \( s_T \) is exogenous, \( 0 < s_T < 1 \) and \( s_N = 1 - s_T \). The elasticity of substitution between the traded-goods basket and the non-traded-goods basket is \( \theta \), which is equal to the elasticity of substitution across traded goods. This assumption ensures that the degree of substitution across goods is not affected by the location of production.

Cost minimization by intermediate sellers gives the following traded-goods price index.

\[ P_{t,T} = \left[ \frac{z^l}{1 - z^h + z^l} P_{t,H}^{1 - \theta} + \frac{1 - z^l}{1 - z^h + z^l} P_{t,F}^{1 - \theta} \right]^{\frac{1}{\theta - 1}} \]

Substituting \( P_{t,F} \) and \( P_{t,H} \) in (5) and (6) into the price index above gives the equilibrium
Finally, cost minimization by final-good sellers gives the consumer price index (CPI).

\[ P_t = \left[ s_T P_{t,T}^{1-\theta} + s_N P_{t,N}^{1-\theta} \right]^{\frac{1}{1-\theta}}, \]  

where \( P_{t,N} \) and \( P_{t,T} \) are given by (7) and (8), respectively. A similar set of price indices holds for the foreign economy.

### 3.5 Terms of Trade and Real Exchange Rate

Define the terms of trade as the export price index relative to the import price index:

\[ \Omega_t = \frac{P_{t,H}}{P_{t,F}}. \]

Substituting (5) and (6) into this definition yields the equilibrium terms of trade.

\[ \Omega_t = \frac{\omega_t}{\chi_t A_{t,H}} \]  

The departure of our terms of trade from the literature can be attributed to the endogenous movements of export-sector productivity. Let \( \hat{x}_t \) denote the percentage deviation of the variable \( x_t \) from its steady state. Furthermore, let \( Cov, V, Std, \) and \( \rho \) denote covariance, variance, standard deviation and correlation. From (10),

\[ \hat{\Omega}_t = \hat{\omega}_t - \hat{\chi}_t - \hat{A}_{t,H}, \]  

\[ Cov(\hat{x}_t, \hat{\Omega}_t) = \left[ \rho(\hat{x}_t, \hat{\omega}_t) \frac{Std(\hat{\omega}_t)}{Std(\hat{x}_t)} - \rho(\hat{x}_t, \hat{A}_{t,H}) \frac{Std(\hat{A}_{t,H})}{Std(\hat{x}_t)} - 1 \right] V(\hat{x}_t). \]  

In standard models without endogenous specialization, \( \rho(\hat{x}_t, \hat{A}_{t,H}) = Std(\hat{A}_{t,H}) = 0. \) According to (4), the overall impact of TFP shocks on export-sector productivity also depends on their impact on relative unit cost. This is because a rise in relative cost discourages endogenous entries. It is possible that, despite a rise in unit cost, positive TFP shocks still
encourage domestic firms to enter the export market, and as a result, \( \rho(\tilde{\chi}_t, \hat{A}_{t,H}) < 0 \). In this case, (12) predicts that endogenous specialization increases the covariance of terms of trade and TFP shocks, and amplifies the impact of relative cost on terms of trade. However, this does not mean that endogenous specialization reduces terms of trade volatility. According to (11), the variance of export-sector productivity has a positive impact on the variance of terms of trade.

Next, we define the real exchange rate (RER) as the price level in the foreign country relative to that in the home country: \( Q_t = S_t P_t^* / P_t \), where \( S_t \) is NER. We substitute the equilibrium CPI in (9) into this definition and use (10) to rewrite RER as follows.

\[
Q_t = \frac{s_T \bar{Z}\Omega_t^{1-\theta} + (1 - \tau)^{1-\theta}}{s_T + (s_T \bar{Z} + s_N (\bar{A}_{t,H}/\bar{A}_{t,N})^{1-\theta})(\Omega_t(1 - \tau))^{1-\theta}},
\]

(13)

where \( \bar{Z} = \bar{z}^f/(1 - \bar{z}^h) \). \( \bar{Z} \) is the range of home export goods relative to that of foreign export goods in the steady state. Hummels and Klenow (2005) refers to \( \bar{Z} \) as the extensive margin of trade. In equilibrium, the RER is driven by the terms of trade and productivity fluctuations in the export sector and the non-traded sector. The difference between our RER and the RER in standard models is that productivity fluctuations in the export sector and in the non-traded sector have been taken as exogenous in the literature. From (13), we can derive deviations of RER in the short run as follows.

\[
\hat{Q}_t = -b_1 \bar{\Omega}_t + b_2 (\hat{A}_{t,N} - \hat{A}_{t,H}),
\]

(14)

where \( b_1 = (\theta - 1)s_T Z\Omega_{t}^{1-\theta}/(s_T Z\Omega_{t}^{1-\theta} + (1 - \tau)^{1-\theta}) + s_T Z + s_N (\bar{A}_{H}/\bar{A}_{N})^{1-\theta}(\theta - 1)((1 - \tau)\bar{\Omega})^{1-\theta} > 0 \) and \( b_2 = (\bar{A}_{H}/\bar{A}_{N})^{1-\theta}(\theta - 1)((1 - \tau)\bar{\Omega})^{1-\theta} > 0 \). Hence, a RER depreciation is caused by a fall in the terms of trade and a rise in the productivity of the non-traded sector relative to the export sector. We derive the variance of RER from (14) as follows.

\[
V(\hat{Q}_t) = b_1^2 V(\hat{\Omega}_t) + b_2^2 V(\hat{A}_{t,H}) + b_2^2 V(\hat{A}_{t,N}) + 2b_1b_2\text{Std}(\hat{\Omega}_t)[\rho(\hat{\Omega}_t, \hat{A}_{t,H})\text{Std}(\hat{A}_{t,H}) - \rho(\hat{\Omega}_t, \hat{A}_{t,N})\text{Std}(\hat{A}_{t,N})]
\]

(15)

Propositions 1-4 imply that endogenous entries have a larger impact on non-traded sector
productivity than export-sector productivity. Intuitively, on average, productivity is higher in the export sector than in the non-traded sector. Then, the effect of entries or exits of marginal firms on sector-level productivity is smaller in the export sector than in the non-traded-sector. Hence, in (15) \( \text{Std}(\widehat{A}_{t,N}) > \text{Std}(\widehat{A}_{t,H}) \). Consequently, endogenous entries can reduce volatility of the RER if \( 0 < \rho(\widehat{\Omega}_t, \widehat{A}_{t,H}) \leq \rho(\widehat{\Omega}_t, \widehat{A}_{t,N}) \).

### 3.6 Allocation of Consumption Baskets

Cost minimization by intermediate sellers yields the allocation of the export-goods basket relative to that of import-goods basket.

\[
\frac{C_{t,H}}{C_{t,F}} = Z\Omega_t^{-\theta}, \tag{16}
\]

where the equilibrium terms of trade is given by (10). This optimal allocation rule predicts that the sellers switch expenditure from export goods to import goods when the terms of trade rise, and vice versa. Likewise, the optimal allocation of the traded-goods basket and the non-traded-goods basket minimizes the cost for final-good sellers.

\[
\frac{C_{t,N}}{C_{t,T}} = s_N \left( \frac{P_{t,N}}{P_{t,T}} \right)^{-\theta}, \tag{17}
\]

where the equilibrium price indices of the traded-goods basket and that of the non-traded-goods basket are given by (7) and (8), respectively. Intuitively, sellers switch expenditure from non-traded goods to traded goods when the price of non-traded goods rises relative to that of traded goods.

### 3.7 Households

The households supply labor in a monopolistically competitive labor market and invest in a perfectly competitive capital market. In the labor market, the wage-setting households are indexed by \( j \in [0,1] \). The set of home residents is \([0,\alpha], \alpha \in (0,1)\). The set of foreign residents is \((\alpha,1]\). The home residents’ optimization problem is described. The foreign residents face a similar problem. The household \( j \)'s utility depends on its consumption \( C_t^j \)
and its labor supply $l^j_t$, which depends on its wage $W^j_t$. The lifetime expected utility is:

$$U^j_t = E_t \sum_{t=0}^{\infty} \beta^t \left[ \frac{\sigma}{\sigma - 1} C^j_t^{\frac{\sigma - 1}{\sigma}} + \frac{\kappa_t}{\mu} (1 - l^j_t(W^j_t))^\mu \right],$$

where $0 < \beta < 1$, $\mu < 1$, $\sigma > 0$ and $\kappa_t > 0$.

Household $j$ accumulates physical capital $K^j_{t+1}$ and a one-period international bond $F^j_{t+1}$. The bond is denominated in the home currency and pays the nominal interest rate $i^j_{t+1}$ between the periods $t$ and $t + 1$. Adjusting bond holdings is assumed to be costly. This assumption prevents bond holdings from becoming infinitely large (Turnovsky, 1985). The cost is quadratic in deviations of the real value of bond holdings from its steady state, assumed to be zero: $\Phi(F^j_{t+1}/P_t) = \phi_f (F^j_{t+1}/P_t)^2/2, \phi_f > 0$.

It is also costly to adjust wages and capital, and the costs are similar to the price adjustment cost in Rotemberg (1982). Specifically, the wage adjustment cost is quadratic in deviations of the wage inflation from its steady state: $h(\pi^w,j_t) = \phi^w (\pi^w,j_t - \bar{\pi}^w,j_t)^2/2, \pi^w,j_t = W^j_t/W^j_{t-1}$ and $\phi^w > 0$. The capital adjustment cost is also quadratic, but, in deviations of investment-capital ratio from depreciation rate, $g(K^j_t, I^j_t) = \phi^k (I^j_t/K^j_t - \delta)^2/2, \phi^k > 0$. Investment is denoted by $I^j_t$ and $\delta$ is the depreciation rate ($0 < \delta < 1$). Hence, capital accumulation is given as follows.

$$K^j_{t+1} + g(K^j_t, I^j_t) = (1 - \delta)K^j_t + I^j_t$$

Let $T^j_t$ denote the government transfer. The budget constraint requires that bond holdings be the gap between income and expenditure.

$$F^j_{t+1} = i^j_{t+1} F^j_t + W^j_t l^j_t + T^j_t P_t + R^j_{t,k} K^j_t - [C^j_t + I^j_t + h(\pi^w,j_t) + \Phi(F^j_{t+1}/P_t)] P_t.$$

The aggregate labor supply is a CES index with substitution elasticity $\eta,

$$L_t = \left[ \frac{1}{(1/\alpha)^{1/\eta} \int_0^\alpha I^j_t(\eta-1)/\eta \, dj} \right]^{\eta/(1-\eta)}.$$ Unit labor cost $W_t = \left[ \frac{1}{\alpha} \int_0^\alpha W^j_t(1-\eta) \, dj \right]^{1-\eta}$ is obtained from cost minimization. Demand for the household $j$’s labor is then $l^j_t = \frac{1}{\alpha} \left( \frac{W^j_t}{W_t} \right)^{-\eta} L_t$.

Household $j$ chooses the stochastic processes $\{W^j_t, F^j_{t+1}, K^j_{t+1}\}_{t=0}^{\infty}$ to maximize its utility subject to its budget constraint, capital accumulation dynamics, demand for its labor and the
transversality condition \( \lim_{j \to \infty} E_t [F^j_{t+s} / \Pi^j_{s=0} (1 + i_{t+s})] \geq 0 \). Moreover, Household \( j \) takes as given the sequences of price, rental rate of capital and interest rate \( \{P_t, R_{t+1,k}, i_{t+1}\}_{t=0}^\infty \), and the initial conditions \( (W^j_{t=1}, F^j_0, K^j_0) \). Let \( T^q_t \) denote the shadow price of capital. All households face an identical problem. Thus, the index \( j \) is dropped from the first-order conditions below.

\[
1 + \phi^f F_{t+1} = \beta (1 + i_{t+1}) E_t \left( \frac{C_t}{C_{t+1}} \right)^{\frac{1}{\sigma}} \frac{P_t}{P_{t+1}} \tag{18}
\]

\[
\frac{\eta \kappa_t C^\frac{1}{\sigma}_t}{(1 - \mu_t)^{1-\mu}} = \frac{(\eta - 1) W_t}{P_t} + \phi^w (\pi^w_t - \bar{\pi}^w_t) \pi^w_t - \beta E_t \left[ \frac{C^\frac{1}{\sigma}_t}{C_{t+1}^\frac{1}{\sigma}} \phi^w (\pi^w_{t+1} - \bar{\pi}^w_{t+1}) \pi^w_{t+1} \right] \tag{19}
\]

\[
1 = \frac{T^q_t}{P_t} \left( 1 - \frac{\phi^k}{K_t} \left( I_t - \delta \right) \right) \tag{20}
\]

\[
T^q_t = \beta E_t \left[ \left( \frac{C_t}{C_{t+1}} \right)^{\frac{1}{\sigma}} R_{t+1,k} + T^q_{t+1} \left( 1 - \delta + \phi^k \frac{I_{t+1}}{K_{t+1}} \left( \frac{I_{t+1}}{K_{t+1}} - \delta \right) \right) \right] \tag{21}
\]

The Euler equation in (18) includes the real value of bond holdings, since adjusting bond holdings is costly. The wage inflation in (19) is forward-looking, because households take into account the marginal benefit from adjusting wages today as a way to avoid the future cost of adjustment. Equation (19) implies that wage inflation rises during a consumption boom, in which the marginal rate of substitution between consumption and labor increases. In (20), households increase investment when the shadow price of capital rises. A rise of the current shadow price of capital also increases the rental rate of capital in (21).

Assume that there is a foreign-currency bond, so that the foreign interest rate \( i^*_t \) between the periods \( t \) and \( t + 1 \) is well-defined. The bond is available only to the foreign residents and has zero supply in equilibrium. A similar set of optimality conditions holds for the foreign households. In equilibrium, free capital mobility ensures that the real interest rate implied by the Euler condition is identical for both home and foreign households. This no-arbitrage condition yields the following interest rate parity condition.

\[
(1 + i_{t+1}) E_t \left[ \left( \frac{C^*_t}{C^*_{t+1}} \right)^{\frac{1}{\sigma}} \frac{S_t P^*_t}{S_{t+1} P^*_t} \right] = (1 + i^*_{t+1}) (1 + \phi^f f^*_{t+1}) E_t \left[ \left( \frac{C^*_t}{C^*_{t+1}} \right)^{\frac{1}{\sigma}} \frac{P^*_t}{P^*_{t+1}} \right] \tag{22}
\]

where \( f^*_{t+1} = F^*_{t+1} / (S_t P^*_t) \).
3.8 Market Clearing Conditions

Markets for all goods and factors clear: $y_t(z) = \alpha c_t(z) + (1 - \alpha)c_t^*(z)/(1 - \tau)$ for $z \in \mathbb{Z}_{t,H} \cup \mathbb{Z}_{t,F}$, $y_t(z) = c_t(z)$ for $z \in \mathbb{Z}_{t,N}$, where $\int_{z \in \mathbb{Z}_{t,H} \cup \mathbb{Z}_{t,N}} l_t(z) = \alpha l_t$ and $\int_{z \in \mathbb{Z}_{t,H} \cup \mathbb{Z}_{t,N}} k_t(z) = \alpha K_t$. Similar conditions hold for the foreign economy. The bond market clears when the following condition holds: $\alpha F_t + (1 - \alpha)F_t^* = 0$.

3.9 Exchange Rate Regimes

We formulate exchange rate variability as an outcome of exchange rate policy of the home central bank. The home central bank adopts the following interest rate rule under the fixed exchange rate system.

$$\ln(i_{t+1}) - \ln(i_t) = (\ln(i^*_{t+1}) - \ln(i^*)) + (\ln(S_t) - \ln(S_0)) + \lambda f_t^*,$$

where $\lambda_f = \phi^f i / (1 + i)$ and $S_0$ is the target exchange rate. This rule and the interest rate parity condition in (22) give $S_t = S_0$. The rule is similar to that in Benigno (2004) and Monacelli (2004). Note that the debt term arises from the assumption that bond holdings cannot explode.

Define real gross domestic product (GDP) as $Y_t = P_t^{-1} \int_{z \in \mathbb{Z}_{t,H} \cup \mathbb{Z}_{t,N}} p_t(z) y_t(z) dz$, and inflation rate as $\pi_t = P_t / P_{t-1}$. The home central bank under the flexible exchange rate system adopts the rule in Clarida, Gali and Gertler (2000).

$$\ln(i_{t+1}) - \ln(i_t) = \lambda_i(\ln(i_t) - \ln(i^*)) + (1 - \lambda_i) \left[ \lambda_\pi(E_t \ln(\pi_{t+1}) - \ln(\bar{\pi})) + \lambda_y(\ln(Y_t) - \ln(\bar{Y})) \right],$$

where $0 < \lambda_i < 1$, $\lambda_\pi > 0$ and $\lambda_y > 0$. We use this rule because it helps explain the volatility of RER between countries that adopt flexible exchange rates in Chari, Kehoe and McGrattan (2002).

The foreign central bank always adopts the following similar rule.

$$\ln(i^*_{t+1}) - \ln(i^*) = \lambda_i(\ln(i^*_t) - \ln(i^*)) + (1 - \lambda_i) \left[ \lambda_\pi(E_t \ln(\pi^*_{t+1}) - \ln(\bar{\pi}^*)) + \lambda_y(\ln(Y^*_t) - \ln(\bar{Y}^*)) \right] + J_t^*,$$
where $J_t^\star$ is the foreign interest rate shock.

To focus on exchange rate policy, we assume a simple fiscal policy such that the government transfer is zero: $T_t = 0$.

### 3.10 Stochastic Process of Shocks

TFP shocks are characterized by the following stationary process.

\[
\ln\left(\frac{X_t}{\bar{X}}\right) = \rho_1 \ln(X_{t-1}/\bar{X}) + \rho_2 \ln(X_{t-1}^\star/\bar{X}^\star) + u_t
\]

\[
\ln\left(\frac{X_t^\star}{\bar{X}^\star}\right) = \rho_1 \ln(X_{t-1}^\star/\bar{X}^\star) + \rho_2 \ln(X_{t-1}/\bar{X}) + u_t^\star
\]

$0 < \rho_1 < 1$ and $0 < \rho_2 < 1$. The variables $u_t$ and $u_t^\star$ are white noises with standard deviation $\sigma_u$ and cross-correlation $\rho_{u,u^\star}$.

Foreign interest rate shocks are characterized by the following process.

\[
\ln(J_t^\star) = \rho_j \ln(J_{t-1}^\star) + j_t,
\]

where $j_t$ is a white noise with standard deviation $\sigma_j$.

### 3.11 Measure of Welfare

We define the welfare measure for each exchange rate regime as the permanent percentage change in consumption, compared to the steady state, that yields the same expected utility as the equilibrium allocation. Let us denote the welfare measure by $\gamma$. By definition, $u((1 + \gamma)\bar{C}, \bar{l}) = E(u(C_t, l_t))$. We derive $\gamma$ by the following steps.

First, we approximate the expected utility with the second-order Taylor expansion. Then,

\[
u((1 + \gamma)\bar{C}, \bar{l}) = u(\bar{C}, \bar{l}) + \bar{C}^{-\frac{1}{2}}E(\tilde{C}_t) - \kappa_l(1 - \bar{l})\mu^{-1}E(\tilde{l}_t)
\]

\[
-\frac{1}{\sigma}C^\sigma V(\tilde{C}_t) + \kappa_l(\mu - 1)\bar{l}^2(1 - \bar{l})^{\mu-2}V(\tilde{l}_t)
\]

(23)

Given that $\mu < 1$, it is clear that the variance of consumption and the variance of labor supply reduce welfare. Next, we use the functional form of our utility function to calculate
the value of \( u((1 + \gamma)\bar{C}, \bar{l}) \). We then rearrange terms to obtain the following expression.

\[
u((1 + \gamma)\bar{C}, \bar{l}) = u(\bar{C}, \bar{l}) + ((1 + \gamma)\bar{C}, \bar{l}) - 1)u(\bar{C}, 0) \tag{24}\]

Then, we substitute (24) into (23) to obtain \( \gamma \).

\[
\gamma = 1 - \left(1 + \frac{\Delta u}{u(\bar{C}, 0)}\right)^{\frac{1}{\sigma}}, \tag{25}
\]

where \( \Delta u = \bar{C}^{-\frac{1}{\sigma}}E(\hat{C}_t) - \kappa_l(1 - \bar{l})^{\mu-1}E(\hat{\bar{l}}_t) - \frac{1}{\sigma}\bar{C}^{\frac{1}{\sigma} - 1}V(\hat{C}_t) + \kappa_l(\mu - 1)\bar{l}^{\mu-2}V(\hat{l}_t) \).

Finally, we calculate the welfare gain from exchange rate flexibility as the difference in \( \gamma \) under the flexible exchange rate regime and that under the fixed exchange rate regime. Our measure of welfare gain is similar to that in Devereux and Engel (2003), Kollmann (2004) and Sutherland (2006).

To understand the influence of each moment on welfare, we decompose the welfare measure into two types. One is driven by the average of consumption and leisure. The other type is driven by the variance of consumption and leisure. Let us denote the two types of gains by \( \gamma^m \) and \( \gamma^v \), respectively. By definition,

\[
u((1 + \gamma^m)\bar{C}, \bar{l}) = u(\bar{C}, \bar{l}) + \bar{C}^{-\frac{1}{\sigma}}E(\hat{C}_t) - \kappa_l(1 - \bar{l})^{\mu-1}E(\hat{\bar{l}}_t),
\]
\[
u((1 + \gamma^v)\bar{C}, \bar{l}) = u(\bar{C}, \bar{l}) - \frac{1}{\sigma}\bar{C}^{\frac{1}{\sigma} - 1}V(\hat{C}_t) + \kappa_l(\mu - 1)\bar{l}^{\mu-2}. \tag{26}\]

We use the utility function to obtain \( \gamma^m \) and \( \gamma^v \) in a similar fashion.

\[
\gamma^m = 1 - \left(1 + \frac{\Delta u^m}{u(\bar{C}, 0)}\right)^{\frac{1}{\sigma}}, \tag{26}\]

where \( \Delta u^m = \bar{C}^{-\frac{1}{\sigma}}E(\hat{C}_t) - \kappa_l(1 - \bar{l})^{\mu-1}E(\hat{\bar{l}}_t) \).

\[
\gamma^v = 1 - \left(1 + \frac{\Delta u^v}{u(\bar{C}, 0)}\right)^{\frac{1}{\sigma}}, \tag{27}\]

where \( \Delta u^v = -\frac{1}{\sigma}\bar{C}^{\frac{1}{\sigma} - 1}V(\hat{C}_t) + \kappa_l(\mu - 1)\bar{l}^{\mu-2}V(\hat{l}_t) \). We can show that \( \gamma \approx \gamma^m + \gamma^v \).

In the next section, we calibrate the model to obtain quantitative predictions.
4 Quantitative Results

We calibrate our model with TFP shocks and foreign interest rate shocks using the second-order approximation technique. The reason is that the first-order approximation technique cannot capture the effect of the variance of endogenous variables on welfare (Schmitt-Grohe and Uribe, 2004).

4.1 Calibration

Table 2 tabulates the benchmark parameters. The parameters related to specialization are chosen to match the long-run elasticity of the extensive margin of exports with respect to country size, which is estimated to be 0.5 in Hummels and Klenow (2005). Specifically, we choose the following functional form: $\bar{a}(z) = n_1 e^{-n_2 z}$ and $\bar{a}^*(z) = 1$, where $n_1 = 3.35$ and $n_2 = 2$. The entry cost parameter is $\phi_a = 1$ and chosen such that the short-run elasticity of the extensive margin with respect to per capita GDP is below 0.85, which is the long-run estimate in Hummels and Klenow (2005). The trade cost parameter comes from Hummels (2001), where $\tau = 0.15$.

For the preferences specification, we set the elasticity of substitution across goods equal to 3. The reason is that Blonigen and Wilson (1999) find that estimates of short-run elasticity of substitution do not exceed 3.52. This number is lower than the estimates of long-run elasticity in the trade literature (Anderson and van Wincoop, 2004; and Hummels, 2001). The weight of the traded-goods in the final consumption basket, or $s_T$, is chosen as 0.455, such that the expenditure share of non-traded goods in final consumption is in the range documented by Falvey and Gemmell (1995). They find that the expenditure share of non-traded goods in industrialized countries varies from 45 percent to 57 percent.

We set the elasticity of intertemporal substitution of consumption, or $\sigma$, to 0.2, since Chari, Kehoe and McGrattan (2002) found in their SDGE model that this value can match the volatility of RER between industrialized countries. The elasticity of intertemporal substitution of leisure is chosen to be the same as the elasticity of intertemporal substitution of consumption, to guarantee a balanced growth path. This implies that $\mu = 1 - 1/\sigma$. The portfolio adjustment cost parameter is 0.00074, from Mendoza (1991).
The elasticity of substitution across labor is 4. We choose this number, because Huang and Liu (2002) illustrate in their calibration exercise that this value can match the persistence of wages and output in the data. Given this elasticity of substitution across labor, we set the wage adjustment cost parameter such that the dynamics of wage inflation from the Euler equation imply that the contract period is 4 quarters, as documented in Taylor (1999).

The country size is symmetric, namely $\alpha = 0.5$. The relative TFP is chosen such that residents in the two countries have the same level of per capita GDP. To be specific, we let $\bar{X} = 1$ and $\bar{X}^* = 1.7441$. The persistence of the TFP shock process and the cross-country correlation of shocks are from the estimates by Kollmann (1996). This TFP shock process has been used by Kollmann (2004) to quantify gains from joining a monetary union. The depreciation rate of capital is 2.5 percent per quarter, as in Backus, Kehoe and Kydland (1994). We calibrate the size of capital adjustment costs parameter or $\phi^k$ to match output volatility of the two countries in response to TFP shocks under the flexible exchange rate regime with the US output volatility. The standard deviation of US quarterly output between 1980:1 and 2009:4 filtered by a band-pass filter keeping cyclical components lasting 6-32 quarters with 12 leads and lags, is 1.03 percent. Specifically, we set $\phi^k = 1$.

The foreign interest rate shocks are assumed to be white noises, as in the empirical literature, such as Clarida, Gali and Gertler (2000). The variance of shocks is calibrated to match the foreign output volatility under the flexible exchange rate regime with output volatility of the US. For this purpose, the standard deviation of foreign interest rate shocks is set to 0.0059.

The characteristics of the two countries in the steady state are as follows. The trade balance and the current account are balanced. The import-to-GDP ratio is 33 percent for the two countries. This degree of trade openness is close to 34 percent, which is the average import-to-GDP ratio of the five crisis countries. The steady-state expenditure share of non-traded goods is 57 percent in the home country and 53 percent in the foreign country. These expenditures shares are in the range documented by Falvey and Gemmell (1995). The home country exports goods in the range $[0,0.25]$ and the foreign country exports goods in the range $[0.41,1]$. The extensive margin of exports becomes 0.22. Intuitively, the home country is smaller and has lower TFP than the foreign country, therefore the home country export
a smaller set of goods than the foreign countries. The implied range of non-traded goods is (0.25,0.41).

4.2 Benchmark Economy with TFP Shocks

Table 3 summarizes the results from 50 simulations over 100 periods, and reports the average of all simulations. To understand the role of endogenous specialization, we must compare the results in our benchmark calibration with the results from a simulation without endogenous specialization. For this reason, besides the benchmark model we also simulate an alternative model in which the pattern of specialization is given by the steady state of the benchmark model. We refer to the two models as Model 1 and Model 2, respectively.

In Table 3, the statistics under the floating exchange rate regime from each model are in Columns 1 and 4. The statistics under the fixed exchange rate regime are in Columns 2 and 5. Differences between the two regimes are in Columns 3 and 6. Columns 7-9 report differences between the two models, thus these columns display the effects of endogenous specialization. Column 7 corresponds to the flexible exchange rate regime, and Column 8 corresponds to the fixed exchange rate regime. Finally, Column 9 displays the effects of endogenous specialization on cross-regime differences.

There are five main findings. First, negative TFP shocks under the fixed NER regime cause a larger number of exporters to quit exporting than under the NER regime. In Columns 3 and 9, a flexible NER reduces the standard deviation of the extensive margin of exports by 0.28 percent. The standard deviation of the extensive margin of exports with fixed NER relative to that with flexible NER is 1.66, and the corresponding number in the case of Russia from Table 1 is 1.57. Hence, TFP shocks can explain why the extensive margin of exports from Russia to the US before the Russian crisis in August 1998 is more volatile than after the crisis, as documented in Section 2.

This result is consistent with the volatility of relative unit cost and its positive correlation with relative TFP, which is higher under the flexible NER regime in Column 1 than the fixed NER in Column 2 (0.95 with flexible NER vs. 0.78 with fixed NER). Given Propositions 1, 2 and Equation (2), this positive correlation suggests that the relative unit cost moves to offset the effect of TFP shocks on the extensive margin of exports, and the offsetting effect
is larger under the flexible NER regime than the fixed NER regime. Consistent with this result, a fixed NER increases the standard deviation of export-sector productivity from 0.40 percent to 0.66 percent.

Second, endogenous specialization reduces the volatility of home consumption, and more so when the NER is fixed (from 0.36 percent to 0.29 percent) than when the NER is flexible (from 0.27 percent to 0.25 percent). To understand these results, let us consider the effects of negative TFP shocks on key variables especially the NER. Figure 1 displays impulse responses to a one-standard deviation decline in home TFP of the NER, the relative unit cost, the relative number of exported products and productivity of the export sector. Regardless of the exchange rate regime, an output contraction following falling TFP prompts the central bank to reduce the interest rate. However, under the flexible exchange rate regime a fall in the interest rate depreciates the NER in Panel A. Since the NER depreciation improves comparative advantage in Panel B, the NER depreciation mitigates the number of quitting exporters in Panel C, as a result of falling TFP. For this reason, endogenous specialization and NER flexibility mitigate the rise in the export-sector productivity in Panel D.

Under the fixed NER system, the home central bank follows the foreign central bank’s interest rate policy. Negative TFP shocks at home have a spillover effect on foreign output, hence the foreign central bank reduces the foreign interest rate. Therefore, even without NER depreciation the home interest rate still falls. At the same time, falling TFP largely decreases competitiveness and generates a large number of quitting exporters as the offsetting wage deflation is low thanks to wage stickiness. Consequently, in Panel D a gain of export-sector productivity under the fixed NER system is greater than under the flexible NER system. This great gain of productivity has a positive effect on income, which reinforces the positive effect of the interest rate cut on consumption growth more than when the NER is flexible.

The offsetting effect of endogenous productivity fluctuations on TFP shocks is also evident from the negative correlation of relative TFP and export-sector productivity. This correlation is -0.42 under the flexible NER regime and -0.39 under the fixed NER regime. Given that the standard deviation of relative TFP is 16.53 percent, the covariance between relative TFP and export-sector productivity is 

\[-0.39 \times 0.0066 \times 0.1653 = -0.043\] percent under the fixed NER regime. The corresponding covariance under the flexible NER regime
is $-0.42(0.0040)(0.1653) = -0.028$ percent. These covariances imply that negative shocks on home TFP increases export-sector productivity when the NER is fixed more than when the NER is flexible, as in Panel D in Figure 1.

Note that even without endogenous entries the effect of the interest rate following negative TFP shocks depends on the exchange rate regime. Since a spillover of falling TFP to foreign output is always smaller than the effect of falling TFP on home output, the rate cut under a fixed NER regime is smaller than under a flexible NER regime. Thus, in the presence of TFP shocks, a floating exchange rate stabilizes consumption even without endogenous specialization, and such a stabilizing effect is enhanced by endogenous productivity fluctuations.

Third, in Columns 7 and 8 endogenous specialization decreases RER volatility but increases terms of trade volatility. These effects of endogenous specialization are further enhanced by exchange rate flexibility (See Column 9). To understand the RER, we have to understand the terms of trade first. Intuitively, given wage stickiness negative TFP shocks cause goods prices to rise before the wage fully falls to catch up with TFP. Hence, negative TFP shocks raise the terms of trade, as reflected by a negative correlation between relative TFP and the terms of trade (-0.83 with flexible NER and -0.80 with fixed NER). At the same time, negative TFP shocks encourage low-productivity firms to quit exporting and raise export-sector productivity. This offsetting impact of endogenous productivity fluctuations is larger when the NER is fixed, according to the covariance between relative TFP and export-sector productivity, as discussed above. Thus, with endogenous entries, TFP shocks increase volatility of the terms of trade when the NER is flexible more than when the NER is fixed.

As for RER volatility, we show in Equation (15) that endogenous entries can reduce the volatility of the RER if $0 < \rho(\hat{\Omega}_t, \hat{A}_{t,H}) \leq \rho(\hat{\Omega}_t, \hat{A}_{t,N})$. This is the case here, because a fall in TFP raises the terms of trade and discourages entries, which raise productivity in both sectors. As a result, the correlation between the terms of trade and the sector-level productivity is positive. Moreover, consistent with Propositions 1-4, this correlation is the same for productivity in both sectors, since the correlation between relative TFP and productivity is identical in both sectors, as displayed in Columns 1 and 2 in Table 3.
Fourth, endogenous specialization increases the volatility of the trade balance relative to output and the volatility of home investment. The increase in the volatility of the trade balance is caused by an increase in the volatility of the terms of trade. This is consistent with the optimal allocation of imports and export goods in Equation (16), which predicts that a rise in the terms of trade switches consumption expenditure from export goods to import goods.

The increase in the terms of trade volatility explains why the volatility of home investment is also increased by endogenous specialization. When endogenous specialization decreases the number of exporters following negative TFP shocks, endogenous specialization decreases demand for factors of production, including capital. The reduction of investment is amplified by endogenous exits of exporters, and more so when the NER is fixed, since negative TFP shocks create a larger number of quitting exporters when the NER is fixed than when the NER is flexible, as explained above.

The last finding is that, in the presence of TFP shocks endogenous specialization increases the benefit of exchange rate flexibility. In Column 9, endogenous specialization increases welfare for home residents and foreign residents by 17 and 6 percentage points relative to the steady state consumption, respectively. Although this welfare gain is small, it is well known that the welfare cost of business cycles is small. The increase in welfare gains comes from an increase in the average consumption and leisure ($\gamma^*$) rather than a decrease in the volatility of consumption and leisure ($\gamma_v$). The cross-regime difference in the average consumption comes from the offsetting effects of NER and sector-level productivity fluctuations, as explained in the above discussion about the second finding. The higher level of average leisure when the NER is flexible also comes from the same mechanism, since the gain of sector-level productivity helps offset the loss of TFP.

Based on the welfare comparison, endogenous specialization reinforces the conventional wisdom that countries suffering from real shocks should opt for a flexible exchange rate regime. In addition, our model can replicate several business cycle properties documented in the literature. To be specific, our model predicts that investment is more volatile than output and consumption. The trade balance relative to output is counter-cyclical. Although we do not report cyclicality of consumption and investment in Table 3, consumption and
investment are both pro-cyclical.

4.3 Benchmark Economy with Foreign Interest Rate Shocks

Table 4 reports the results when we subject the benchmark economy to foreign interest rate shocks. There are four important findings.

First, in the presence of foreign interest rate shocks, the volatility of the extensive margin of exports is higher with floating NER than with fixed NER. The standard deviation of the extensive margin of exports in Columns 1 and 7 is roughly 10 times of that in Columns 2 and 8. This result suggests that monetary shocks offer an explanation why the extensive margin of exports from Brazil, Korea and Thailand to the US becomes more volatile in the post-crisis period than in the pre-crisis period, as documented in Section 2.

The reason behind this result is that endogenous specialization increases the volatility of the relative cost, and particularly more so when the NER is flexible in Column 7 than when the NER is fixed in Column 8. To illustrate the point, consider when the foreign central bank raises the foreign interest rate. Figure 2 illustrates impulse responses to a one-standard deviation increase in the foreign interest rate of the NER, the relative unit cost, the relative number of exported products and productivity of the export sector. In Panel A, with a floating NER regime the NER depreciates. The NER depreciation improves comparative advantage by lowering the relative wage and the relative unit cost in Panel B. If the NER is fixed, a foreign rate hike will cause a rate hike at home and reduces the domestic aggregate demand. Given wage stickiness, a fall in the aggregate demand causes wages to fall gradually. As a result, the improvement in comparative advantage in Panel B is smaller and more gradual with a fixed NER than with a flexible NER. Therefore, an increase in the relative number of exporters in Panel C and a fall in the export-sector productivity in Panel D are larger with a flexible NER than a fixed NER. Consistent with Panel D, the standard deviation of the export-sector productivity in Table 4 is 0.24 percent when the NER is flexible and higher than 0.02 percent when the NER is fixed.

Second, given foreign interest rate shocks, endogenous specialization increases consumption volatility and more so with flexible NER than fixed NER. As explained above, when the foreign central bank raises its interest rate, that will generates a larger number of new
exporters when NER is flexible than when NER is fixed. These new exporters cause export-sector productivity to fall. The loss of export-sector productivity will reinforce the contractionary effect of foreign rate hikes on the domestic output through a reduction in the demand for home exports. Hence, endogenous specialization amplifies the negative effect on consumption of foreign contractionary monetary policy, and particularly more so with floating NER than fixed NER. A similar pattern and intuition applies to the volatility of labor supply and investment, since these variables are positively correlated with the domestic output.

Third, foreign interest rate shocks make endogenous specialization increase the volatility of terms of trade and trade balance, and more so with a flexible NER than a fixed NER. The reason is that the terms of trade are driven by the relative cost, of which volatility is amplified by endogenous specialization, particularly when the NER is flexible. The same pattern applies to the trade balance, because demand for exports and imports are governed by the terms of trade according to Equation (16).

The final finding concerns the welfare gains from the flexible NER. Endogenous specialization reduces the average consumption and leisure of the home residents when the NER is flexible, and therefore, reduces the welfare gain from exchange rate flexibility for the home residents. This welfare loss of the home residents is much larger than the welfare gain from a rise in the average consumption and leisure of the foreign residents. Thus, for the world as a whole, endogenous specialization reduces gains from exchange rate flexibility in the presence of monetary shocks. In other words, endogenous specialization reduces the costs of fixing exchange rates in the presence of monetary shocks. Hence, endogenous specialization reinforces the conventional wisdom that countries suffering from monetary shocks should opt for a fixed exchange rate regime.

Although the welfare measures in Columns 3 and 6 suggest that the flexible NER regime dominates the fixed NER regime in both Models 1 and 2, this result does not necessarily imply that endogenous specialization works against the conventional wisdom, because our emphasis is on the differences between the two models in Columns 7-9. The outcome that the flexible NER regime dominates in Models 1 and 2 can arise from the assumption that the interest rate rules chosen by the central banks are arbitrary and not necessarily optimal.
rules. Still, the rules in our study are capable of producing important properties of important variables, as documented in the literature. For instance, with interest rate shocks the model predicts that the RER is more volatile when the NER is flexible than when the NER is fixed, as found by Baxter and Stockman (1989). Also, investment is predicted to be more volatile than output and consumption. In addition, our model predicts that consumption and investment are pro-cyclical regardless of the exchange rate regime, and the trade balance to output ratio is counter-cyclical when the NER is flexible.

To gain further insight about the effects of endogenous specialization, next we present a sensitivity analysis.

4.4 Sensitivity Analysis

Our sensitivity analysis focuses on the role of endogenous specialization in the presence of TFP shocks, because we are interested in exploring the case in which endogenous specialization increases welfare gains from floating NER. We vary the parameters for the country size and the standard deviation of shocks. The effects of endogenous specialization on differences between the flexible exchange rate regime and the fixed exchange rate regime are tabulated in Table 5.

4.4.1 Effects of Country Size

Case 1 in Table 5 displays the effects of endogenous specialization in the benchmark model, therefore it presents the same statistics as Column 9 in Table 3. In the benchmark model, the home country and the foreign country have symmetric size, or $\alpha = 0.5$. To understand the effects of country size, we change the value of $\alpha$ to 0.667 and 0.333. The former implies that the home country size is twice of the foreign country size, and the latter implies that the home country size is half of the foreign country size. We refer to these cases as Case 2 with large $\alpha$, and Case 3 with small $\alpha$, respectively.

As the home country size falls from 0.667 in Case 2, to 0.5 in Case 1, and to 0.333 in Case 3, the effect of endogenous specialization as measured by the standard deviation of the export-sector productivity becomes larger, from -0.25 to -0.26 and -0.33, respectively.
Hence, the stabilizing effect of the NER and endogenous specialization is increased as the country gets smaller, as confirmed by the change in the standard deviation of consumption. As the country size gets smaller, a flexible NER causes the trade balance relative to output becomes much less volatile as well.

We can understand these results from the effects of country size on trade openness and the extensive margin of exports. In theory, a small country has a small supply of labor, thus it produces a small set of goods and the value of its output is small. For this reason, a small country must import a large number of goods and its import share in consumption expenditure is high. We confirm this pattern in our quantitative exercise. To be precise, in Case 1, \( \alpha = 0.5 \), the import share is 0.33 and the extensive margin of exports is 0.42. In Case 2, \( \alpha = 0.667 \), the import share becomes 0.20 and the extensive margin of exports becomes 0.47. In Case 3, \( \alpha = 0.333 \), the import share becomes 0.59 and the extensive margin of exports becomes 0.35. Clearly, the import share or the degree of trade openness is decreasing in country size, but the extensive margin of exports is increasing in country size. These correlations are confirmed by the empirical work by Hummels and Klenow (2005).

As a small country becomes more open to trade, expenditure switching among traded goods becomes more responsive to the terms of trade fluctuations following TFP shocks. Hence, consumption volatility for a small country is higher than a large country. In addition, as Crucini (1997) has pointed out, a small country faces a large amount of capital inflows in response to positive shocks on TFP, hence output volatility of a small country becomes higher than that of a large country. For that reason, the role of NER flexibility together with endogenous specialization in expenditure switching and reallocation of capital becomes even more important for a smaller country than a large country.

Since endogenous specialization amplifies the trade balance adjustments by changing the extensive margin of exports, these changes have large impacts when the initial extensive margin of trade is small. This is the case for a small country. Consequently, the positive effect of endogenous specialization on the welfare gain from floating NER also increases as the country size falls. In Table 5, the increase in welfare gains induced by endogenous specialization following a fall in the country size comes from an increase in the average consumption and leisure for both home and foreign residents. Intuitively, TFP shocks of the
same size have larger impacts on the productivity of a small pool of labor and output in a small country than those in a large country. For this reason, the increase in the average consumption and leisure is larger for a small country than a large country. Although the variance of consumption and labor rises as the country size falls, that has a marginal effect on the welfare measure which is mostly driven by the average consumption and leisure.

4.4.2 Effects of Size of Shocks

Next, in Case 4 we double the standard deviation of TFP shocks and report the results in Table 5. Floating NER reduces the standard deviation of the export-sector productivity from the level with fixed NER by 0.60 percent. Compared to the benchmark case, doubling the standard deviation of shock roughly doubles the effect of endogenous specialization on differences across exchange rate regimes. The stabilizing effect of NER also becomes more pronounced by endogenous specialization, as indicated by an increase in cross-regime differences in the standard deviation of home consumption (from 0.05 percent to 0.14 percent).

The welfare gain from exchange rate flexibility is increased by an increase in the size of shocks too. Compared to the benchmark case, doubling the standard deviation of shock roughly doubles the effect of endogenous specialization on the benefit of exchange rate flexibility. Both home and foreign residents experience welfare gains particularly from an increase in the average consumption and leisure. Although large shocks increase the volatility of consumption and leisure, they have a marginal effect on welfare.

5 Concluding Remarks

Our SDGE model with dynamics of comparative advantage is motivated by two stylized facts. First, the number of exported products, or the extensive margin of exports, moves at the business cycle frequency. Second, the movement is sensitive to the exchange rate regime. Our model explains cross-regime differences in the volatility of the extensive margin of exports using two different types of shocks.

To be precise, TFP shocks cause the extensive margin of exports to be more volatile under a fixed exchange rate regime than a flexible exchange rate regime, as in the case of
Russia. In this case, the model predicts that currency depreciation reduces the number of exporters, because currency depreciation is caused by adverse shocks on TFP. However, foreign interest rate shocks cause the extensive margin of exports to become more volatile under a flexible exchange rate regime than a fixed exchange rate regime, as in the case of Brazil, Korea and Thailand. In this case, the model predicts that currency depreciation in response to a foreign interest rate hike increases the number of exporters. Indonesia is an exception in the sense that its extensive margin of exports is not sensitive to the exchange rate regime. In light of our model, it is plausible that Indonesia faces both TFP shocks and foreign interest rate shocks at the same time and the effects of the two types of shocks cancel out.

The theoretical prediction that the volatility of the extensive margin of exports depends on the exchange rate regime and the type of shocks has raised a question about the welfare effect of movements of the extensive margin of exports. Our cross-regime welfare comparison indicates that the endogenous determination of the number of exporters increases the benefit of flexible NER in the presence of TFP shocks, but decreases the benefit of flexible NER when shocks are from the foreign interest rate. These welfare effects of the extensive margin of exports reinforce the conventional wisdom that a country facing real shocks tends to favor flexible exchange rate regimes, but a country facing monetary shocks tends to favor fixed exchange rate regimes. Quantitatively, the welfare effect of movements of the extensive margin of exports is small, similar to the scale of the welfare effect of business cycle fluctuations in the literature.

In the sensitivity analysis, we show that an increase in the degree of openness caused by a reduction of country size can enhance the welfare effects of movements of the extensive margin of exports. The welfare gain from NER flexibility in response to TFP shocks is found to be further enhanced by endogenous specialization as the country size becomes smaller and the country becomes more open to trade. Our work highlights a potentially useful role for endogenous specialization as an additional channel for consumption smoothing for a small country facing TFP shocks.
References


Figure 1: Impulse responses to negative shocks on the home TFP

A. Nominal exchange rate

B. Relative unit cost

C. Relative number of exported products

D. Home export-sector productivity

Flexible NER regime —, Fixed NER regime -x-
Figure 2: Impulse responses to positive shocks on the foreign interest rate

A. Nominal exchange rate

B. Relative unit cost

C. Relative number of exported products

D. Home export-sector productivity

Flexible NER regime —, Fixed NER regime -x-
Table 1: Volatility of the extensive margin of exports and the intensive margin of exports

<table>
<thead>
<tr>
<th>Countries and periods</th>
<th>Standard deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$nx_t$</td>
</tr>
<tr>
<td>Brazil</td>
<td></td>
</tr>
<tr>
<td>Pre-crisis, 1995:1-1998:12</td>
<td>2.59</td>
</tr>
<tr>
<td>Indonesia</td>
<td></td>
</tr>
<tr>
<td>Pre-crisis, 1992:7-1997:6</td>
<td>1.46</td>
</tr>
<tr>
<td>Korea</td>
<td></td>
</tr>
<tr>
<td>Pre-crisis, 1992:7-1997:6</td>
<td>1.50</td>
</tr>
<tr>
<td>Russia</td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td></td>
</tr>
<tr>
<td>Pre-crisis, 1992:7-1997:6</td>
<td>1.11</td>
</tr>
<tr>
<td>Post-crisis, 1997:7-2002:6</td>
<td>2.05</td>
</tr>
</tbody>
</table>

Notes:

$nx_t$ is the natural logarithm of the number of products exported to the US; $vx_t$ is the natural logarithm of the real value per product being exported to the US; $rx_t$ is the natural logarithm of the real value of exports to the US; and $|\Delta s_t|$ is the absolute monthly percentage change of nominal exchange rate defined as units of national currency per the US dollar. All series except for $\Delta s_t$ are filtered by a band-pass filter, of which cyclical components last from 18 to 96 months. The length of leads and lags of the moving average filter is 24 months.
Table 2: Benchmark parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specialization</strong></td>
<td></td>
</tr>
<tr>
<td>Country size</td>
<td>$\alpha = 0.5$</td>
</tr>
<tr>
<td>Relative productivity</td>
<td>$n_1 = 3.35, n_2 = 2$</td>
</tr>
<tr>
<td>Relative long-run TFP</td>
<td>$\bar{x}/\bar{x}^* = 1/1.7441$</td>
</tr>
<tr>
<td>Entry cost parameter</td>
<td>$\phi_a = 4$</td>
</tr>
<tr>
<td>Trade costs</td>
<td>$\tau = 0.15$</td>
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<tr>
<td><strong>Households</strong></td>
<td></td>
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<tr>
<td>Elasticity of substitution of goods</td>
<td>$\theta = 3$</td>
</tr>
<tr>
<td>Weight of traded goods in final consumption</td>
<td>$s_T = 0.455$</td>
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<tr>
<td>Discount factor</td>
<td>$\beta = 0.99$</td>
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<tr>
<td>Intertemporal elasticity of substitution</td>
<td>$\sigma = 0.2$</td>
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<tr>
<td>Elasticity of labor supply</td>
<td>$\mu = 1 - 1/\sigma$</td>
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<tr>
<td>Elasticity of substitution of labor</td>
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<tr>
<td>Portfolio adjustment cost parameter</td>
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<tr>
<td>Wage adjustment cost parameter</td>
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<tr>
<td><strong>Capital Accumulation</strong></td>
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<td>Capital share</td>
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<td>Depreciation rate</td>
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<td>Capital adjustment costs parameter</td>
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<td><strong>Monetary policy</strong></td>
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<td>Long-run inflation</td>
<td>$\bar{\pi} = \bar{\pi}^* = 1.0358^{1/4}$</td>
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<tr>
<td>Interest rate rule</td>
<td>$\lambda_i = 0.79, \lambda_\pi = 2.15, \lambda_y = 0.93$</td>
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<tr>
<td><strong>Productivity shocks</strong></td>
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<tr>
<td>Persistence</td>
<td>$\rho_1 = 0.81$</td>
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<tr>
<td>Spillover</td>
<td>$\rho_2 = 0.03$</td>
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<tr>
<td>Volatility</td>
<td>$\sigma_u = 0.0059, \rho_{u,u^*} = 0.18$</td>
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<tr>
<td><strong>Foreign interest rate shocks</strong></td>
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<tr>
<td>Persistence</td>
<td>$\rho_j = 0$</td>
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<tr>
<td>Volatility</td>
<td>$\sigma_j = 0.0059$</td>
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Table 3: Benchmark Economy Calibrated with TFP Shocks

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Model 1: Endogenous specialization</th>
<th>Model 2: Exogenous specialization</th>
<th>Effects of endogenous specialization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Float Fix (1)-(2)</td>
<td>Float Fix (4)-(5)</td>
<td>Float NER Fix NER</td>
</tr>
<tr>
<td><strong>Standard deviation (%)</strong></td>
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<td></td>
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<td>0 0 0</td>
<td>0.43 0.71 -0.28</td>
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<tr>
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<td>0 0 0</td>
<td>0.40 0.66 -0.26</td>
</tr>
<tr>
<td>$\omega$</td>
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<td>0.89 0.77 0.12</td>
<td>0.00 0.02 -0.02</td>
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<td>$\Omega$</td>
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<td>0.15 0.28 -0.13</td>
<td>0.02 0.01 0.01</td>
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<td>$REW$</td>
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<td>0.97 0.66 0.32</td>
<td>0.01 -0.17 0.18</td>
</tr>
<tr>
<td>$Y$</td>
<td>0.99 1.57 -0.58</td>
<td>1.00 1.51 -0.52</td>
<td>-0.01 0.06 -0.07</td>
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<tr>
<td>$Y^*$</td>
<td>0.99 1.05 -0.07</td>
<td>0.97 1.14 -0.17</td>
<td>0.01 -0.09 0.10</td>
</tr>
<tr>
<td>$C$</td>
<td>0.25 0.29 -0.04</td>
<td>0.27 0.36 -0.09</td>
<td>-0.02 -0.06 0.05</td>
</tr>
<tr>
<td>$C^*$</td>
<td>0.27 0.28 -0.01</td>
<td>0.25 0.26 0.00</td>
<td>0.02 0.02 -0.01</td>
</tr>
<tr>
<td>$l$</td>
<td>0.13 0.43 -0.30</td>
<td>0.12 0.37 -0.24</td>
<td>0.01 0.06 -0.06</td>
</tr>
<tr>
<td>$l^*$</td>
<td>0.15 0.15 -0.01</td>
<td>0.14 0.20 -0.06</td>
<td>0.01 -0.05 0.06</td>
</tr>
<tr>
<td>$I$</td>
<td>2.22 3.83 -1.61</td>
<td>2.09 3.34 -1.25</td>
<td>0.13 0.49 -0.37</td>
</tr>
<tr>
<td>$I^*$</td>
<td>2.12 2.61 -0.48</td>
<td>2.08 2.66 -0.58</td>
<td>0.04 -0.06 0.10</td>
</tr>
<tr>
<td>$TB/Y$</td>
<td>0.33 0.59 -0.26</td>
<td>0.29 0.50 -0.21</td>
<td>0.04 0.08 -0.05</td>
</tr>
</tbody>
</table>

**Correlation**

<table>
<thead>
<tr>
<th></th>
<th>Model 1: Endogenous specialization</th>
<th>Model 2: Exogenous specialization</th>
<th>Effects of endogenous specialization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Float Fix (1)-(2)</td>
<td>Float Fix (4)-(5)</td>
<td>Float NER Fix NER</td>
</tr>
<tr>
<td>$\chi,Z$</td>
<td>0.42 0.39 0.03</td>
<td>0 0 0</td>
<td>0.42 0.39 0.03</td>
</tr>
<tr>
<td>$\chi, A_H$</td>
<td>-0.42 -0.39 -0.03</td>
<td>0 0 0</td>
<td>-0.42 -0.39 -0.03</td>
</tr>
<tr>
<td>$\chi, A_N$</td>
<td>-0.42 -0.39 -0.03</td>
<td>0 0 0</td>
<td>-0.42 -0.39 -0.03</td>
</tr>
<tr>
<td>$\chi, RER$</td>
<td>0.99 0.89 0.10</td>
<td>0.98 0.85 0.13</td>
<td>0.01 0.04 -0.04</td>
</tr>
<tr>
<td>$\chi, \omega$</td>
<td>0.95 0.78 0.17</td>
<td>0.99 0.94 0.05</td>
<td>-0.04 -0.16 0.12</td>
</tr>
<tr>
<td>$\chi, \Omega$</td>
<td>-0.83 -0.80 -0.03</td>
<td>-0.84 -0.85 0.00</td>
<td>0.01 0.04 -0.03</td>
</tr>
<tr>
<td>$Y, TB/Y$</td>
<td>-0.43 -0.58 0.15</td>
<td>-0.30 -0.34 0.04</td>
<td>-0.13 -0.24 0.11</td>
</tr>
</tbody>
</table>

**Welfare (%)**

<table>
<thead>
<tr>
<th></th>
<th>Model 1: Endogenous specialization</th>
<th>Model 2: Exogenous specialization</th>
<th>Effects of endogenous specialization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Float Fix (1)-(2)</td>
<td>Float Fix (4)-(5)</td>
<td>Float NER Fix NER</td>
</tr>
<tr>
<td>Home</td>
<td>-0.10 -0.28 0.18</td>
<td>-0.08 -0.08 0.00</td>
<td>-0.02 -0.19 0.17</td>
</tr>
<tr>
<td>$\gamma_m$</td>
<td>-0.10 -0.25 0.15</td>
<td>-0.08 -0.06 -0.02</td>
<td>-0.02 -0.19 0.17</td>
</tr>
<tr>
<td>$\gamma_v$</td>
<td>0.00 -0.03 0.03</td>
<td>0.00 -0.02 0.02</td>
<td>0.00 -0.01 0.01</td>
</tr>
<tr>
<td>Foreign</td>
<td>0.13 0.06 0.07</td>
<td>0.13 0.13 0.01</td>
<td>0.00 -0.06 0.06</td>
</tr>
<tr>
<td>$\gamma_m^*$</td>
<td>0.14 0.07 0.07</td>
<td>0.14 0.13 0.01</td>
<td>0.00 -0.07 0.06</td>
</tr>
<tr>
<td>$\gamma_v^*$</td>
<td>-0.01 -0.01 0.00</td>
<td>0.00 -0.01 0.00</td>
<td>0.00 0.00 0.00</td>
</tr>
<tr>
<td>World</td>
<td>0.01 -0.11 0.12</td>
<td>0.03 0.02 0.00</td>
<td>-0.01 -0.13 0.12</td>
</tr>
</tbody>
</table>

**Notations:** $\gamma^m$=welfare driven by the average of consumption and leisure; $\gamma^v$=welfare driven by the variance of consumption and leisure; $Z$=extensive margin of exports; $Y$=home output; $C$=consumption; $l$=labor supply; $I$=investment; $TB$=home trade balance; $\Omega$=terms of trade; RER=real exchange rate; REW=relative wage; $\omega$=relative unit cost; $\chi$=relative TFP; $A_H$=export-sector productivity; $A_N$=non-traded sector productivity

**Note:** Reported statistics are the average over 50 simulations.
Table 4: Benchmark Economy Calibrated with Foreign Interest Rate Shocks

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Model 1: Endogenous Specialization</th>
<th>Model 2: Exogenous Specialization</th>
<th>Effects of endogenous specialization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)  (2)  (3)=</td>
<td>(4)  (5)  (6)=</td>
<td>(7)= (8)= (9)=</td>
</tr>
<tr>
<td></td>
<td>Float  Fix  (1)-(2)</td>
<td>Float  Fix  (4)-(5)</td>
<td>Float  Fix  (7)-(8)</td>
</tr>
<tr>
<td>NER NER</td>
<td>NER NER</td>
<td>NER NER</td>
<td></td>
</tr>
<tr>
<td>Standard  deviation (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>0.20  0.02  0.19</td>
<td>0  0  0</td>
<td>0.20  0.02  0.19</td>
</tr>
<tr>
<td>$A_H$</td>
<td>0.24  0.02  0.21</td>
<td>0  0  0</td>
<td>0.24  0.02  0.21</td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.22  0.01  0.20</td>
<td>0.16  0.01  0.15</td>
<td>0.06  0.01  0.05</td>
</tr>
<tr>
<td>$\Omega$</td>
<td>0.09  0.00  0.09</td>
<td>0.09  0.00  0.08</td>
<td>0.00  0.00  0.00</td>
</tr>
<tr>
<td>RER</td>
<td>0.07  0.00  0.07</td>
<td>0.09  0.00  0.09</td>
<td>-0.02  0.00  -0.02</td>
</tr>
<tr>
<td>REW</td>
<td>0.47  0.02  0.46</td>
<td>0.47  0.01  0.46</td>
<td>0.00  0.01  0.00</td>
</tr>
<tr>
<td>$Y$</td>
<td>0.15  0.80  -0.64</td>
<td>0.03  0.97  -0.94</td>
<td>0.12  -0.17  0.30</td>
</tr>
<tr>
<td>$Y^*$</td>
<td>0.85  0.80  0.05</td>
<td>0.87  0.97  -0.10</td>
<td>-0.02  -0.17  0.16</td>
</tr>
<tr>
<td>$C$</td>
<td>0.07  0.12  -0.05</td>
<td>0.02  0.14  -0.11</td>
<td>0.04  -0.02  0.06</td>
</tr>
<tr>
<td>$C^*$</td>
<td>0.11  0.12  -0.01</td>
<td>0.10  0.14  -0.03</td>
<td>0.01  -0.02  0.03</td>
</tr>
<tr>
<td>$l$</td>
<td>0.02  0.39  -0.37</td>
<td>0.01  0.47  -0.46</td>
<td>0.01  -0.08  0.09</td>
</tr>
<tr>
<td>$l^*$</td>
<td>0.42  0.39  0.03</td>
<td>0.43  0.47  -0.04</td>
<td>-0.01  -0.08  0.08</td>
</tr>
<tr>
<td>$I$</td>
<td>0.63  1.55  -0.92</td>
<td>0.42  1.89  -1.47</td>
<td>0.21  -0.34  0.55</td>
</tr>
<tr>
<td>$I^*$</td>
<td>2.04  1.55  0.49</td>
<td>2.05  1.89  0.16</td>
<td>-0.01  -0.34  0.33</td>
</tr>
<tr>
<td>$TB/Y$</td>
<td>0.24  0.01  0.24</td>
<td>0.23  0.01  0.22</td>
<td>0.02  0.00  0.02</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Welfare (%)</th>
<th>Home</th>
<th>$\gamma_m$</th>
<th>$\gamma_v$</th>
<th>Foreign</th>
<th>$\gamma_m^*$</th>
<th>$\gamma_v^*$</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.03  -0.09</td>
<td>-0.03  -0.07</td>
<td>0.00  -0.02</td>
<td>-0.04  0.01</td>
<td>-0.03  -0.02</td>
<td>-0.03  -0.04</td>
<td>-0.03  -0.04</td>
</tr>
<tr>
<td></td>
<td>0.06</td>
<td>0.04</td>
<td>0.02</td>
<td>-0.05</td>
<td>-0.04</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>0.00  -0.09</td>
<td>0.00  -0.06</td>
<td>0.00  -0.03</td>
<td>-0.04  0.01</td>
<td>-0.02</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>0.09</td>
<td>0.06</td>
<td>0.03</td>
<td>-0.02</td>
<td>-0.02</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>-0.03  0.01</td>
<td>-0.04  0.00</td>
<td>0.00  -0.03</td>
<td>0.01</td>
<td>0.02</td>
<td>-0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.02  0.00</td>
<td>-0.03  0.01</td>
<td>0.01  0.00</td>
<td>-0.02</td>
<td>-0.01</td>
<td>-0.01</td>
<td></td>
</tr>
</tbody>
</table>

Notations: $\gamma_m$ = welfare driven by the average of consumption and leisure; $\gamma_v$ = welfare driven by the variance of consumption and leisure; $Z$ = extensive margin of exports; $Y$ = home output; $C$ = consumption; $l$ = labor supply; $I$ = investment; $TB$ = home trade balance; $\Omega$ = terms of trade; $RER$ = real exchange rate; $REW$ = relative wage; and $\omega$ = relative unit cost.

Note: Reported statistics are the average over 50 simulations.
Table 5: Sensitivity Analysis with TFP Shocks: Effects of Endogenous Specialization on Differences between the Flexible Exchange Regime and the Fixed Exchange Rate Regime

<table>
<thead>
<tr>
<th></th>
<th>Case 1: Benchmark</th>
<th>Case 2: Large α shocks</th>
<th>Case 3: Small α shocks</th>
<th>Case 4: Large α shocks</th>
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</thead>
<tbody>
<tr>
<td><strong>Standard deviation (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>$Z$</td>
<td>-0.28</td>
<td>-0.37</td>
<td>-0.27</td>
<td>-0.66</td>
</tr>
<tr>
<td>$A_H$</td>
<td>-0.26</td>
<td>-0.25</td>
<td>-0.33</td>
<td>-0.60</td>
</tr>
<tr>
<td>$\omega$</td>
<td>-0.02</td>
<td>0.00</td>
<td>-0.05</td>
<td>-0.14</td>
</tr>
<tr>
<td>$\Omega$</td>
<td>0.01</td>
<td>0.00</td>
<td>-0.02</td>
<td>-0.06</td>
</tr>
<tr>
<td>$RER$</td>
<td>0.04</td>
<td>0.04</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>$REW$</td>
<td>0.18</td>
<td>0.13</td>
<td>0.10</td>
<td>0.09</td>
</tr>
<tr>
<td>$Y$</td>
<td>-0.07</td>
<td>-0.07</td>
<td>-0.05</td>
<td>-0.26</td>
</tr>
<tr>
<td>$Y^*$</td>
<td>0.10</td>
<td>0.15</td>
<td>0.16</td>
<td>0.17</td>
</tr>
<tr>
<td>$C$</td>
<td>0.05</td>
<td>0.10</td>
<td>0.07</td>
<td>0.14</td>
</tr>
<tr>
<td>$C^*$</td>
<td>-0.01</td>
<td>0.04</td>
<td>0.01</td>
<td>0.03</td>
</tr>
<tr>
<td>$l$</td>
<td>-0.06</td>
<td>-0.04</td>
<td>-0.04</td>
<td>-0.11</td>
</tr>
<tr>
<td>$l^*$</td>
<td>0.06</td>
<td>0.06</td>
<td>0.05</td>
<td>0.10</td>
</tr>
<tr>
<td>$I$</td>
<td>-0.37</td>
<td>-0.27</td>
<td>-0.36</td>
<td>-0.90</td>
</tr>
<tr>
<td>$I^*$</td>
<td>0.10</td>
<td>0.24</td>
<td>0.19</td>
<td>0.10</td>
</tr>
<tr>
<td>$TB/Y$</td>
<td>-0.05</td>
<td>-0.03</td>
<td>-0.05</td>
<td>-0.13</td>
</tr>
<tr>
<td><strong>Welfare (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td>0.17</td>
<td>0.08</td>
<td>0.19</td>
<td>0.36</td>
</tr>
<tr>
<td>$\gamma_m$</td>
<td>0.17</td>
<td>0.08</td>
<td>0.19</td>
<td>0.34</td>
</tr>
<tr>
<td>$\gamma_v$</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>Foreign</td>
<td>0.06</td>
<td>-0.14</td>
<td>0.13</td>
<td>-0.19</td>
</tr>
<tr>
<td>$\gamma^*_m$</td>
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<td>0.14</td>
<td>-0.18</td>
</tr>
<tr>
<td>$\gamma^*_v$</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.01</td>
</tr>
<tr>
<td>World</td>
<td>0.12</td>
<td>0.01</td>
<td>0.15</td>
<td>0.08</td>
</tr>
</tbody>
</table>

**Notations:** $\gamma^m$ = welfare driven by the average of consumption and leisure; $\gamma^v$ = welfare driven by the variance of consumption and leisure; $Z$ = extensive margin of exports; $Y$ = home output; $C$ = consumption; $l$ = labor supply; $I$ = investment; $TB$ = home trade balance; $\Omega$ = terms of trade; $RER$ = real exchange rate; $REW$ = relative wage; and $\omega$ = relative unit cost.

**Note:** Reported statistics are the average over 100 simulations.