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The Extensive Margin of Trade and Monetary Policy

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Abstract

This paper studies the effects of monetary policy shocks on firms' participation in exporting. We develop a two-country dynamic stochastic general equilibrium model in which heterogeneous firms make forward-looking decisions on whether to participate in the export market and prices are staggered across firms and time. We show that while lower interest rates and a currency depreciation associated with an expansionary monetary policy help to increase the value of exporting, the inflationary effects of the policy stimulus weaken the competitiveness of some firms, resulting in a contraction in firms' export participation. In contrast, positive productivity shocks lead to a currency depreciation and an expansion in export participation at the same time. We show that, overall, the extensive margin is more sensitive to firms' price competitiveness with other firms in the export market than to exchange rate movements or interest rates.

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1 Introduction

With the exceptionally sluggish recovery from the Great Recession around the world, the prolonged period of expansionary monetary policy stance and the introduction of quantitative easing programs in a number of advanced economies reignited a debate over the role of a domestic-currency depreciation in stimulating the domestic economy through shifts in aggregate demand. In particular, some policy-makers raised a concern that such stimulative monetary policy measures would lead to competitive devaluation of the currencies of these countries that would give an advantage to the export sector in support of their domestic industry.

While the standard beggar-thy-neighbour argument focuses on shifts in aggregate demand toward domestic goods and the resulting changes in trade flows, little has been studied on its effects on individual firms' participation in international trade. This, in part, may be due to the perception that the adjustment along the extensive margin of trade is sluggish and hence its relevance to monetary policy transmission is limited. At first glance, previous empirical studies using low frequency trade data suggest that the evolution of the extensive margin of trade is gradual. For example, Bernard and Jensen (2004) report that firms' export status exhibits high persistence in the U.S. manufacturing sector. However, more recent studies have revealed that the extensive margin of trade is in fact highly volatile over business cycles and more so than output. Alessandria and Choi (2008) report that the extensive margin of exports is 1.5 times as volatile as GDP for the United States, and Naknoi (2015) reports that the extensive margin of exports to the United States is three times more volatile than the GDP of exporting countries. These findings shed new light on the dynamics of firms' export participation over business cycles and offers a new dimension of monetary policy transmission.

In this paper, we examine the effects of monetary policy shocks on firms' participation in exporting using a two-country DSGE model and analyze different channels through which monetary policy affects firms' export participation decisions. We show that, while lower interest rates and a depreciation of the domestic currency due to an expansionary monetary policy shock raise the value of export participation, inflationary effects of the monetary stimulus raise domestic production costs and weaken the competitiveness of some exporters, resulting in their exit and discouraging entry of less productive firms.

For our analysis, we extend the two-country dynamic stochastic general equilibrium model of Imura (2016) wherein firms make forward-looking decisions on whether and how much to export, and prices are staggered across firms and time. Following the exporter dynamics of Alessandria and Choi (2007), the presence of a sunk cost of entering the export market implies that firms' export participation decisions are dynamic, as they evaluate the expected future profitability of exporting against the alternative value of not exporting in the current period. As firms in our model face price rigidities in addition to persistent shocks to their productivity each period, firm-level heterogeneity in prices, productivity and export status provides a more realistic framework to study the implications of monetary policy for individual firms' decisions to export.

In our model economy, a firm's value of export participation is directly influenced by relative export prices, the exchange rate, interest rates and foreign demand. The monetary authority in each country follows a Taylor-rule interest rate policy function that reacts to domestic inflation and the real exchange rate. Since we assume that new entrants and incumbent exporters borrow to finance their respective export costs prior to production, a change in the policy rate directly influences the profitability of export participation through changes in the financing costs. In addition, the monetary authority indirectly influences the profitability of exporting and hence export participation through general-equilibrium effects on the exchange rate, production costs and export prices.

Our quantitative analysis reveals that, while an expansionary monetary policy shock increases aggregate export revenues for that country, it entails a contraction of export participation among domestic firms. When exported goods are priced in the currency of the destination market (local currency pricing), for a given level of exported goods, a real depreciation of the producers' currency (or, equivalently, a real appreciation of the destination currency) increases export revenues in their currency. At the same time, the lower interest rate reduces the cost of financing export costs. The depreciation and the lower interest rate both raise the profitability of export participation, and hence have the potential to expand the extensive margin of trade. However, inflationary effects of the monetary stimulus raise production costs and hence optimal export prices, thereby weakening the competitiveness of some firms in the export market. We find that, overall, firms' decisions to participate in exporting are more sensitive to their price competitiveness against other exporters and firms in the destination market. Therefore, for some potential entrants and incumbent exporters, the loss of competitiveness due to the rising production costs and higher prices dominates the positive effects of currency depreciation and lower interest rates, and we see a contraction in export participation. The increase in aggregate exports and the contraction along the extensive margin thus imply a reallocation of production resources toward more competitive firms and larger market shares for those surviving exporters.

In contrast, we show that a positive productivity shock leads to a depreciation of the domestic currency and an expansion of export participation at the same time. In this case, higher productivity leads to a lower marginal cost of production and hence lower optimal prices, supporting the competitiveness of home firms in the export market. In addition, the increasing consumption in the home country relative to that of the foreign country leads to a real depreciation of the home currency, which further contributes to an increase in export profitability. In this case, we see both a depreciation of the currency and an expansion of export participation.

Our finding that a positive productivity shock encourages export participation but a monetary stimulus leads to a contraction in export participation has an important implication for exporter dynamics when an economy faces a downturn due to a negative productivity shock and the monetary authority responds with an expansionary monetary policy shock. A negative productivity shock would reduce the country's total exports and the number of firms participating in exporting. If the monetary authority responds to the recessionary effects of the negative productivity shock with an expansionary policy shock, then our model predicts that it would reduce the extensive margin even further, while supporting the recovery of the domestic economy.

We also consider various Taylor-rule specifications and examine their effects on the dynamic paths of the extensive margin of trade. We show that an interest rate rule that is more aggressive on stabilizing domestic inflation moderates fluctuations in the extensive margin of the country's exports. When inflation is more tightly controlled, it reduces fluctuations in the real exchange rate, which attenuates the changes in real export revenues. At the same time, the reduced inflationary pressures support the competitiveness of domestic firms in the export market, and the fluctuations along the extensive margin of trade are also dampened. Exploring a scope for an international policy cooperation, we show that when the monetary authority in both countries take exchange rate fluctuations into their policy considerations, neither margin of exports is affected relative to the baseline case, but the GDP expansion is shared more evenly across the two countries, with a smaller expansion for the home country and a larger positive spillover to the foreign country.

The procyclical responses of the extensive margin to productivity shocks and its countercyclical responses to monetary policy shocks that we show in this paper have an important implication for the cyclicality of exporter dynamics. Naknoi (2015) reports that, for a median country in her sample of 99 countries, the extensive margin of exports to the United States is almost uncorrelated with output of the exporters' origin country. Our findings suggest that monetary policy shocks may play an important role in explaining the lack of positive comovement between the extensive margin and output.

Finally, we provide suggestive empirical evidence from vector autoregression (VAR) analysis that the extensive margin of U.S. exports declines persistently in response to an expansionary U.S. monetary policy shock. Qualitatively, this is consistent with the results of our model that the extensive margin of exports experiences a contraction in response to an expansionary monetary policy shock.

The remainder of the paper is organized as follows. Section 2 reviews the related literature. In section 3, we describe our model economy in detail. Section 4 summarizes calibration and steady-state characteristics of the model. Results are presented in section 5. Section 6 concludes.

2 Related literature

Over the past decade, the extensive margin of trade has become an important dimension in the literature of international business cycles, starting with the seminal work by Melitz (2003) and its application to the general equilibrium analysis in Ghironi and Melitz (2005) and Alessandria and Choi (2007).

Alessandria and Choi (2007) developed a model of forward-looking export participation choices by introducing large sunk costs of entry into the export market and per-period continuation costs of exporting for incumbent exporters. They calibrated the model to match the entry and exit dynamics of U.S. exporters and showed that export decisions have negligible effects on the dynamics of net exports and the real exchange rate. Imura (2016) extended their model by introducing price rigidities and showed that when an aggregate shock has significant effects on optimal export prices, the delay in intensive margin adjustments due to price rigidities leads to sizable shifts in the profitability of export participation. This in turn generates larger responses in the number of exporters and amplifies the responses of trade flows relative to a model without exporter entry and exit. In our present paper, we build upon her model and introduce working capital in the production of tradable intermediate goods and an explicit monetary policy rule to study the transmission of monetary policy shocks to firms' export decisions.

Some existing studies have examined the implications of domestic firm entry (or product creation) for monetary policy in closed-economy settings. Bilbiie, Ghironi and Melitz (2007) study optimal monetary policy in a DSGE model with product creation, and Bilbiie, Fujiwara and Ghironi (2014) analyze the effects of variety creation on optimal inflation. Bergin and Corsetti (2008) report empirical evidence that the extensive margin within the domestic market increases in response to expansionary monetary policy shocks. They explain this finding using a general equilibrium model with price rigidities and firm entry into the domestic market and show that a fall in the real interest rate raises the expected discounted profits from creating a new firm, thereby encouraging the entry of new firms. In their environment, firms' entry decisions are static, and all firms set the same price one period ahead under their assumption of symmetry. Therefore, there is no price dispersion between incumbent firms and potential entrants, and hence firms' entry decisions do not depend on the pricing behavior of incumbent firms. In contrast, our model assumes firm-level heterogeneity in productivity and the timing of price adjustment, and export participation decisions are forward-looking due to sunk entry costs. Therefore, the evolution of price differentials among incumbent exporters as well as between incumbents and potential entrants alters their market share in the destination market, and hence monetary policy affects export entry/exit decisions through its impact on the price dynamics. Using a two-country monetary model with firm entry into the domestic market, Cavallari (2013) shows that firm entry in the domestic market amplifies the international transmission of monetary policy shocks because changes in the terms of trade affect the relative price of investment to create a new firm.

Despite the growing number of studies on international business cycles with the extensive margin of international trade, there is much less existing work analyzing the role of monetary policy in the presence of exporter entry and exit. Cooke (2014) examines the effects of monetary shocks on entry of intermediate-good exporters using a framework of two-stage production and trade where exchange rate pass-through to consumption-good products can be complete (under producer currency pricing) or incomplete (under local currency pricing), while pass-through to intermediate-good prices, which are flexible, is complete. In his model, a depreciation of the domestic currency due to a monetary expansion increases (decreases) entry of intermediate-good exporters when pass-through to consumption-good prices is incomplete (complete). This is due to his two-stage production structure wherein changes in home households' demand for final goods directly affect foreign producers' demand for home exports of intermediate goods, and the degree of the shift in household demand is determined by exchange rate pass-through to consumer-good prices. In contrast, in our framework, the extensive margin of exports declines in response to an expansionary monetary policy regardless of the currency of pricing. In our model, the foreign demand for the home country's exports is not directly affected by the level of aggregate consumption in the home country, as is the case in Cooke (2014), and only indirectly through its effects on the real exchange rate. Therefore, changes in production costs and hence relative prices of exports have more dominant effects on the foreign demand for home exports in our quantitative analysis. Further, exporters in our model make entry/exit decisions in the export market and also face price rigidities at the same time, whereas Cooke's framework assumes that prices are flexible for firms making export entry/exit decisions. Therefore, our model generates important interactions between entry/exit decisions and the current and expected future rise in inflation, which gives rise to a more prominent effect of the rising production costs on firms' export decisions.

Cooke (2016) studies optimal monetary policy in a two-country model with exporter entry/exit decisions, similar to the setup of Ghironi and Melitz (2005). He shows that as a home monetary contraction improves the terms of trade, consumption increases, and policy-makers have an incentive to set higher interest rates, which lead to higher long-run inflation. Higher interest rates force less productive firms to exit the market, thereby raising the economy-wide productivity. In his model, prices are flexible, and monetary policy generates real effects because households face restrictions in their choice of portfolio composition. In contrast, we explicitly model price rigidities and study the stabilizing effects of monetary policy on trade flows and firms' export participation.

3 Model

The model economy consists of two symmetric countries: Home and Foreign. In each country, there is a continuum of identical households, a unit mass of monopolistically competitive firms each producing a differentiated tradable intermediate good, and final-good producers who combine domestically produced intermediate goods and imported intermediate goods. Final goods are non-tradable.

Intermediate-good firms are heterogeneous in productivity, export costs and the timing of price adjustment. Each period, they face persistent firm-level productivity shocks. All intermediate-good firms produce and sell in the domestic market; however, exporting is costly and involves export costs that depend on firms' export status in the previous period. If a firm did not export in the previous period, it must pay a sunk entry cost in order to start exporting.[1] Once in the export market, incumbent exporters pay a continuation cost every period in order to remain in the export market. These export costs are i.i.d. across firms, time and countries. In any given period, firms reset their domestic and export prices separately with some probability. This price-adjustment probability varies across firms depending on the number of periods since their most recent price adjustment.

The following subsections describe the model economy from the perspective of the home country. Analogous conditions hold for the foreign country. Foreign counterparts to home-country variables are indicated by an asterisk.

3.1 Intermediate good producers

3.1.1 Static problem

Each intermediate good firm i has the following CES production technology:

$$y_t(i) = z(i) A_t K_t(i)^{\nu} L_t(i)^{1-\nu}, \tag{1}$$

where $z(i)$ is firm-specific productivity in the current period, A_t is aggregate productivity, $K_t(i)$ is capital rented from domestic households, and $L_t(i)$ is a labor input. The firm-specific productivity $z(i)$ is discrete and follows a Markov switching process with transition probabilities $prob(z' = z_{\tilde{c}} | z = z_c) = \pi_{c\tilde{c}}$. The firm's static problem minimizes the production cost:

$$\min_{K_t(i), L_t(i)} w_t L_t(i) + r_t K_t(i)$$

subject to equation (1), where w_t is real wage and r_t is the rental rate of capital.

3.1.2 Profits

Since the production function has constant returns to scale, we can decompose a firm's total profit into profits from domestic sales and those from exports. Consider a firm in the domestic market with current productivity z_c and an effective price $P^D_{j,t}(z_s)$, which was set j periods ago when this firm had productivity z_s. Let $y^H_{j,t}(z_s)$ denote domestic demand for this firm's output. The real profit of this firm from domestic sales is

$$d^D_t\left(z_c, P^D_{j,t}(z_s)\right) = \frac{P^D_{j,t}(z_s)}{P_t} y^H_{j,t}(z_s) - w_t L^D_t\left(z_c, P^D_{j,t}(z_s)\right) - r_t K^D_t\left(z_c, P^D_{j,t}(z_s)\right), \tag{2}$$

[1] We assume that a firm that has exported at some point in the past and is resuming to export in the current period also has to pay the same sunk entry cost as first-time exporters.

where P_t is the aggregate price index of the home country.[2]

In addition to selling in the domestic market, intermediate-good firms can choose to export to the foreign country if they pay export costs that are paid as labor costs for hiring additional workers. Consider an exporter with current productivity z_c. Let $P^X_{j,t}(z_s)$ denote an export price this firm set j periods ago when it had productivity z_s. We assume local currency pricing, and hence $P^X_{j,t}(z_s)$ is denominated in the currency of the foreign country. The firm's real export profit, excluding export costs, is

$$d^X_t\left(z_c, P^X_{j,t}(z_s)\right) = Q_t\frac{P^X_{j,t}(z_s)}{P^*_t}y^{H*}_{j,t}(z_s) - w_tL^X_t\left(z_c, P^X_{j,t}(z_s)\right) - r_tK^X_t\left(z_c, P^X_{j,t}(z_s)\right), \tag{3}$$

where $y^{H*}_{j,t}(z_s)$ is the foreign demand for this firm's exports, Q_t is real exchange rate (home consumption good per unit of foreign consumption good), and P^*_t is the aggregate price index of the foreign country.

3.1.3 Domestic prices

Let α_j be the probability of price adjustment in the current period given that the firm last adjusted its price j periods ago. We assume that all firms adjust their price with probability 1 within J periods: $\alpha_J = 1$.

Let $V^D_{0,t}(z_c)$ denote the value of a firm in the domestic market that has current productivity level z_c and is currently adjusting its domestic-market price:

$$V^D_{0,t}(z_c) = \max_{P^D_{0,t}(z_c)} d^D_t\left(z_c, P^D_{0,t}(z_c)\right)+\beta\mathbf{E}_t\frac{\lambda_{t+1}}{\lambda_t}\left[\alpha_1\sum_{\tilde{c}=1}^{n_z}\pi_{c\tilde{c}}V^D_{0,t+1}(z_{\tilde{c}})+(1-\alpha_1)\sum_{\tilde{c}=1}^{n_z}\pi_{c\tilde{c}}V^D_{1,t+1}\left(z_{\tilde{c}}, P^D_{0,t}(z_c)\right)\right] \tag{4}$$

for $c = 1, \cdots, n_z$, where β is the household subjective discount factor, λ_t is the date-t household marginal utility of consumption, and $V^D_{1,t+1}(\cdot)$ is the value of the firm next period if it cannot adjust its price next period. This firm chooses $P^D_{0,t}(z_c)$ in order to maximize (4).

The domestic-market value of a firm that is not currently adjusting its price and has current productivity z_c and an effective price $P^D_{j,t}(z_s)$, is

$$V^D_{j,t}\left(z_c, P^D_{j,t}(z_s)\right) = d^D_t\left(z_c, P^D_{j,t}(z_s)\right)+\beta\mathbf{E}_t\frac{\lambda_{t+1}}{\lambda_t}\left[\alpha_{j+1}\sum_{\tilde{c}=1}^{n_z}\pi_{c\tilde{c}}V^D_{0,t+1}(z_{\tilde{c}})+(1-\alpha_{j+1})\sum_{\tilde{c}=1}^{n_z}\pi_{c\tilde{c}}V^D_{j+1,t+1}\left(z_{\tilde{c}}, P^D_{j,t}(z_s)\right)\right]$$

for $c = 1, \cdots, n_z$, $s = 1, \cdots, n_z$, and $j = 1, \cdots, J-2$, and

$$V^D_{J-1,t}\left(z_c, P^D_{J-1,t}(z_s)\right) = d^D_t\left(z_c, P^D_{J-1,t}(z_s)\right) + \beta\mathbf{E}_t\frac{\lambda_{t+1}}{\lambda_t}\sum_{\tilde{c}=1}^{n_z}\pi_{c\tilde{c}}V^D_{0,t+1}(z_{\tilde{c}})$$

[2] If the firm adjusts its price in the current period, then $j = 0$ and $z_s = z_c$

for $c = 1, \cdots, n_z$, and $s = 1, \cdots, n_z$.

3.1.4 Export prices

Exporters must pay export costs that depend on their export status in the previous period. If a firm did not export in the previous period and chooses to enter the export market in the current period, it must pay an i.i.d. sunk entry cost η drawn from a time-invariant distribution $\eta \sim G^E(\eta)$. If a firm was an exporter in the previous period and chooses to continue exporting in the current period, it must pay a continuation cost ξ drawn from a time-invariant distribution $\xi \sim G(\xi)$. We assume that these export costs must be paid before production and exporting take place. In order to finance the export costs, firms borrow intraperiod loans at a nominal interest rate i_t.

Let $V_t^E(z_c, \eta)$ denote the value of exporting for a potential entrant (a firm that was not an exporter last period) that has current productivity z_c and an entry cost draw η. If this firm decides to enter the export market in the current period, it sets an optimal price for its exports upon entry. We assume that the export price may differ from the current price the firm uses in the domestic market. The value of exporting for this potential entrant can be expressed as

$$V_t^E(z_c, \eta) = \max \left\{ \max_{P_{0,t}^X(z_c)} \left[d_t^X \left(z_c, P_{0,t}^X(z_c) \right) - i_t \eta w_t + \beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} H_{1,t+1} \left(z_{\tilde{c}}, P_{0,t}^X(z_c), \xi_{t+1} \right) \right], \right.$$
$$\left. \beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} V_{t+1}^E(z_{\tilde{c}}, \eta_{t+1}) \right\} \quad (5)$$

for $c = 1, \cdots, n_z$, where $H_{j,t+1}(\cdot)$ is the expected value of exporting next period defined below. The first term inside the binary max operator is the value of entering the export market in the current period with the optimal price $P_{0,t}^X(z_c)$, and the second term is the value of not entering this period (and hence zero export profit this period) and being a potential entrant again next period. Prior to learning whether it will reset its export price in the current period, the export value of this incumbent exporter is

$$H_{j,t} \left(z_c, P_{j,t}^X(z_s), \xi \right) = \alpha_j V_{0,t}^X(z_c, \xi) + (1 - \alpha_j) V_{j,t}^X \left(z_c, P_{j,t}^X(z_s), \xi \right)$$

for $c = 1, \cdots, n_z$, $s = 1, \cdots, n_z$, and $j = 1, \cdots, J-1$, and

$$H_{J,t}(z_c, \xi) = V_{0,t}^X(z_c, \xi) \quad (6)$$

for $c = 1, \cdots, n_z$.

Next, we describe the Bellman equations of incumbent exporters. Let $V_{0,t}^X(z_c, \xi)$ be the value of an incumbent exporter that is resetting its price this period and has current productivity z_c and an i.i.d. export cost ξ. Let $V_{j,t}^X \left(z_c, P_{j,t}^X(z_s), \xi \right)$ be the exporting value of an incumbent that is not able to adjust its price this period and has current productivity z_c, an effective price $P^X_{j,t}(z_s)$ and an i.i.d. export cost ξ. The export value for incumbent exporters conditional on price reset is

$$V^X_{0,t}(z_c,\xi) = \max\left\{ \max_{P^X_{0,t}(z_c)} \left[d^X_t \left(z_c, P^X_{0,t}(z_c)\right) - i_t \xi w_t + \beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} H_{1,t+1}\left(z_{\tilde{c}}, P^X_{0,t}(z_c), \xi_{t+1}\right) \right], \beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} V^E_{t+1}(z_{\tilde{c}}, \eta_{t+1}) \right\} \quad (7)$$

for $c = 1, \cdots, n_z$, and the values conditional on no price reset are

$$V^X_{j,t}\left(z_c, P^X_{j,t}(z_s), \xi\right) = \max\left\{ d^X_t \left(z_c, P^X_{j,t}(z_s)\right) - i_t \xi w_t + \beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} H_{j+1,t+1}\left(z_{\tilde{c}}, P^X_{j,t}(z_s), \xi_{t+1}\right), \beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} V^E_{t+1}(z_{\tilde{c}}, \eta_{t+1}) \right\} \quad (8)$$

for $c = 1, \cdots, n_z$, $s = 1, \cdots, n_z$, $j = 1, \cdots, J-2$, and

$$V^X_{J-1,t}\left(z_c, P^X_{J-1,t}(z_s), \xi\right) = \max\left\{ d^X_t \left(z_c, P^X_{J-1,t}(z_s)\right) - i_t \xi w_t + \beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} H_{J,t+1}\left(z_{\tilde{c}}, \xi_{t+1}\right), \beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} V^E_{t+1}(z_{\tilde{c}}, \eta_{t+1}) \right\} \quad (9)$$

for $c = 1, \cdots, n_z$, and $s = 1, \cdots, n_z$.

Incumbent exporters with current productivity z_c that are resetting prices in the current period choose $P^X_{0,t}(z_c)$ so as to maximize equation (7). Entrants with current productivity z_c choose $P^X_{0,t}(z_c)$ that solves equation (5). Since the optimal price does not depend on the export costs, for a given level of current firm-specific productivity z_c, entrants and price-resetting incumbent exporters choose the same optimal price $P^X_{0,t}(z_c)$.

3.1.5 Exporter entry and exit decisions

We now turn to how firms make decisions on whether or not to participate in the export market. Let $\eta^E_t(z_c)$ denote the maximum entry cost that last period's non-exporters with current productivity z_c are willing to pay in order to start exporting this period. This threshold entry cost equates the value of entering the export market (the first element of the binary max operator in equation (5)) to the value of not entering this period (the second element of the binary max operator):

$$\beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} V^E_{t+1}(z_{\tilde{c}}, \eta_{t+1}) = d^X_t \left(z_c, P^X_{0,t}(z_c)\right) - i_t \eta^E_t(z_c) w_t + \beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} H_{1,t+1}\left(z_{\tilde{c}}, P^X_{0,t}(z_c), \xi_{t+1}\right)$$

for $c = 1, \cdots, n_z$.

Similarly, let $\xi_t^0(z_c)$ denote the maximum continuation cost that incumbent exporters with current productivity z_c that are adjusting price this period are willing to pay in order to continue exporting in the current period. From equation (7), this threshold cost equates the value of continuation and the value of exiting the export market this period:

$$\beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} V_{t+1}^E(z_{\tilde{c}}, \eta_{t+1}) = d_t^X \left(z_c, P_{0,t}^X(z_c)\right) - i_t \xi_t^0(z_c) w_t + \beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} H_{1,t+1}\left(z_{\tilde{c}}, P_{0,t}^X(z_c), \xi_{t+1}\right)$$

for $c = 1, \cdots, n_z$.

Finally, using equations (8) and (9), we can define the maximum export cost $\xi_t^j(z_c, z_s)$ that non-price-adjusting incumbent exporters with current productivity z_c and an effective export price $P_{j,t}^X(z_s)$ are willing to pay in order to continue exporting this period:

$$\beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} V_{t+1}^E(z_{\tilde{c}}, \eta_{t+1}) = d_t^X \left(z_c, P_{j,t}^X(z_s)\right) - i_t \xi_t^j(z_c, z_s) w_t + \beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} H_{j+1,t+1}\left(z_{\tilde{c}}, P_{j,t}^X(z_s), \xi_{t+1}\right)$$

for $c = 1, \cdots, n_z$, $s = 1, \cdots, n_z$, and $j = 1, \cdots, J-2$, and

$$\beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} V_{t+1}^E(z_{\tilde{c}}, \eta_{t+1}) = d_t^X \left(z_c, P_{J-1,t}^X(z_s)\right) - i_t \xi_t^{J-1}(z_c, z_s) w_t + \beta \mathbf{E}_t \frac{\lambda_{t+1}}{\lambda_t} \sum_{\tilde{c}=1}^{n_z} \pi_{c\tilde{c}} H_{J,t+1}\left(z_{\tilde{c}}, \xi_{t+1}\right)$$

for $c = 1, \cdots, n_z$, and $s = 1, \cdots, n_z$.

Using the threshold export participation costs derived above, along with the continuous time-invariant distributions of export costs η and ξ, we can determine firms' probabilities of entry and continuation in the export market prior to the realizations of these costs. For potential entrants, the probability of entering the export market is $\zeta_t^E(z_c) = G^E\left(\eta_t^E(z_c)\right)$ for $c = 1, \cdots, n_z$. For price-adjusting incumbent exporters, the probability of remaining in the export market is $\zeta_t^0(z_c) = G\left(\xi_t^0(z_c)\right)$ for $c = 1, \cdots, n_z$. For non-price-adjusting incumbents, the probability of remaining in the export market is $\zeta_t^j(z_c, z_s) = G\left(\xi_t^j(z_c, z_s)\right)$ for $c = 1, \cdots, n_z$, $s = 1, \cdots, n_z$, and $j = 1, \cdots, J-1$.

3.1.6 Evolution of firm distributions

Let $\theta_{j,t}(z_c, z_s)$ denote the mass of firms in the domestic market starting date t with productivity z_c and a domestic price $P_{j,t}^D(z_s)$. The evolution of the distribution of firms is

$$\theta_{j+1,t+1}(z_{\tilde{c}}, z_{\tilde{s}}) = (1 - \alpha_j) \sum_{c=1}^{n_z} \pi_{c\tilde{c}} \theta_{j,t}(z_c, z_{\tilde{s}})$$

for $j = 1, \cdots, J-1$, $\tilde{s} = 1, \cdots, n_z$, and $\tilde{c} = 1, \cdots, n_z$. The mass of firms in the domestic market starting $t+1$ with productivity $z_{\tilde{c}}$ and a domestic price $P^D_{1,t+1}(z_{\tilde{s}})$ is

$$\theta_{1,t+1}(z_{\tilde{c}}, z_{\tilde{s}}) = \pi_{\tilde{s}\tilde{c}} \sum_{j=1}^{J} \sum_{s=1}^{n_z} \alpha_j \theta_{j,t}(z_{\tilde{s}}, z_s)$$

for $\tilde{s} = 1, \cdots, n_z$, and $\tilde{c} = 1, \cdots, n_z$. Since there is a unit mass of firms in the domestic market, $\theta(\cdot)$ sums up to 1: $\sum_{j=1}^{J} \sum_{c=1}^{n_z} \sum_{s=1}^{n_z} \theta_{j,t}(z_c, z_s) = 1$.

The evolution of the mass of exporters can be described in a similar way but taking into account the probability of entry/exit in the export market. Let $\psi_{j,t}(z_c, z_s)$ be the mass of incumbents starting date t with productivity z_c and an export price $P^X_{j,t}(z_s)$, and let $N^E_t(z_c)$ be the mass of entrants with productivity z_c at time t. The evolution of the distribution of price-adjusting incumbents is

$$\psi_{1,t+1}(z_{\tilde{c}}, z_{\tilde{s}}) = \pi_{\tilde{s}\tilde{c}} \zeta^0_t(z_{\tilde{s}}) \sum_{j=1}^{J} \sum_{s=1}^{n_z} \alpha_j \psi_{j,t}(z_{\tilde{s}}, z_s) + \pi_{\tilde{s}\tilde{c}} N^E_t(z_{\tilde{s}})$$

for $\tilde{c} = 1, \cdots, n_z$, and $\tilde{s} = 1, \cdots, n_z$, where the first term on the right hand side of the equation is the mass of price-adjusting incumbents continuing to export at time t, and the second term represents the mass of entrants at time t. The evolution of the distribution of non-price-adjusting incumbents is

$$\psi_{j+1,t+1}(z_{\tilde{c}}, z_{\tilde{s}}) = (1-\alpha_j) \sum_{c=1}^{n_z} \zeta^j_t(z_c, z_{\tilde{s}}) \pi_{c\tilde{c}} \psi_{j,t}(z_c, z_{\tilde{s}}),$$

for $j = 1, \cdots, J-1$, $\tilde{s} = 1, \cdots, n_z$, and $\tilde{c} = 1, \cdots, n_z$. The mass of entrants with productivity z_c at time t is

$$N^E_t(z_c) = \zeta^E_t(z_c) \left[\sum_{j=1}^{J} \sum_{s=1}^{n_z} \theta_{j,t}(z_c, z_s) - \sum_{j=1}^{J} \sum_{s=1}^{n_z} \psi_{j,t}(z_c, z_s) \right]$$

for $c = 1, \cdots, n_z$.

3.2 Final good producers

Final good producers combine domestically produced intermediate goods and imported foreign intermediate goods to produce final goods D_t:

$$D_t = \left\{ \omega \left[\int_0^1 y^H_t(i)^{\frac{\gamma-1}{\gamma}} di \right]^{\frac{\gamma}{\gamma-1} \frac{\rho-1}{\rho}} + (1-\omega) \left[\int_{i \in \Theta_t} y^F_t(i)^{\frac{\gamma-1}{\gamma}} di \right]^{\frac{\gamma}{\gamma-1} \frac{\rho-1}{\rho}} \right\}^{\frac{\rho}{\rho-1}}, \tag{10}$$

where ω is the home bias, γ is an elasticity of substitution between intermediate goods produced in the same country, ρ is the elasticity of substitution between home and foreign intermediate goods (Armington elasticity), and Θ_t is a set of foreign intermediate goods available in the home country in period t. Because firms enter and exit the export market over time, the variety of imported products available in the country is time-varying. Final goods are sold at the price P_t to the domestic household for consumption C_t and investment in physical capital I_t: $D_t = C_t + I_t$.

Final good producers choose $y_t^H(i)$ and $y_t^F(i)$ to solve

$$\max_{y_t^H(i), y_t^F(i)} P_t D_t - \int_0^1 P_t^D(i) y_t^H(i) di - \int_{i \in \Theta} P_t^{X*}(i) y_t^F(i) di$$

subject to the production technology (10). This yields demand for each intermediate good i:

$$y_t^H(i) = \omega^\rho \left(\frac{P_t^D(i)}{P_t^D} \right)^{-\gamma} \left(\frac{P_t^D}{P_t} \right)^{-\rho} D_t,$$

and

$$y_t^F(i) = (1-\omega)^\rho \left(\frac{P_t^{X*}(i)}{P_t^{X*}} \right)^{-\gamma} \left(\frac{P_t^{X*}}{P_t} \right)^{-\rho} D_t,$$

where $P_t^D = \left[\int_0^1 P_t^D(i)^{1-\gamma} di \right]^{\frac{1}{1-\gamma}}$ is the price index of domestically produced intermediate goods and $P_t^* = \left[\int_{i \in \Theta_t} P_t^{X*}(i)^{1-\gamma} \right]^{\frac{1}{1-\gamma}}$ is the price index of intermediate goods imported from the foreign country, which reflects the changes in the variety of imported goods available in the home country (Θ_t) due to endogenous entry and exit of foreign exporters over time.

Foreign final good producers solve an analogous problem. Their demand for imports from the home country is

$$y_t^{H*}(i) = (1-\omega)^\rho \left(\frac{P_t^X(i)}{P_t^X} \right)^{-\gamma} \left(\frac{P_t^X}{P_t^*} \right)^{-\rho} D_t^*.$$

Therefore, the real exports for the home country are

$$EX_t = \int_{i \in \Theta_t^*} Q_t \frac{P_t^X(i)}{P_t^*} y_t^{H*}(i) di.$$

3.2.1 Price index

The aggregate price index across all goods available in the home country is

$$P_t = \left[\omega^\rho \left(P_t^D \right)^{1-\rho} + (1-\omega)^\rho \left(P_t^{X*} \right)^{1-\rho} \right]^{\frac{1}{1-\rho}},$$

where the price index for domestically-produced goods P_t^D is

$$P_t^D = \left[\sum_{j=1}^{J} \sum_{c=1}^{n_z} \sum_{s=1}^{n_z} \alpha_j \theta_{j,t}(z_c, z_s) P_{0,t}^D(z_c)^{1-\gamma} + \sum_{j=1}^{J-1} \sum_{c=1}^{n_z} \sum_{s=1}^{n_z} (1-\alpha_j) \theta_{j,t}(z_c, z_s) P_{j,t}^D(z_s)^{1-\gamma} \right]^{\frac{1}{1-\gamma}},$$

and the price index for imported goods P_t^{X*} is

$$P_t^{X*} = \left[\sum_{c=1}^{n_z} N_t^{E*}(z_c) P_{0,t}^{X*}(z_c)^{1-\gamma} + \sum_{j=1}^{J} \sum_{c=1}^{n_z} \sum_{s=1}^{n_z} \alpha_j \zeta_t^{0*}(z_c) \psi_{j,t}^{*}(z_c, z_s) P_{0,t}^{X*}(z_c)^{1-\gamma} \right.$$
$$\left. + \sum_{j=1}^{J-1} \sum_{c=1}^{n_z} \sum_{s=1}^{n_z} (1-\alpha_j) \zeta_t^{j*}(z_c, z_s) \psi_{j,t}^{*}(z_c, z_s) P_{j,t}^{X*}(z_s)^{1-\gamma} \right]^{\frac{1}{1-\gamma}}.$$

Since $\gamma > 1$, P_t^{X*} is decreasing in the number of available variety of exports, consistent with the results in the literature on product variety (Feenstra, 1994; Ghironi and Melitz, 2005).

3.3 Household

There is a continuum of identical households in each country. They consume final goods, C_t; make investment, I_t, in physical capital; and provide labor, L_t, to domestic intermediate-good producers. Households earn labor income, $w_t L_t$, and capital rental income, $r_t K_t$. They also purchase two types of one-period bonds. One is a state-contingent international bond $B(s^{t+1})$, sold at price $q(s^{t+1}|s^t)$ in units of the home currency, which yields payoffs contingent on the realization of a particular state s_{t+1} at time $t+1$. The other is domestically issued bonds B_t^D with nominal return i_t.

A representative household chooses C_t, L_t, K_{t+1}, $B_{t+1}(s^{t+1})$ and B_t^D to solve

$$\max \mathbf{E}_t \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\sigma_c} C_t^{1-\sigma_c} + \chi \frac{1}{1-\sigma_L} (1-L_t)^{1-\sigma_L} \right]$$

subject to a period budget constraint:

$$\sum_{s^{t+1}} q(s^{t+1}|s^t) B(s^{t+1}) + P_t C_t + P_t I_t + B_t^D = B(s^t) + P_t d_t + P_t w_t L_t + P_t r_t K_t + i_{t-1} B_{t-1}^D,$$

and the law of motion for capital:

$$K_{t+1} = (1-\delta) K_t + I_t - \frac{\kappa}{2} \left(\frac{I_t}{K_t} - \delta \right)^2 K_t.$$

Because we assume that the international bond markets are complete, the first-order condition with respect to optimal purchases of international state-contingent bonds in the two countries implies that the real exchange rate is proportional to the relative marginal utility of consumption:

$$Q_t = e_0 \frac{\lambda_0}{\lambda_0^*} \frac{P_0^*}{P_0} \frac{\lambda_t^*}{\lambda_t}, \tag{11}$$

where $Q_t \equiv e_t \frac{P_t^*}{P_t}$ and e_t is the nominal exchange rate.[3]

3.4 Monetary policy rule

The monetary authority in each country sets a nominal interest rate i_t according to a policy rule with some persistence that reacts to fluctuations in domestic inflation and the real exchange rate:

$$\hat{i}_t = \rho_i \hat{i}_{t-1} + (1-\rho_i)\left(\phi_\pi \hat{\pi}_t + \phi_Q \hat{Q}_t\right) + \hat{\mu}_t, \tag{12}$$

where variables with a hat denote percentage deviations from steady-state values, $\pi_t \equiv P_t/P_{t-1}$ is domestic inflation and μ_t is a monetary policy shock.

3.5 GDP and related variables

We define GDP as

$$Y_t = \frac{\omega^\rho \left(\frac{P_t^D}{P_t}\right)^{1-\rho} D_t + Q_t(1-\omega)^\rho \left(\frac{P_t^X}{P_t^*}\right)^{1-\rho} D_t^*}{\frac{P_t^Y}{P_t}},$$

where P_t^Y is the GDP deflator defined as

$$\frac{P_t^Y}{P_t} \equiv (1-g_t)\frac{P_t^D}{P_t} + g_t Q_t \frac{P_t^X}{P_t^*},$$

and g_t is the export-to-GDP ratio defined as

$$g_t \equiv \frac{Q_t(1-\omega)^\rho \left(\frac{P_t^X}{P_t^*}\right)^{1-\rho} D_t^*}{\frac{P_t^Y}{P_t} Y_t}.$$

4 Calibration

The model is calibrated to the quarterly frequency. The household subjective discount factor is 0.99 to imply the annual real interest rate of 4 percent. We assume that the household period utility is log in consumption ($\sigma_c = 1$) and linear in leisure ($\sigma_L = 0$). The weight on leisure in the utility function χ is set equal to 1.8 so that the households work 1/3 of their time in steady state.

The elasticity of substitution, ρ, between domestically produced intermediate goods and imported intermediate goods is 1.5 following the literature (see, for example, Backus, Kehoe and Kydland (1994) and Chari, Kehoe and McGrattan (2002)). The intratemporal elasticity of substitution γ is 3.8 as in Ghironi and Melitz (2005).

[3] In our calibration, we normalize $e_0 \frac{\lambda_0}{\lambda_0^*} \frac{P_0^*}{P_0} = 1$.

Table 1: Parameter values

Subjective discount factor	β	0.99
Exponent on consumption	σ_c	1
Exponent on leisure	σ_L	0
Weight on leisure in utility	χ_2	1.8
Armington elasticity	ρ	1.5
Share of capital in production	ν	0.4
Capital depreciation rate	δ	0.025
Steady-state inflation	$\bar{\pi}$	$1.02^{1/4}$
Elasticity of substitution	γ	3.8
Capital adjustment cost	κ	5.85
Price adjustment probabilities	α_j	[0.05 0.09 0.25 0.49 0.7 1]
Home bias in final goods	ω	0.762
Upper support on entry cost dist.	η_U	2.78
Upper support on continuation cost dist.	ξ_U	0.179
Firm-level productivity		
persistence	ρ_z	0.81
standard deviation	σ_z	0.085
number of levels	n_z	2
Monetary policy rule		
persistence	ρ_i	0.8
exponent on inflation	ϕ_π	2
exponent on exchange rate	ϕ_Q	0.1

Table 2: Target statistics and model moments

	Data	Model	
Mass of exporters	0.21	0.23	Bernard et al. (2003)
Continuation rate	0.97	0.87	Bernard & Jensen (2004)
Entry rate	0.04	0.04	Bernard & Jensen (2004)
Imports/GDP	0.12	0.12	Drozd & Nosal (2012)
Productivity relative to nonexporters	1.12–1.18	1.13	Bernard & Jensen (1999)
Mean price adjustment frequency (qtr)	1.07–3.27	2.66	Bils & Klenow (2004) Nakamura & Steinsson (2008)

The share of capital in the production function ν is set equal to 0.4. The depreciation rate of capital δ is 0.025 so that capital depreciates by 10 percent annually. The investment adjustment cost κ is set equal to 5.85 so that the standard deviation of investment relative to that of GDP is 2.91 as in the data.[4] We assume that there are two levels of firm-level productivity: $n_z = 2$.

The price adjustment hazard is assumed to rise convexly in the time since last price reset and implies full adjustment by $J = 6$. The average age of domestic prices over the steady-state distribution of firms is 2.7 quarters, to be within the estimated range of 1.4–4.3 quarters from micro-level price adjustments in the recent literature (see, for example, Bils and Klenow (2004) and Nakamura and Steinsson (2008)). The steady-state annual inflation rate is set to 2 percent.

We assume that entry and continuation costs (η and ξ, respectively) are both drawn from uniform distributions with lower support 0. We jointly calibrate the home bias parameter ω, the upper support of entry costs η_U, that of continuation costs ξ_U, and the persistence and volatility of the firm-level productivity (ρ_z and σ_z) to match (i) the mass of exporters, (ii) the average rate of entry, (iii) the average rate of exit, (iv) the average productivity of exporters relative to that of non-exporters, and (v) the imports-to-GDP ratio in the U.S. data. In our model, the steady-state mass of exporters is 23 percent of all the firms in the economy, to be in line with the findings of Bernard et al. (2003) from data on U.S. manufacturers in 1992. For the entry and exit rates, Bernard and Jensen (2004) report that, on average each year, 87 percent of the exporters continued exporting in the following year and 14 percent of non-exporters began exporting in the following year. These numbers translate to a 97 percent quarterly continuation rate and a 4 percent quarterly

[4] The simulation is driven by shocks to productivity and monetary policy in both countries. The process for productivity shocks has persistence of 0.95, the standard deviation of 0.007, and the cross-country correlation of 0.25, as in Kehoe and Perri (2002). The process for monetary policy shocks has persistence of 0.12, the standard deviation of 0.0024, and no exogenous cross-country spillovers, as in Smets and Wouters (2007). The model statistics are computed as the average of 100 simulations, each simulation with 1000 periods, where the relevant series have been logged and HP filtered.

entry rate. In our model, the probability that incumbent exporters continue exporting next period is 87 percent quarterly while the probability of non-incumbent firms entering the export market is 4 percent quarterly. Exporters are 13 percent more productive relative to non-exporters in our steady state, to be in line with the observed range of 12 to 18 percent (Bernard and Jensen, 1999). The steady-state ratio of imports to GDP is 0.12, as in the data (Drozd and Nosal, 2012). Table 1 summarizes the parameter values used in the baseline calibration, and the calibration target moments and the corresponding steady-state moments from our model are reported in Table 2.

5 Results

In this section, we examine a series of impulse responses of our model economy to country-specific aggregate shocks with a focus on the dynamics of the extensive margin of trade. As discussed in section 3.1.5, firms' export decisions depend on the value of exporting (entry of new exporters, or continuation of incumbent exporters) relative to the value of not exporting (no entry for potential entrants, or exit for incumbent exporters). Equations (5) and (7) suggest that the value of exporting is directly influenced by movements in certain aggregate variables, such as the exchange rate, export prices, the interest rate, and the aggregate demand in the destination market. Of course, these variables are in turn affected by the evolution of the aggregate state of the economy through general equilibrium effects.

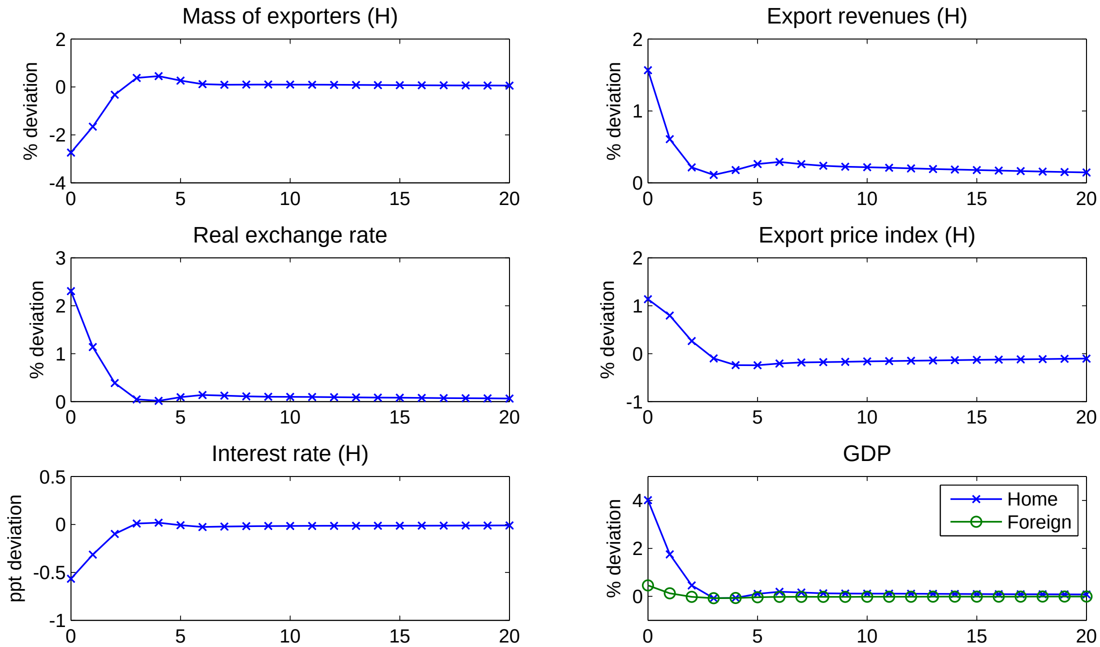
5.1 Monetary policy shocks

We begin our analysis with an expansionary monetary policy shock. Figure 1 shows the impulse responses of our model economy to a 1 percent expansionary monetary policy shock in the home country. The persistence of the shock is set to 0.12 as estimated by Smets and Wouters (2007), and there is no exogenous shock spillover to the foreign country.

With the policy stimulus, we see an immediate increase in the output of the home country. The rise in home consumption relative to that in the foreign country leads to a real depreciation of the home currency by 2.3 percent at the impact of the shock. At the same time, the inflationary effects of the expansionary shock exert an upward pressure on the current and expected future costs of production, and this leads firms to start raising their prices. In our local-currency-pricing setting, the increase in the price of home exports (relative to the foreign CPI) reduces the foreign demand for home exports; however, this decline is more than offset by the strong real appreciation of the foreign currency, and we see an increase in the home country's real export revenues.

For individual firms making decisions on export participation, the lower interest rate reduces the cost of financing export costs, and the real appreciation of the foreign currency raises the profitability of exporting. However, we see that export participation (the extensive margin of trade) declines 2.7 percent at the impact of the shock. For incumbent exporters, the rising production

Figure 1: Impulse responses to an expansionary monetary policy shock in the home country

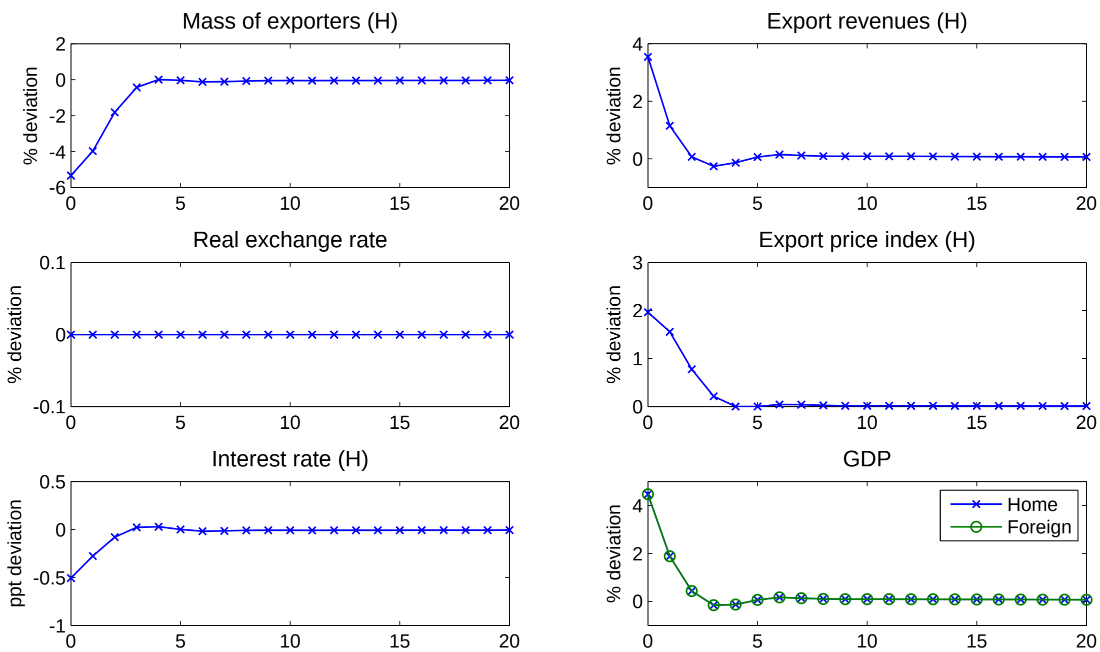


Notes: Impulse responses to a 1 percent expansionary monetary policy shock in the home country. The persistence is set equal to 0.12, with no exogenous shock spillover to the foreign country.

costs imply lower profitability of exporting. The potential export-market share of potential entrants is diminishing because their optimal prices chosen upon entry reflect rising costs of production and thus are higher than the average price of incumbent exporters whose prices adjust gradually as the result of nominal rigidities. Therefore, despite the real depreciation of their currency and the lower interest rate, the loss of competitiveness due to the inflationary pressure dominates in some firms' export decisions. These results highlight the contrasting relative importance of a policy-induced depreciation for a country's aggregate exports and individual firms' participation in international trade. While the real depreciation contributes to increasing the value of a given unit of export sales, the inflationary effects of the shock in the domestic economy reduce some firms' market share in the export market, thereby diminishing the value of their participation in international trade. As a result, the increased real exports are shared by fewer, more competitive exporters, with each of them having a larger market share.

The importance of firms' competitiveness over exchange rate movements in influencing the dynamics of the extensive margin of trade becomes clearer when we consider simultaneous expansionary monetary policy shocks in both home and foreign countries. In this case, because the dynamic path of consumption is symmetric in the two countries, the shocks cancel out their effects on their respective currency, and the real exchange rate remains at the steady-state level throughout. In addition, relative to the impulse responses in figure 1, the foreign expansionary

Figure 2: Impulse responses to simultaneous expansionary monetary policy shocks in the home and foreign countries



Notes: Impulse responses to simultaneous 1 percent expansionary monetary policy shocks in the home and foreign countries. The persistence is set equal to 0.12, with no exogenous shock spillover to the other country.

monetary policy shock generates a sizable increase in foreign consumption, which increases foreign demand for home exports.

In figure 2, we see that the higher aggregate demand in the foreign country due to the expansionary monetary policy shock there leads to an immediate, sizable increase in home real exports relative to the level we saw in figure 1. In contrast, we continue to see a fall in exporter participation of home exporters despite the stronger foreign demand and the lower home interest rate. Since the real exchange rate remains at the steady-state level in this case, the changes in home export prices are attributed to the rising current and expected future cost of production in the home country, and the loss of competitiveness leads to fewer firms participating in international trade.

When incumbent exporters face rising production costs, some of them find the real appreciation of their foreign sales insufficient to cover their production costs (because of productivity heterogeneity) and export costs (because of their i.i.d. continuation cost draw), and they exit the export market. On the other hand, for average potential entrants, because they face sunk entry costs that are on average substantially larger than the average continuation cost paid by incumbent exporters, their potential profit share from the rise in foreign demand is smaller than that of average incumbent exporters. In addition, because of the rising production cost in the home country, the optimal export price chosen by potential exporters is higher than the average export price of incumbent exporters, which further reduces the potential market share of potential exporters. As a result, we see a contraction along the extensive margin of trade.

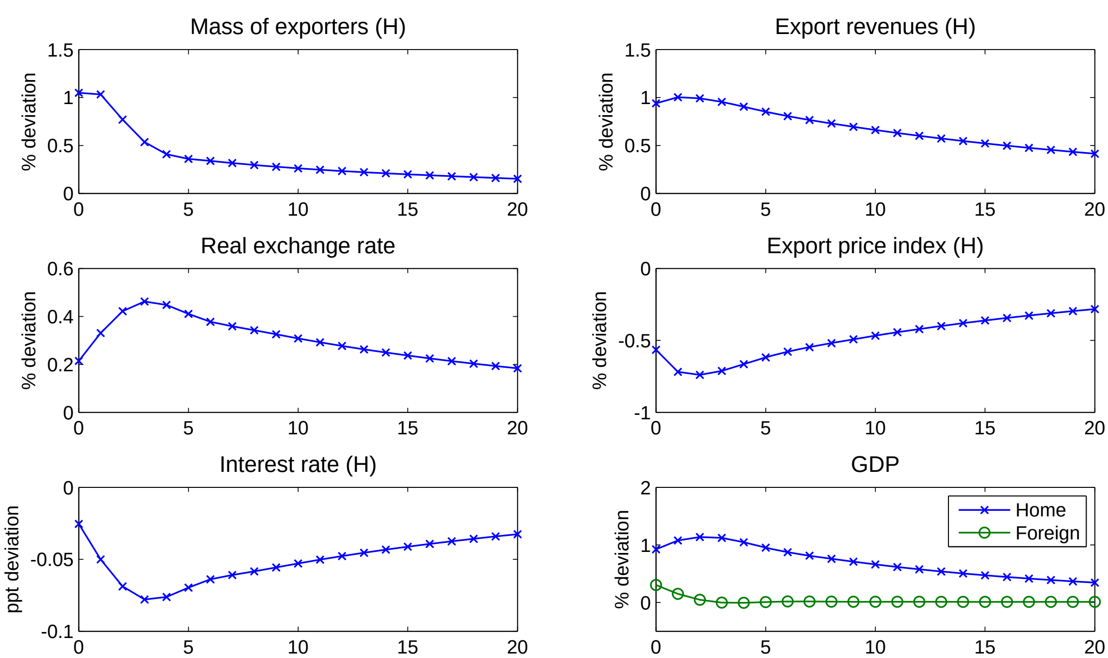
5.2 Productivity shock

We next examine the dynamic responses of our model economy to a positive productivity shock in the home country. We will see that, in contrast to the contraction of the extensive margin in response to an expansionary monetary policy shock as seen in figure 1, positive productivity shocks lead to an expansion of the extensive margin of trade along with a depreciation of the currency.

Figure 3 shows the impulse responses of the same set of variables as in figures 1 and 2, to a 1 percent positive productivity shock in the home country, with persistence of 0.906 following Backus, Kehoe and Kydland (1992) and without exogenous cross-country spillover to the foreign country. As the shock expands the home country's production capacity, GDP increases. The higher consumption in the home country relative to the foreign country implies that the real exchange rate depreciates for the home currency. At the same time, the higher productivity lowers the marginal cost of production for home intermediate-good producers, and they start lowering their prices. The lower price of home exports relative to the aggregate price index in the foreign country increases the demand for home exports, and, with the appreciation of the foreign currency, we see an increase in the home country's exports.

Because potential entrants optimally set their prices upon entry, their prices are lower than

Figure 3: Impulse responses to a positive productivity shock in the home country



Notes: Impulse responses to a 1 percent positive productivity shock in the home country. The persistence of the shock is 0.906 as in Backus, Kehoe and Kydland (1992), and there is no exogenous spillover of the shock to the foreign productivity process.

the average export price of incumbent exporters facing price rigidities. As a result, the potential market share of new entrants increases relative to that of an average incumbent exporter. At the same time, the lower domestic inflation leads the monetary authority to lower the interest rate, which contributes to lowering the borrowing costs for exporters to finance export costs. The increased price competitiveness of home exports, the real depreciation of the home currency, and the lower home interest rate together increase the value of exporting, thereby encouraging export participation.[5]

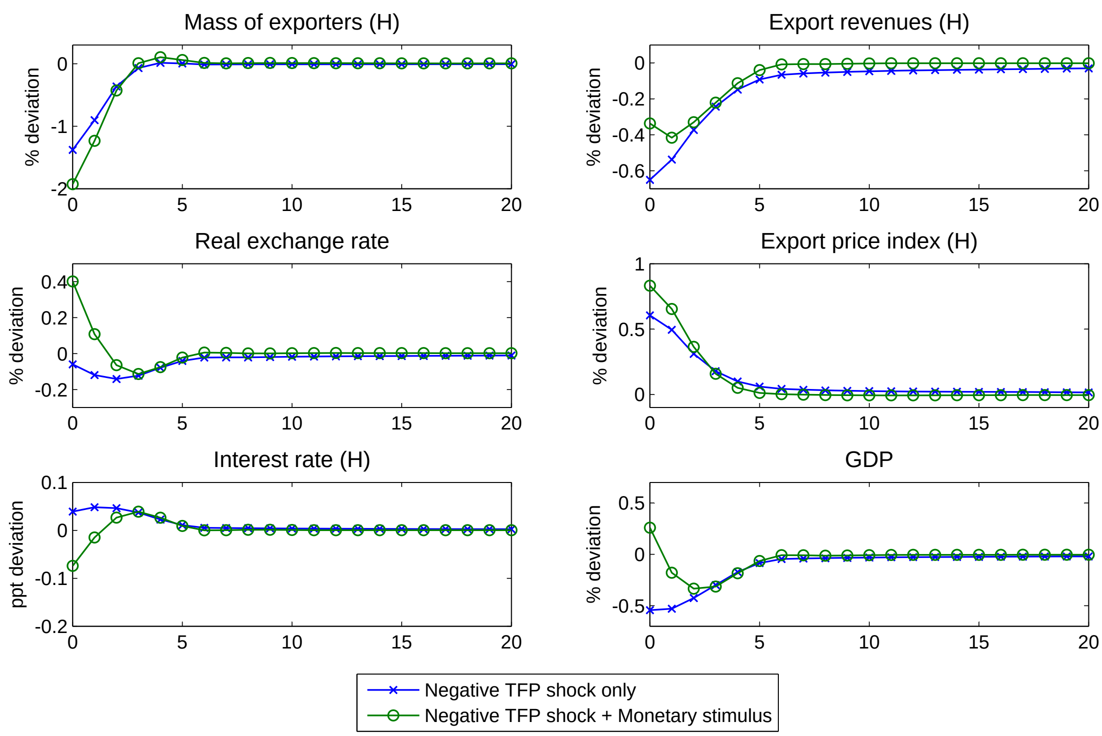
The procyclical responses of the extensive margin to productivity shocks and its countercyclical responses to monetary policy shocks that we saw in section 5.1 offer an important implication for the cyclicality of exporter dynamics. Existing studies have reported that firm dynamics within the *domestic* market are procyclical (see, for example, Bergin and Corsetti, 2008); however, studies on international trade reveal that exporter dynamics in the export market do not necessarily comove with aggregate output. For example, Naknoi (2015) reports that for a median country in her sample of 99 countries, the extensive margin of exports to the United States is almost uncorrelated with output of the exporters' origin country.[6] Our findings suggest that monetary policy shocks may be a contributing factor for the lack of procyclicality in the extensive margin of exports over business cycles.

Our results also have an interesting implication for the effects of monetary stimulus on the extensive margin of trade in the face of an economic downturn. As we saw in figure 1, an expansionary monetary policy can lead to increased real exports, but it also results in a contraction of export participation because of the rising costs of production. This implies that an expansionary monetary policy shock designed to counteract an economic downturn (due to a negative productivity shock) may not lead to an increased participation of domestic firms in exporting. Such scenario is presented in figure 4, which shows the dynamic responses of our model economy to a negative home productivity shock and a simultaneous expansionary monetary policy shock in the home country. The productivity shock is -1 percent with persistence of 0.5, and the monetary policy shock is -0.2 percent with the persistence of 0.12. We see that, while the expansionary monetary policy helps to dampen the fall in export revenues, it amplifies the fall in the number of exporters as the inflationary effects of the shock raise production costs and erodes the value of exporting.

[5] In figure 3, we see that the mass of exporters changes immediately following the shock. This is in contrast to the hump-shaped response of the extensive margin to a productivity shock in a flexible-price model of Alessandria and Choi (2007). One may wonder that such a sharp fall in the mass of exporters is driven by incumbent exporters circumventing price rigidities by exiting the export market and then re-entering next period with an optimal price (since entrant exporters are able to optimize their prices). We tested this possibility with a version of our model in which prices are adjusted with probability one within two periods, thus eliminating the benefits of strategic re-entry. We find that this model still exhibits an immediate peak response of the extensive margin to productivity shocks, ruling out the possibility of strategic re-entry as the reason for the absence of hump-shaped responses of the mass of exporters in our model. We thank George Alessandria for the suggestion.

[6] Alessandria and Choi (2008) also report that the correlation between the number of exporters and output is -0.35 while that for the number of domestic establishments and output is 0.28 for the United States over the period between 1975 and 2006.

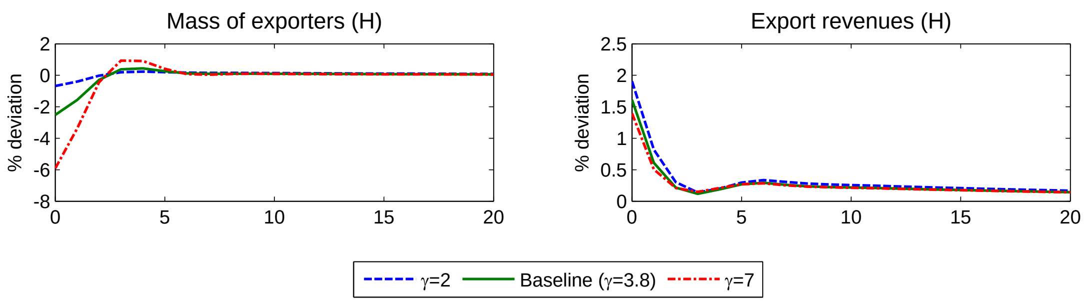
Figure 4: Impulse responses to a negative home productivity shock and a simultaneous expansionary monetary policy in the home country



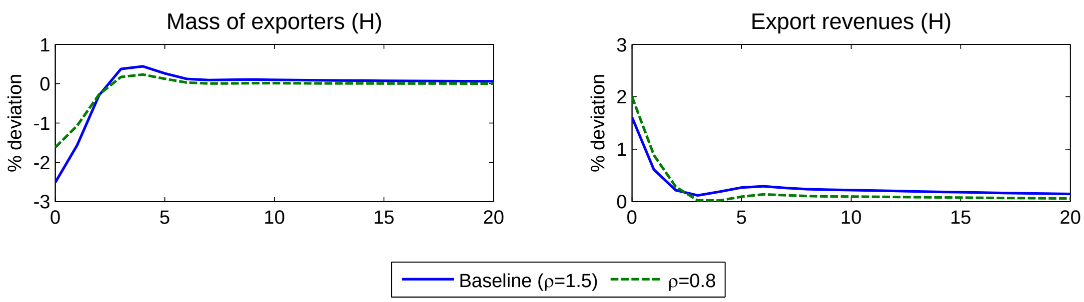
Notes: Blue lines: Impulse responses to a 1 percent negative productivity shock in the home country with a persistence of 0.5. Green lines: Impulse responses to a 1 percent negative productivity shock in the home country with a persistence of 0.5 and a simultaneous expansionary monetary policy shock in the home country of the size 0.2 percent with persistence of 0.12.

Figure 5: Impulse responses to an expansionary monetary policy shock under various elasticity levels for γ and ρ

(a) Varying γ



(b) Varying ρ



Notes: Panel (a): Impulse responses to a 1 percent expansionary monetary policy shock in the home country, under different values of the elasticity of substitution, γ. The persistence of the shock is 0.12, with no exogenous spillover of the shock to the foreign monetary policy. Panel (b): Impulse responses to the same 1 percent expansionary monetary policy shock in the home country, from our baseline model and an otherwise identical model with a lower Armington elasticity ($\rho = 0.8$).

5.3 The role of the elasticity of substitution

In figures 1 and 2, we saw that firms' export participation in our model is highly sensitive to their prices relative to other exporters and the price level in the destination economy. The responsiveness of trade to changes in prices, at least quantitatively, depends on the elasticity of substitution between different good varieties. There are two types of elasticity of substitution in our model: the elasticity of substitution between goods produced within the same country γ; and the elasticity of substitution between goods produced in different countries ρ (Armington elasticity). In this subsection, we examine how various degrees of each elasticity affect export decisions.[7]

[7]When $n_z > 1$ as in our baseline calibration, export probabilities of some firm types reach 0 (1) as we increase (decrease) γ or ρ, in which case the model cannot be solved using the linear method we employ. Therefore, in order to ensure that an interior fraction of each firm type exports in any given period, we consider a special case with $n_z = 1$ for the analysis in this subsection.

We first vary the elasticity of substitution between goods produced in the same country γ, which is set to 3.8 in our baseline calibration. In figure 5a, we see that the responsiveness of the extensive margin of trade is increasing in this elasticity of substitution. Other things being equal, a higher elasticity implies that demand falls more for a given increase in the price of an exported good. Therefore, in the presence of price rigidities, potential and incumbent exporters with prices that are higher than the average export price face a reduced potential export market share and hence export profitability, and we see stronger selection effects among exporters as the elasticity of substitution increases. Qualitatively, however, lowering the elasticity of substitution does not increase export participation in response to the monetary policy shock. The initial response of the extensive margin of trade is still negative (-0.7 percent at the impact of the shock) when the elasticity is lowered to 2, which implies a markup of 100 percent.

We next examine how the Armington elasticity ρ affects the dynamic responses of the extensive margin of trade. There is much debate regarding the estimates of this elasticity, and various values have been used in the literature on international business cycles.[8] In our baseline calibration, it is set to 1.5, implying that domestic and foreign goods are substitutes. We compared our baseline results with those from an otherwise identical model with $\rho = 0.8$, where domestic and foreign goods are now complements. In figure 5b, we see that, similar to the case for γ above, the magnitude of the fall in the extensive margin of trade is increasing in the value of the Armington elasticity, but qualitatively, the negative response remains. With a lower Armington elasticity, total foreign demand for home exports becomes less elastic to the deviation of the home export price relative to the foreign CPI, and firms' export profitability is less affected by price increases. As a result, we see a smaller fall along the extensive margin of trade.

5.4 Alternative Taylor-rule specifications and exporter dynamics

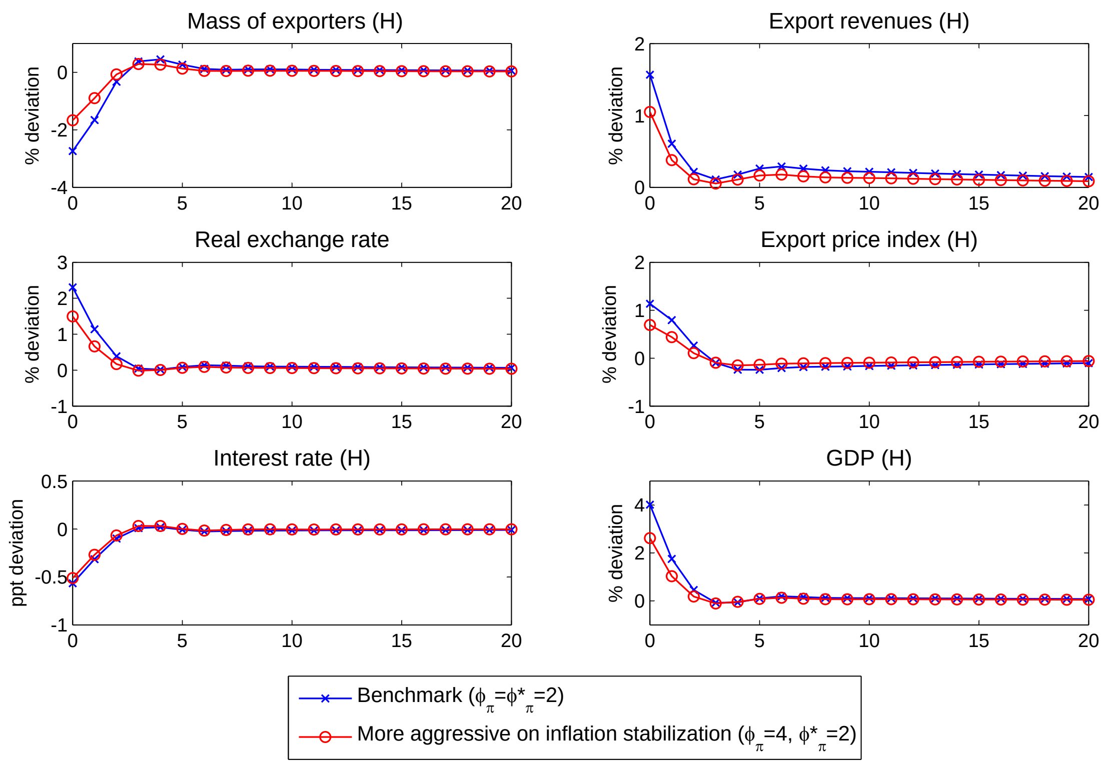
5.4.1 Inflation stabilization

Our results above suggest that inflationary effects of an expansionary monetary policy shock undermine the competitiveness of some exporters, discouraging their participation in international trade, despite the currency depreciation and the lower interest rate. It has been shown in the monetary policy literature that the monetary authority that is systematically more aggressive toward stabilizing inflation is able to better anchor inflation expectations. In this subsection, we examine the effects of monetary policy stance toward inflation stabilization on the dynamics of the extensive margin of trade.

Figure 6 compares the impulse responses of our model economy with an expansionary monetary policy shock in the benchmark calibration (ϕ_π=2 in equation (12)) and in an otherwise identical model wherein the monetary authority in the home country is more aggressive toward inflation fluctuations (ϕ_π=4). As expected, with a higher weight on inflation in the policy reaction

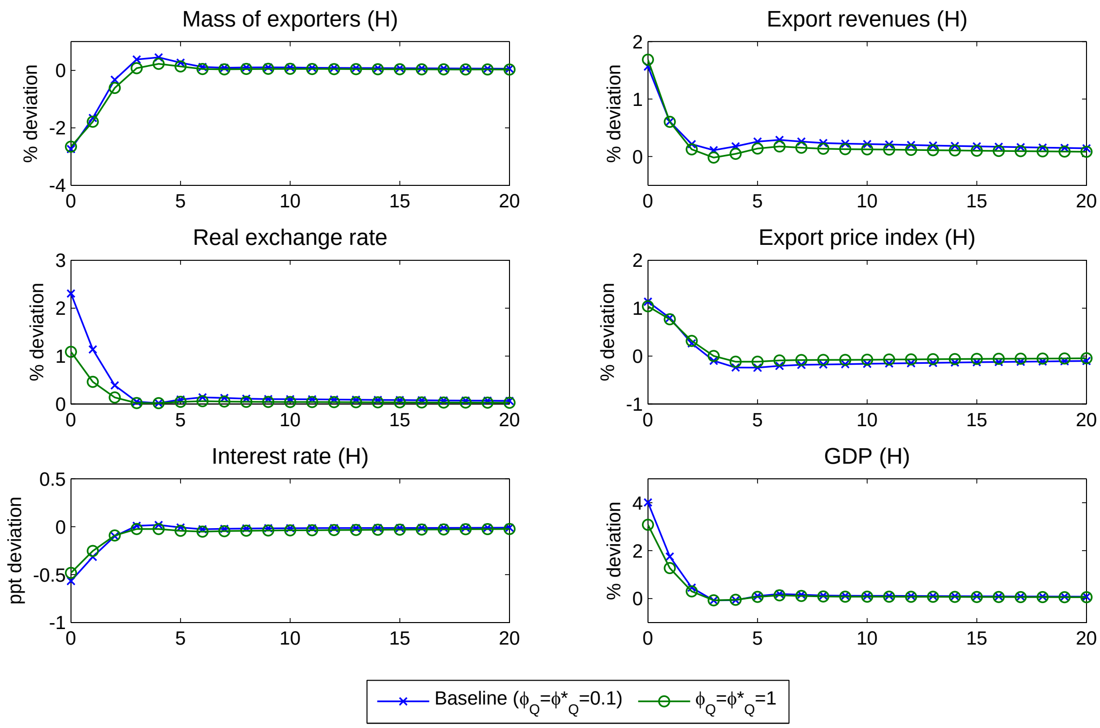
[8] See, for example, Backus, Kehoe and Kydland (1994), Heathcote and Perri (2002) and Ruhl (2008).

Figure 6: Impulse responses to a home expansionary monetary policy shock under different monetary policy responsiveness to inflation



Notes: Impulse responses to an expansionary monetary policy shock in the home country, from our baseline model and an otherwise identical model wherein the monetary authority in the home country is systematically more aggressive toward controlling inflation. The benchmark responses are the same as those in figure 1. The alternative model assumes that the Taylor rule coefficient on inflation ϕ_π is 4 for the home country.

Figure 7: Impulse responses to an expansionary monetary policy shock in the home country under varying policy responsiveness to exchange rate movements



Notes: Impulse responses to an expansionary monetary policy shock in the home country, from our baseline model and an otherwise identical model wherein the monetary authority in both countries is systematically more responsive to real exchange rate movements. The benchmark responses are the same as those in figure 1. The alternative model assumes that the Taylor rule coefficient on the real exchange rate is 1 in both countries ($\phi_Q = \phi_Q^* = 1$).

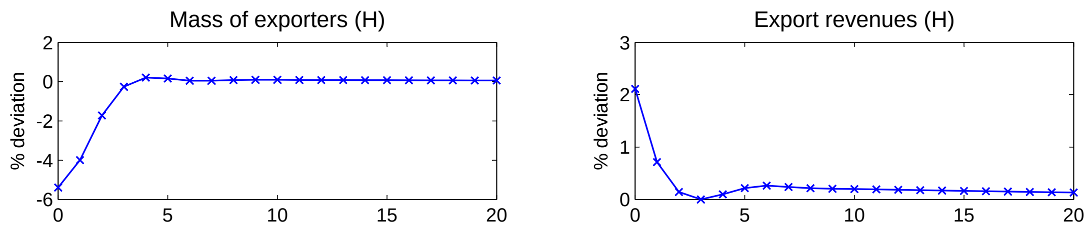
function, the expansion in the home country is moderated, and the real exchange rate depreciates by less. This weaker inflationary pressure in the home country alleviates the loss of competitiveness for home firms in the export market, and the fall in the extensive margin of trade is dampened.[9]

5.4.2 Policy responsiveness to exchange rate movements

In an open-economy environment, a country's external position may be a concern for monetary policy-makers, and the monetary authority may respond to fluctuations in the exchange rate of its currency, in addition to its inflation stabilization objective. In this subsection, we consider an alternative Taylor-rule specification in which the monetary authority in both countries places a sizable weight on exchange rate movements in their respective policy reaction function.

[9]We find that making the policy function in the foreign country also sensitive to inflation ($\phi_\pi = \phi_\pi^* = 4$) does not alter the dynamic responses of the export-related variables shown in figure 6 in any significant way. The figure is available upon request

Figure 8: Impulse responses to an expansionary monetary policy shock in the home country under producer currency pricing



Notes: Impulse responses to an expansionary monetary policy shock in the home country from an otherwise identical model with producer currency pricing. The size and persistence of the shock are identical to those in figure 1.

In figure 7, we see that making the policy reaction function in both countries more responsive to fluctuations in the real exchange rate has negligible effects on the extensive margin of trade in response to an expansionary monetary policy shock in the home country. In this case, in response to pressure for appreciation of the foreign currency due to the relative increase in home consumption, the foreign monetary authority responds by lowering its interest rate. This brings expansionary effects on foreign GDP and consumption, and foreign demand for home exports expands. This increase in foreign demand, however, is offset by the attenuated appreciation of the foreign currency. Further, we also see that the dynamic path of the export price index for the home country is little affected by the alternative Taylor-rule specifications. This implies negligible changes in the competitiveness of home exporters relative to the baseline case, and the response of exporter participation is little affected by the monetary authority's stance to exchange rate fluctuations.

5.5 Comparison to the producer-currency-pricing setting

In our baseline model, we assumed that firms set the prices of their exports in the currency of the destination economy (local-currency pricing). In a recent study, Cooke (2014) shows that in response to a monetary expansion, the extensive margin of trade expands under local currency setting, while it declines under producer currency pricing. We examined whether the extensive margin responses are affected by the assumption of the currency in which exports are priced in our model framework.

In figure 8, we find that, also under producer currency pricing, the extensive margin of trade falls in response to an expansionary monetary policy shock. As in the case of local currency pricing, a rise in the marginal cost of production dominates the effects of the foreign currency appreciation, and the resulting rise in export prices reduces the demand for exports of some exporters. This is in contrast to the implications of Cooke's model (2014), where expenditure switching due to exchange rate movements leads to changes in demand at upstream production, which in turn drives demand for intermediate goods at the downstream production level where exporter entry and exit occur.

5.6 Suggestive evidence from U.S. export data

We provide suggestive empirical evidence supporting our theoretical results that the extensive margin of exports declines in response to an expansionary monetary policy shock. Figure 9 shows the VAR responses of the extensive margin of U.S. exports and the U.S. dollar exchange rate index to a one standard deviation expansionary monetary policy shock. Following Armenter and Koren (2014), we measure the extensive margin of exports using monthly data on the number of shipments collected through customs forms for each export shipment from the U.S. Census Bureau. The sample period covers from January 2002 to November 2017.[10] The ordering of the variables in our VAR specification is [U.S. monetary policy rate, foreign industrial production index, the extensive margin of U.S. exports, the U.S. exchange rate]. The foreign industrial production index is a trade weighted average of industrial production indexes for 10 major trade partners for the United States, and is included to account for changes in foreign demand for U.S. exports. Based on residual tests, we include four lags in the VAR.

We see that an expansionary monetary policy shock leads to a depreciation of the U.S. dollar in the short run, and the response is statistically significant during the peak responses (right panel). With the depreciation of the currency, we see a delayed but persistent negative response in the extensive margin of U.S. exports (left panel), consistent with our theoretical results. Since our data are at the monthly frequency, the delayed response in the extensive margin is likely to be due to the contractual nature of international trade. In the short- to medium-run, the extensive margin contracts statistically significantly for about 10 months following the shock.[11]

6 Conclusions

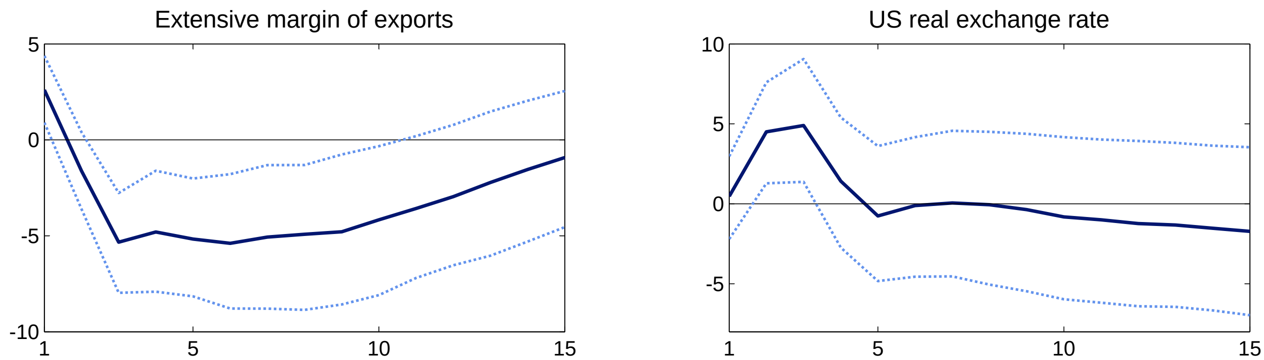
In this paper, we examined the response of the extensive margin of trade to monetary policy shocks and the role of various aggregate factors affecting individual firms' decision to participate in international trade. We developed a two-country dynamic stochastic general equilibrium model wherein heterogeneous firms make state-contingent, dynamic decisions on whether and how much to export and prices are staggered across firms and time.

We showed that while a lower interest rate and a currency depreciation associated with an expansionary monetary policy both contribute to increasing the profitability of export participation, inflationary effects of the policy stimulus weaken the competitiveness of exporters and lead to

[10] Detailed descriptions of the data are in Appendix A.

[11] We also estimated a two-stage VAR specification, in which we first regressed the U.S. policy rate on domestic inflation and output, and then estimated the response of the extensive margin of trade to the policy rates residuals obtained from the first-stage regression. We chose to estimate such a two-stage regression instead of including inflation and output directly in order to keep the number of variables in the final VAR specification at a minimum. The results are similar to our baseline specification. The figures are available upon request.

Figure 9: VAR responses of the extensive margin to an expansionary monetary policy shock



Notes: VAR responses of the extensive margin of exports and the U.S. real exchange rate to a 1 standard deviation, expansionary monetary policy shock in the United States. The dotted lines indicate the 68 percent confidence intervals.

a contraction in firms' export participation. This is in contrast to an implication of a productivity shock that generates an expansion along the extensive margin of trade while depreciating the currency. Qualitatively, our findings are robust to the assumed degrees of the elasticity of substitution between goods and whether exported goods are priced in the destination currency or the producers' currency. Further, our results lend support to empirical findings that the extensive margin of trade is not necessarily procyclical, unlike the firm dynamics (or product creation) within the domestic market, and we provided suggestive empirical evidence using VAR that the extensive margin of trade responds negatively to an expansionary monetary policy shock.

The current model framework can be extended in a number of ways to address some of the recent developments in the trade literature. One important direction may be an analysis of the implication of global value chains for firms' export participation. For example, recent empirical studies have reported that international input-output linkages contribute substantially to cross-country comovement of producer price inflation (Auer, Levchenko and Saure, 2017; Auer, Borio and Filardo, 2017). This finding implies that, in our framework, domestic monetary policy shocks may have less impact on export participation by firms in its own country, but may have stronger effects on exporter dynamics in trade partners' economies. Such an extension would allow for a new direction for the analysis of monetary policy transmission in open economies.

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Appendix

A Data descriptions

The extensive margin of U.S. exports is measured by the count of U.S. export shipments from the U.S. Census Bureau, which is publicly available from January 2002 onward. Our sample period covers the period from January 2002 to November 2017. Since this sample period includes the period when the Federal Reserve used quantitative easing programs, we use Leo Krippner's monthly average Shadow Short Rate (SSR) estimates for the period between January 2002 and November 2017. Leo Krippner's series, available at www.rbnz.govt.nz/research-and-publications/research-programme/additional-research/measures-of-the-stance-of-united-states-monetary-policy, contains three different summary measures of the the United States monetary policy stance (Krippner, 2013). We focus our attention on SSR, which approximates an effective federal funds rate adjusted by the monetary policy stimulus implied by the Federal Reserve Bank's balance sheet position. The foreign industrial production index is an export-weighted industrial production index of 10 major trade partners for the United States that include Canada, Japan, South Korea, Mexico, Turkey, UK, Brazil, India, Russia and EU19, reported by OECD. The exchange rate is a geometric U.S. export-weighted index of the following 16 bilateral exchange rates against the U.S. dollar: Argentine peso, Australian dollar, Brazilian real, Canadian dollar, Chinese renminbi, Indian rupee, Indonesian rupiah, Japanese yen, Mexican peso, Russian ruble, Saudi riyal, South African rand, South Korean won, Turkish lira, British pound and the Euro. These 16 currencies are representative of the G20 economies other than the United States. All series are seasonally adjusted and detrended using a linear trend.

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