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# Capital, Finance, and Trade Collapse\*

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## Abstract

This paper proposes a model of international trade with capital accumulation and financial intermediation. This is achieved by embedding the Melitz (2003) model into an incomplete-markets neoclassical framework with an endogenous credit market. The model preserves the analytical tractability of the original Melitz model despite non-trivial distribution of firms' net worth and capital stocks. We use the model to examine the differential effects of financial and non-financial shocks on aggregate output and international trade flows. The model predicts that trade volume declines far more sharply and significantly than that of output (with an elasticity larger than 3) under financial shocks than under non-financial shocks. The prediction is consistent with the stylized fact that most countries that experienced major financial crises had significantly larger and sharper contraction in exports than aggregate output (as is also true during the recent financial crisis). In the long run, however, a deeper financial market is a great source of "comparative advantage"—it raises not only the level of aggregate productivity but also the ratio of trade volume to domestic output.

*Keywords:* Credit Crunch, Financial Crisis, Trade Collapse, Trade Finance, Borrowing Constraints, Heterogeneous Firms.

*JEL codes:* E22, E32, E44, F00, F10, F11, F41..

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# 1 Introduction

It is a well-known challenge to incorporate capital accumulation and financial intermediation into the New New Trade Theory. The challenge lies in how to track firms' distribution of debts and capital stocks when computing their exporting and borrowing decisions under fixed exporting costs. Without explicitly modeling capital accumulation and credit arrangement at the firm level, however, the power of the New New Trade Theory would be significantly limited, not only in terms of realism (because international trade involves foreign direct investment and relies heavily on trade finance) but also in terms of theoretical potential (because international trade theory would otherwise remain isolated from genuine dynamic analysis and consequently would be unable to benefit from the rapid development in the fields of economic growth, business cycles, and macro- and international finance). Perhaps even more importantly, a trade model without capital means that the model cannot be used to study one of the most fundamental forces of international trade—the Heckscher-Ohlin mechanism of relative factor intensities—in a dynamic setting.<sup>1</sup>

One case in point relates to the global imbalances in international trade. Standard trade models cannot explain why trade can be imbalanced across countries for a prolonged period. In particular, they cannot explain why developing countries (such as China) with comparative advantages in producing future goods have been running trade surpluses while industrial nations (such as the United States) with comparative advantages in producing present goods are running trade deficits (see Deardorff, 2010). To explain the global trade-imbalance puzzle, asset trading and capital flows must be incorporated into trade models in addition to comparative advantages in productivity and labor costs.<sup>2</sup>

Another case in point is the recent financial crisis. It is now well documented that one of the most striking aspects of this financial crisis is the subsequent collapse in world trade, especially among developed countries with deeper financial markets. This decline in trade is so severe that it is now referred to as the Great Trade Collapse puzzle by the existing literature. For example, the average cross-country decline in total trade volume between

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<sup>1</sup>The original Melitz (2003) model has firm dynamics and a semi capital stock at the aggregate level (proportional to the number of firms) due to firm entry and exit. However, this setup captures only the extensive margin of the aggregate capital stock without an intensive margin. Thus the model cannot be used to study firms' capital and investment decisions as in neoclassical business cycle models. Consequently, the distribution of firms' capital stocks and cross-country capital flows cannot be analyzed with the original Melitzian framework.

<sup>2</sup>See, e.g., Wen (2011).

2008 and 2009 is 17% for the G7 countries (Figure 1). In addition, relative to the magnitude of aggregate output decline, the drop in trade volume is 3.4 times that of output, significantly larger than that in the 1983-2007 Great Moderation period (historically this figure was only 2.8 on average). However, a severe trade collapse during a financial crisis is not a new phenomenon. Many countries that had financial crises also experienced sharp contraction in trade volume relative to output. To quote Amiti and Weinstein (2011, p.1), "[A] striking feature of many financial crises is the collapse of exports relative to output".

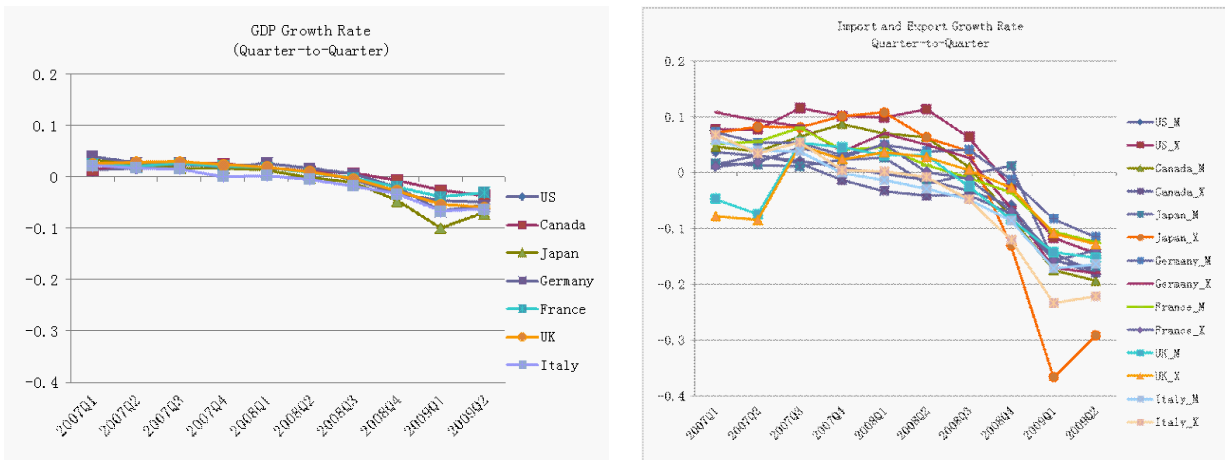


Figure 1. Declines in GDP (left) and Trade (right).

Why would a financial crisis trigger a disproportionately larger decline in trade volume relative to gross domestic product (GDP)? It would be difficult to rely solely on non-financial shocks (such as aggregate productivity or aggregate demand shocks) to explain the Great Trade Collapse because changes in aggregate productivity and demand during the crisis period are endogenous—they are themselves the consequences of the financial crisis, not the root of the crisis. But to predict the effects of financial shocks (e.g., a credit crunch) on trade through aggregate demand, we need a model that can characterize financial intermediation (credit arrangement) and the distribution of exporters' creditworthiness or debt positions, among other things.

This paper proposes a model of international trade with capital accumulation and financial intermediation by embedding the Melitz (2003) model into an incomplete-markets Ramsey framework. Endogenous credit arrangements among heterogeneous firms exist, so financial assets can be traded and firms can use capital as collateral to engage in borrowing under limited contract enforceability. Because of the additional operational costs involved

in exports (e.g., due to the longer distance of shipping or time lags associated with international trade), only high-productivity firms opt to export and such firms will have a higher demand for working capital and outside credit to finance their activities than non-exporters. Since financial markets facilitate the flow of capital to where it is needed, this asymmetry in credit demand between exporters and non-exporters implies that financial shocks hindering the flow of capital have an asymmetric impact on trade volume and domestic sales. The model proposed in this paper preserves the analytical tractability of the original Melitz model with closed-form solutions for firms' export and borrowing decisions despite a well-defined distribution of firm wealth (such as capital stock) and a non-trivial form of borrowing constraints.<sup>3</sup>

A calibrated version of the model is applied to examine the effects of financial and non-financial shocks on aggregate trade flows; the effects are found to be highly asymmetric. Under financial shocks that resemble a credit crunch, the decline in trade volume can be several times or an order of magnitude larger than that in GDP. But under non-financial shocks (such as aggregate productivity shocks), the decline in trade volume is comparable to that of GDP (as predicted by standard representative-firm models). These predictions are consistent with historical experiences. For example, Ronci (2004) documents that in many countries that had financial crisis trade volume contracted far more sharply and significantly than GDP. Also, using a measure of an international-trade wedge, Levchenko, Lewis, and Tesar (2010a) show that the overall trade wedge during the recent financial crisis reached  $-40\%$  whereas the mean value of the wedge was only  $-1.6\%$  in the Great Moderation period since 1983. They thus conclude that the recent trade collapse does represent a puzzle from the perspective of standard neoclassical business cycle models.

Another immediate implication of our model is that deeper financial markets enhance aggregate productivity and international trade in the long run. Consequently, both GDP level and the trade volume-to-GDP ratio rise with financial development in our model. This is also consistent with the empirical facts documented by the existing literature (e.g., see Manova, 2011).

The intuition behind our results is simple. Exporters are more productive than non-exporters. Hence, during a normal time when the financial market is functioning properly, capital will be channeled from low productivity firms (in the domestic-goods sector) to high-productivity firms (in the export sector). This upward capital flow improves the efficiency of

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<sup>3</sup>We do not consider firm entry in this paper. However, introducing firm entry into our model is relatively straightforward.

resource allocation and raises the level of aggregate productivity and output. However, the heavy reliance on external finance also makes exporters more vulnerable to financial shocks. During a financial crisis (due to either higher default risk or lowered borrowing limit), the upward flow of financial capital is hindered. Consequently, capital withdraws from the export sector and retreats to the domestic sector, causing a disproportionately larger drop in trade volume relative to aggregate income.

Our paper relates to a large body of literatures on trade, finance, and financial crisis. The links between financial conditions and international trade have been studied empirically by many people. For example, Manova (2008) investigates the impact of equity market liberalizations on the export behaviors of 91 countries in the 1980-1997 period and finds that financially vulnerable sectors increase exports disproportionately more as a response to equity market liberalizations and the effects of liberalizations are more pronounced in economies with initially less active stock markets. Beck (2002) shows that financial development presents a large causal impact on the level of exports of manufactured good. Beck (2003) shows that countries with better developed financial system have higher export shares in GDP and that industries that use more external finance have larger trade balances. Chor and Manova (2011) show that credit conditions have an important effect on trade. Their empirical findings based on monthly U.S. imports data suggest that countries experiencing higher interbank rates—and thus worse credit market conditions—tend to export less to the U.S. during the peak of the crisis. Amiti and Weinstein (2011) use a unique dataset, covering the Japanese financial crisis from 1990 through 2010, to demonstrate that the health of banks providing external finance has a much larger effect on exports than on domestic sales. Raddatz (2008) shows there is greater comovement between sectors that have stronger trade credit links. Iacovone and Zavacka (2009) demonstrate that in countries experiencing banking crises exports fell systematically more in financially dependent industries.<sup>4</sup>

Another segment of the existing literature relies on non-financial shocks to explain the Great Trade Collapse. For example, Alessandria, Kaboski, and Midrigan (2010) argue that aggregate productivity shocks can explain the trade collapse when dynamic inventory adjustment is taken into account. Eaton et al. (2011) argue that demand shocks are the main driving force behind the trade collapse while other shocks, such as current account shocks and trade friction shocks have played only an insignificant role. Chen (2011) examines intermediate-goods trade under demand shocks and show that demand shocks can generate

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<sup>4</sup>See Chen, Contessi, and Nicola (2012) for a survey on the recent literature on the relationship between international trade and access to finance.

large responses in trade volume. Bems, Johnson, and Yi (2010) argues that vertical linkages amplify demand disturbances on trade volume in an input-output framework. Their defense for the importance of demand shocks in the Great Trade Collapse is that financial intermediation is severely affected during the crisis, reducing the economy's efficiency in transforming inputs into outputs and leading to reductions in overall productivity and demand.

These important contributions improve our understanding of the Great Trade Collapse. But a deeper question regarding the non-financial shock theory is why aggregate demand (or supply) changed simultaneously in different countries during the recent financial crisis. What was coordinating these country-specific demand (supply) shocks? Another challenge to the non-financial shock theories is explaining why this recent recession is more severe than the others in the Great Moderation period—and particularly why the recent collapse in trade volume is far larger than that in GDP compared with historical recessions. It appears that changes in demand or productivity in 2009 are the result of the financial crisis rather than the fundamental cause of the crisis (as illustrated by our model). So, as Bems, Johnson, and Yi (2010, p.32) state, "[A] clearly preferred framework would be one that...digs deeper into the sources of shocks that drive the joint behavior of demand, output and trade," and "an even deeper methodology is one that marries a financial sector, as well as trade structure...to the framework."

Our approach to financial intermediation and credit arrangement is related to the work of Wang and Wen (2009). In their model, firms accumulate capital but face idiosyncratic uncertainty in the rate of returns to fixed investment. Firms rely on internal cash flows and external credits to finance fixed investment. When firms can perfectly share the risks in investment through a perfectly functioning financial market, only the most productive firm would borrow and invest while the other firms opt to lend and remain inactive in investing. However, due to incomplete financial markets and limited contract enforcement, firms are borrowing constrained and the borrowing limit hinges on a firm's collateral (capital stock) a la Kiyotaki and Moore (1997). As a consequence, the economy not only has a relatively lower dispersion of firms' investment activities but is also more vulnerable to aggregate (non-financial) shocks. Thus, their model predicts that financial development can reduce output volatility at the aggregate level but raise the lumpiness of firm-level investment, which is consistent with the well-documented empirical pattern of a negative correlation between financial development and aggregate volatility (e.g., Easterly, Islam, and Stiglitz, 2001) and the rising volatility and dispersion of firm-level activities in the recent decades.<sup>5</sup>

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<sup>5</sup>Empirical studies have shown that for publicly traded firms, their volatility has been increasing over the

Our model differs from that of Wang and Wen (2009) in several aspects. First, firms in our model face idiosyncratic productivity shocks a la Melitz (2003) whereas Wang and Wen (2009) assume idiosyncratic shocks to the rate of investment returns. Second, we allow the existence of a capital rental market, whereas Wang and Wen let firms accumulate capital through self-investment. This change in assumption for the capital market is crucial for us to obtain closed-form firm-level decision rules in a Melitzian model. Last but not least, we have an open-economy model with exporters and non-exporters while their model is a closed-economy model.<sup>6</sup>

The rest of the paper is organized as follows. Section 2 describes the model and solves firms' decision rules in closed form. Section 3 studies the aggregate implications of the model under financial and non-financial shocks, as well as long-run implications of financial development on international trade. Section 4 concludes the paper with remarks for future studies.

## 2 The Model

### 2.1 The General Environment

We consider an infinite-horizon, small open-economy model. But in contrast to standard small open-economy models, the domestic interest rate is endogenously determined in a credit market in our model rather than exogenously fixed. There is a representative final-goods producer that uses intermediate goods to produce final output. The production technology is given by

$$Y_t = [\varphi(M_{ht})^{\frac{\mu-1}{\mu}} + (1 - \varphi)(M_{ft})^{\frac{\mu-1}{\mu}}]^{\frac{\mu}{\mu-1}}, \quad (1)$$

where  $M_{ht}$  denotes intermediate goods produced domestically and  $M_{ft}$  denotes imported intermediate goods. The elasticity of substitution between the two types of intermediate goods is given by the parameter  $\mu \geq 0$ .

There are a continuum of intermediate-goods firms indexed by  $i \in [0, 1]$ . They produce intermediate goods by combining capital and labor according to the productivity function:

$$y_{it} = (A_t z_{it} k_{it})^\alpha l_{it}^{1-\alpha}, \quad (2)$$

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postwar period (see the references in Wang and Wen, 2009).

<sup>6</sup>To simplify analysis, we assume a small open-economy in this paper. Extending our model to a multi-country framework is relatively straightforward without losing the tractability of our basic model. In fact, we expect our results to be further enhanced because collapses in exports and imports can be reinforced through international-demand linkages.



where  $A_t$  denotes aggregate productivity shock in period  $t$ , which is common for all intermediate-goods firms; and  $z_{it}$  denotes a firm-specific productivity shock, which is i.i.d across firms and time with distribution  $\Phi(z) = \Pr[z_i \leq z]$ . Intermediate-goods firms can choose to sell their output either in the domestic market or abroad. A firm must pay a fixed cost  $f_t$  to export (as in Melitz, 2003; and Ghironi and Melitz, 2005).<sup>7</sup>

Heterogeneous productivity shocks imply the need for risk-sharing across firms. We assume there exists a financial (bond) market through which firms can engage in risk-sharing via borrowing and lending across heterogeneous firms (as in Wang and Wen, 2009). The financial market can improve aggregate productive efficiency by allowing high-productivity firms to produce more output through borrowing working capital while letting low-productivity firms to produce less or remain inactive but gain through savings. For example, a firm with high productivity in period  $t$  may opt to enter the foreign market and borrow from other firms to cover its additional operational costs, while a firm with low productivity may opt to sell locally or be inactive and become a lender by investing in bonds issued by high-productivity firms. However, because of limited contract enforcement, firms are borrowing constrained by their net worth. Consequently, a financial crisis that reduces the borrowing limit can severely depress the economy by hindering financial capital to flow from low- to high-productivity firms. Because exporters rely more heavily on credit finance than non-exporters, the trade volume will incur a disproportionately larger hit than the average output across all firms.

A continuum of identical households trade the equity shares of intermediate-goods firms. In each period, an intermediate-goods firm first pays its dividends to equity holders before the idiosyncratic productivity shock is realized; it then decides whether to serve the foreign market or domestic market and how much to borrow and save. To export, a firm must pay a fixed cost  $f_t$  in terms of the final good in the home country.

## 2.2 The Household's Problem

A representative household in the home country has a fixed endowment of time. The household chooses consumption  $C_t$ , hours worked  $H_t$ , and equity holdings for firm  $i$ 's share  $q_{it}$  ( $i \in [0, 1]$ ) to maximize lifetime utility:

$$\max \sum_{t=0}^{\infty} \beta^t \left[ \log C_t - \frac{H_t^{1+\gamma}}{1+\gamma} \right] \quad (3)$$

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<sup>7</sup>We do not assume that exporters need outside credit to finance the fixed costs (see, e.g., Chaney, 2005). This assumption would enhance our results.

subject to the budget constraint,

$$P_t C_t + \int q_{it+1}(v_{it} - d_{it})di = w_t H_t + \int q_{it} v_{it} di, \quad (4)$$

where  $P_t$  is the final good's price,  $d_{it}$  is the dividend payment from firm  $i$ , and  $v_{it}$  is firm  $i$ 's value before dividends. This setup is similar to that in Wang and Wen (2009).

Denoting  $\Lambda_t$  as the Lagrangian multiplier of the household budget constraint, the first-order conditions for  $\{C_t, H_t, q_{it+1}\}$  are given, respectively, by

$$P_t \Lambda_t = \frac{1}{C_t} \quad (5)$$

$$\Lambda_t w_t = H_t^\gamma \quad (6)$$

$$v_{it} = d_{it} + \beta E_t \frac{\Lambda_{t+1}}{\Lambda_t} v_{it+1} \quad (7)$$

The last equation implies that firm  $i$ 's value is given by the present value of future dividends:

$$v_{it} = E_t \sum_{s=0}^{\infty} \beta^s \frac{\Lambda_{t+s}}{\Lambda_t} d_{it+s} \quad (8)$$

### 2.3 The Problem of Final-Goods Firms

Denote the price of domestically produced intermediate goods sold in the domestic market by  $p_{ht}$ , those sold in the foreign market by  $p_{ht}^*$ , and the price of foreign-produced intermediate goods sold in the home country by  $p_{ft}$ . Since this is a small open economy, all firms take  $p_{ht}^*$  and  $p_{ft}$  as exogenously given. The objective function of the representative final-goods firm is to solve

$$\max_{M_{ht}, M_{ft}} P_t Y_t - p_{ht} M_{ht} - p_{ft} M_{ft} \quad (9)$$

subject to equation (1). The demand functions for intermediate inputs are given by

$$\frac{Y_t}{M_{ht}} = \left( \frac{p_{ht}}{P_t} \frac{1}{\varphi} \right)^\mu \quad (10)$$

$$\frac{Y_t}{M_{ft}} = \left( \frac{p_{ft}}{P_t} \frac{1}{1-\varphi} \right)^\mu. \quad (11)$$

The production function is constant return to scale, so the profit of the firm is 0:

$$P_t Y_t = p_{ht} M_{ht} + p_{ft} M_{ft} \quad (12)$$

## 2.4 The Problem of Intermediate-Goods Firms

We assume a competitive capital rental market. Perfectly competitive financial intermediaries (entrepreneurs or investors) take savings from firms, transform the savings into capital, and then rent the capital back to firms. This assumption dramatically simplifies our model in terms of obtaining closed-form solutions.<sup>8</sup>

There is also a financial (bond) market where firms can engage in lending and borrowing by trading bonds. A firm can borrow the amount  $b_t$  at the beginning of period  $t$  in the bond market and pay back the loan at the end of period  $t$  with gross interest rate  $1 + r_t$ . At the end of each period  $t$ , after paying dividends to households and debts to the lenders, a firm's net worth (savings) is denoted by  $s_t$  in terms of final goods, which can be used to finance the next-period capital:

$$k_{t+1} = s_t + b_{t+1}, \quad (13)$$

where  $b_{t+1}$  denotes borrowing in the next period. Notice that we allow  $b_{t+1} < 0$ , implying that a firm can choose to be a lender.

The firm will then enter the next period (say  $t + 1$ ) and draw a productivity shock  $z_{t+1}$  in the beginning of  $t + 1$  before making production decisions. To help finance its capital used in period  $t + 1$ , the firm can borrow the amount  $b_{t+1}$  with the credit constraint,

$$b_{t+1} \leq \theta_{t+1} k_{t+1}, \quad (14)$$

where  $\theta_{t+1} \in (0, 1)$  is an indicator of financial conditions in period  $t + 1$ . Equations (13) and (14) imply

$$b_{t+1} \leq \frac{\theta_{t+1}}{1 - \theta_{t+1}} s_t, \quad (15)$$

where  $\frac{\theta}{1-\theta}$  is the leverage ratio.<sup>9</sup>

Upon the realization of  $z_{t+1}$ , a firm can decide whether to (i) produce and sell in the foreign market, (ii) produce and sell in the domestic market, or (iii) remain inactive and become a lender. After production and sales, the firm pays its debt in the amount  $(1 + r_{t+1}) b_{t+1}$  to the financial intermediary and dividends  $d_{t+1}$  to equity holders, carrying net worth  $s_{t+1}$  (in terms of final goods) to the next period  $t + 2$ , so on and so forth.

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<sup>8</sup>To allow the distribution of exporters and non-exporters to change over time under aggregate shocks, firms in our model draw productivity shocks every period, unlike the Melitz (2003) model.

<sup>9</sup>Notice that we allow firms to use debt as collateral. This is not important for our results, as it simply scales up the borrowing limit by a factor of  $\frac{1}{1-\theta}$ .

Denote  $x_t/P_t$  as the firm's maximum ex post cash flow (measured in final goods) after choosing production and sales and paying its debt  $(1 + r_t)b_t$ , but before paying dividends. More specifically, depending on the firm's production and market status, we have

$$\frac{x_t}{P_t} = \begin{cases} \max \left\{ \frac{p_{ht}^*}{P_t} (A_t z_t k_t)^\alpha l_t^{1-\alpha} - \frac{w_t}{P_t} l_t + (1 - \delta)k_t - (1 + r_t)b_t - f_t \right\} & \text{if exporting} \\ \max \left\{ \frac{p_{ht}}{P_t} (A_t z_t k_t)^\alpha l_t^{1-\alpha} - \frac{w_t}{P_t} l_t + (1 - \delta)k_t - (1 + r_t)b_t \right\} & \text{if not exporting} \\ -(1 + r_t)b_t & \text{if inactive} \end{cases}, \quad (16)$$

where the first line denotes an exporting firm's real cash flow, the second line a domestic firm's real cash flow, and the third line an inactive firm's real cash flow. With these notations, the intermediate-goods firm's saving problem (dividends policy) is to solve

$$\max E_0 \sum_{t=0}^{\infty} \beta^s \frac{\Lambda_t}{\Lambda_0} d_t \quad (17)$$

subject to

$$d_t = x_t - P_t s_t. \quad (18)$$

**Proposition 1** *The decision of  $s_t$  is independent of the history of each firm's cash flow and idiosyncratic shocks,  $\{x_{t-j}, z_{t-j}\}_{j=0}^t$ .*

**Proof.** Notice that (i) only  $x_{t+1}$  depends on  $s_t$  (through  $k_{t+1}$ ) and (ii) only  $z_{t+1}$  can affect  $x_{t+1}$ . The first-order condition for  $s_t$  in the above problem is

$$P_t = \beta \frac{\Lambda_{t+1}}{\Lambda_t} \frac{\partial E_t[x_{t+1}]}{\partial s_t}, \quad (19)$$

where  $P_t$  is the marginal cost of saving and the right-hand side is the expected marginal return to saving. Given that the future marginal product of capital is i.i.d, the expected future return to saving depends only on the distribution of  $z$  and hence is the same for all firms. So this optimal first-order condition ensures that the history of idiosyncratic shocks and cash flows,  $\{z_{t-j}, x_{t-j}\}_{j=0}^t$ , are irrelevant for the choice of  $s_t$  (because maximizing  $x_{t+1}$  is an intra period problem and does not involve any dynamic considerations).<sup>10</sup> ■

<sup>10</sup>This is the consequence of the existence of a rental market.

Hence, in a symmetric equilibrium, all intermediate-goods firms will bring the same amount of savings (net worth)  $s_t$  to the next period.<sup>11</sup> This means that a firm making more profit pays more dividends and a firm making less profit pays proportionately less, and all firms end up with the same net worth  $s_t$  to enter the next period  $t + 1$ . This property greatly simplifies the model as it makes the distribution of firms' savings degenerate. Consequently, the model is analytically tractable despite a well-defined distribution of firms' capital stocks and debts. This is analogous to the trade-imbalance model of Wen (2011), where the objective function for an exporting firm is quasi-linear with the marginal cost of production independent of a firm's individual characteristics.

Next we turn to the intraperiod optimal decisions of a firm in period  $t + 1$ . It is easy to verify that the intraperiod objective of a firm is to maximize its cash flow  $x_{t+1}$  by choosing the capital stock  $k_{t+1}$ , labor demand  $l_{t+1}$ , the level of debt  $b_{t+1}$ , and market status (i.e., whether to be an exporter or not). That is, given the firm's last-period net worth  $s_t$ , the real interest rate  $r_{t+1}$ , the real wage  $\frac{w_{t+1}}{P_{t+1}}$ , and the relative prices  $\left\{ \frac{p_{h,t+1}}{P_{t+1}}, \frac{p_{h,t+1}^*}{P_{t+1}} \right\}$ , the firm solves the following problem after the productivity shock  $z_{t+1}$  is realized:

$$\max_{\{k_{t+1}, l_{t+1}, b_{t+1}\}} x_{t+1} \quad (20)$$

subject to the constraints (13), (14), and (16). Denoting

$$\lambda_t \equiv \frac{1}{1 - \theta_t}, \quad (21)$$

we have the following proposition:

**Proposition 2** Denoting  $\pi_{d,t+1} \equiv \alpha \left( \frac{(1-\alpha)p_{h,t+1}}{w_{t+1}} \right)^{\frac{1-\alpha}{\alpha}}$  and  $\pi_{x,t+1} \equiv \alpha \left( \frac{(1-\alpha)p_{h,t+1}^*}{w_{t+1}} \right)^{\frac{1-\alpha}{\alpha}}$ , the

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<sup>11</sup>In our model, because of constant returns to scale and the linearity of dividends in  $s_t$ , the optimal level of  $s_t$  may be viewed as indeterminate at the firm level (since equation (19) is independent of  $s_t$ ). However, this indeterminacy has no effect on aggregate dynamics because the aggregate savings can be uniquely determined. Moreover, this indeterminacy is just a limiting phenomenon because we can easily resolve the indeterminacy problem by introducing either a production function with diminishing returns to scale or a quadratic adjustment cost function in  $s_t$  into the dividend, which will make equation (19) depend on  $s_t$  and enable us to solve for  $s_t$  uniquely. Clearly, the solution for  $s_t$  will then be the same across firms. In other words, indeterminacy at the firm level is only a limiting case and it does not matter for our results.

optimal cash flow  $x_{t+1}$  and decision rules for  $\{l_{t+1}, k_{t+1}, b_{t+1}\}$  are given, respectively, by

$$\frac{x_{t+1}}{P_{t+1}} = \begin{cases} (1 + r_{t+1})s_t, & \text{if } z_{t+1} \leq \underline{Z}_{t+1}^* \\ (1 + r_{t+1})s_t + \left[ \frac{p_{h,t+1}}{P_{t+1}} A_{t+1} z_{t+1} \pi_{d,t+1} - (r_{t+1} + \delta) \right] \lambda_{t+1} s_t, & \text{if } z_{t+1} \in \left( \underline{Z}_{t+1}^*, \overline{Z}_{t+1}^* \right) \\ (1 + r_{t+1})s_t + \left[ \frac{p_{h,t+1}^*}{P_{t+1}} A_{t+1} z_{t+1} \pi_{x,t+1} - (r_{t+1} + \delta) \right] \lambda_{t+1} s_t - f_{t+1}, & \text{if } z_{t+1} \geq \overline{Z}_{t+1}^* \end{cases} \quad (22)$$

$$l_{t+1} = \begin{cases} 0, & \text{if } z_{t+1} \leq \underline{Z}_{t+1}^* \\ A_{t+1} z_{t+1} \left[ \frac{(1-\alpha)p_{h,t+1}}{w_{t+1}} \right]^{\frac{1}{\alpha}} \lambda_{t+1} s_t, & \text{if } z_{t+1} \in \left( \underline{Z}_{t+1}^*, \overline{Z}_{t+1}^* \right) \\ A_{t+1} z_{t+1} \left[ \frac{(1-\alpha)p_{h,t+1}^*}{w_{t+1}} \right]^{\frac{1}{\alpha}} \lambda_{t+1} s_t, & \text{if } z_{t+1} \geq \overline{Z}_{t+1}^* \end{cases} \quad (23)$$

$$k_{t+1} = \begin{cases} 0, & \text{if } z_{t+1} \leq \underline{Z}_{t+1}^* \\ \lambda_{t+1} s_t, & \text{if } z_{t+1} \in \left( \underline{Z}_{t+1}^*, \overline{Z}_{t+1}^* \right) \\ \lambda_{t+1} s_t, & \text{if } z_{t+1} \geq \overline{Z}_{t+1}^* \end{cases} \quad (24)$$

$$b_{t+1} = \begin{cases} -s_t, & \text{if } z_{t+1} \leq \underline{Z}_{t+1}^* \\ (\lambda_{t+1} - 1)s_t, & \text{if } z_{t+1} \in \left( \underline{Z}_{t+1}^*, \overline{Z}_{t+1}^* \right) \\ (\lambda_{t+1} - 1)s_t, & \text{if } z_{t+1} \geq \overline{Z}_{t+1}^* \end{cases} \quad (25)$$

where the two cutoffs,  $\{\underline{Z}^*, \overline{Z}^*\}$ , satisfy

$$\frac{p_{h,t+1}}{P_{t+1}} A_{t+1} \underline{Z}_{t+1}^* \pi_{d,t+1} = r_{t+1} + \delta \quad (26)$$

$$\frac{p_{h,t+1}^*}{P_{t+1}} A_{t+1} \overline{Z}_{t+1}^* \pi_{x,t+1} - \frac{f_{t+1}}{\lambda_{t+1} s_t} = \frac{p_{h,t+1}}{P_{t+1}} A_{t+1} \overline{Z}_{t+1}^* \pi_{d,t+1} \quad (27)$$

The first cutoff  $\underline{Z}_{t+1}^*$  (the production cutoff) determines whether a firm is active or inactive in production, and the second cutoff  $\overline{Z}_{t+1}^*$  (the export cutoff) determines whether a firm exports or not.

**Proof.** See Appendix. ■

The above proposition shows the allocating role of the financial (bond) market. It allows the most productive firms to export and borrow from the other firms, the least productive firms to save through the financial market (receiving positive returns on their savings), and the middle-range firms to operate in the domestic market (Figure 2).

Henceforth, we assume that productivity shocks  $z$  follow the Pareto distribution,

$$\Phi(z) = 1 - z^{-\eta} \quad (28)$$

with support  $z \in [1, \infty)$  and the shape parameter  $\eta \geq 1$ . By Proposition 2, we obtain a firm's expected cash flow (before the productivity shock is realized):

$$E[x_{t+1}] = P_{t+1}(1+r_{t+1})s_t + \left( A_{t+1}p_{h,t+1}\pi_{t+1}\frac{\eta}{\eta-1}(\underline{Z}_{t+1}^*)^{-\eta+1} - P_{t+1}(r_{t+1}+\delta)(\underline{Z}_{t+1}^*)^{-\eta} \right) \lambda_{t+1}s_t \\ + \lambda_{t+1}s_t A_{t+1} (p_{h,t+1}^*\pi_{x,t+1} - p_{h,t+1}\pi_{t+1}) \frac{\eta}{\eta-1}(\bar{Z}_{t+1}^*)^{-\eta+1} - P_{t+1}f_{t+1}(\bar{Z}_{t+1}^*)^{-\eta} \quad (29)$$

This expression allows us to solve equation (19):

$$\frac{\partial E[x_{t+1}]}{\partial s_t} = P_{t+1}(1+r_{t+1}) + (A_{t+1}p_{h,t+1}\pi_{t+1}\frac{\eta}{\eta-1}(\underline{Z}_{t+1}^*)^{1-\eta} - P_{t+1}(r_{t+1}+\delta)(\underline{Z}_{t+1}^*)^{-\eta})\lambda_{t+1} \\ + A_{t+1}(p_{h,t+1}^*\pi_{x,t+1} - p_{h,t+1}\pi_{t+1})\frac{\eta}{\eta-1}(\bar{Z}_{t+1}^*)^{1-\eta}\lambda_{t+1} \\ = P_{t+1}(1+r_{t+1}) + \frac{1}{\eta-1}P_{t+1}(r_{t+1}+\delta)(\underline{Z}_{t+1}^*)^{-\eta}\lambda_{t+1} + \frac{\eta}{\eta-1}P_{t+1}f_{t+1}\frac{1}{s_t}(\bar{Z}_{t+1}^*)^{-\eta}, \quad (30)$$

where the last equality in the above equation uses equations (26) and (27) by substituting the linear terms of  $\underline{Z}_{t+1}^*$  and  $\bar{Z}_{t+1}^*$  in the expression while keeping those non-linear terms with exponential  $-\eta$ .

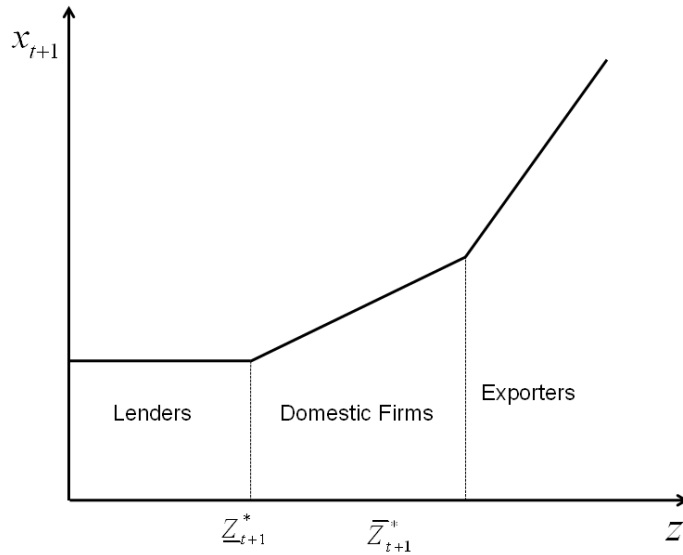


Figure 2. Cutoffs of Firm Type.

In our model, unlike the model of Melitz (2003), exporters do not sell in the domestic market. This simplification can be enriched by allowing heterogeneous goods. The most important feature of our model is that the distribution of firms' saving (net worth)  $s_t$  is degenerate, which permits closed-form characterization of the distributions of firms' cash flows  $x_t$ , capital stocks  $k_t$ , and other decision variables.

## 2.5 Competitive Equilibrium

A competitive equilibrium is defined as the sequences of  $\{s_{it}, x_{it}, b_{it}, l_{it}, k_{it}\}_{t=0}^{\infty}$ ,  $\{C_t, H_t, q_{it}\}_{t=0}^{\infty}$ , and  $\{w_t, r_t, v_t, P_t, p_{ht}\}_{t=0}^{\infty}$  for all  $i \in [0, 1]$  such that

1. Intermediate-goods firms solve problems (17) and (20)
2. Final-goods firms solve problem (9)
3. The household solves problem (3)
4. All markets clear. The market clearing conditions include

(4.a) the equity market clearing:

$$q_{i,t} = 1, \quad i \in [0, 1] \text{ and } t \geq 0 \quad (31)$$

(4.b) the labor market clearing:

$$H_t = \int l_{it} di \quad (32)$$

(4.c) the Intermediate-goods market clearing:

$$M_{ht} = \int_{\bar{Z}_t^*}^{\bar{Z}_t^*} A_t z \lambda_t s_{t-1} \frac{(1-\alpha)^{\frac{1-\alpha}{\alpha}}}{(w_t/p_{ht})^{\frac{1-\alpha}{\alpha}}} d\Phi(z) = A_t \lambda_t s_{t-1} \frac{\pi dt}{\alpha} (\bar{Z}_t^{*1-\eta} - \bar{Z}_t^{*1-\eta}) \frac{\eta}{\eta-1} \quad (33)$$

$$M_{ht}^* = \int_{\bar{Z}_t^*}^{\infty} A_t z \lambda_t s_{t-1} \frac{(1-\alpha)^{\frac{1-\alpha}{\alpha}}}{(w_t/p_{ht}^*)^{\frac{1-\alpha}{\alpha}}} d\Phi(z) = A_t \lambda_t s_{t-1} \frac{\pi_{xt}}{\alpha} \bar{Z}_t^{*1-\eta} \frac{\eta}{\eta-1} \quad (34)$$



(4.d) the bond market clearing:

$$\int_1^{\underline{Z}_t^*} -s_{t-1} d\Phi(z) + \int_{\underline{Z}_t^*}^{+\infty} (\lambda_t - 1) s_{t-1} d\Phi(z) = 0 \quad (35)$$

(4.e) the rental market clearing:

$$K_{t+1} = s_t = S_t \quad (36)$$

(4.f) the final-goods market clearing:

$$Y_t = C_t + f_t \int_{\underline{Z}_t^*}^{\infty} d\Phi(x) + K_{t+1} - (1 - \delta)K_t \quad (37)$$

Notice that the equity market clearing condition implies

$$\begin{aligned} P_t C_t &= w_t H_t + \int (x_{it} - P_t s_{it}) di = w_t H_t + X_t - P_t S_t \\ &= p_{ht} M_{ht} + p_{ht}^* M_{ht}^* + P_t (1 - \delta) S_{t-1} - P_t f_t \int_{\underline{Z}_t^*}^{\infty} d\Phi(x) - P_t S_t, \end{aligned} \quad (38)$$

the labor market clearing implies

$$\begin{aligned} H_t &= \int_{\underline{Z}_t^*}^{\bar{Z}_t^*} A_t z \lambda_t s_{t-1} \frac{(1 - \alpha)^{\frac{1}{\alpha}}}{(w_t/p_{ht})^{\frac{1}{\alpha}}} d\Phi(z) + \int_{\bar{Z}_t^*}^{\infty} A_t z \lambda_t s_{t-1} \frac{(1 - \alpha)^{\frac{1}{\alpha}}}{(w_t/p_{ht}^*)^{\frac{1}{\alpha}}} d\Phi(z) \\ &= A_t \lambda_t s_{t-1} \left[ \left( \frac{\pi_t}{\alpha} \right)^{\frac{1}{1-\alpha}} \frac{\eta}{\eta - 1} (\underline{Z}_t^{*1-\eta} - \bar{Z}_t^{*1-\eta}) + \left( \frac{\pi_{xt}}{\alpha} \right)^{\frac{1}{1-\alpha}} \frac{\eta}{\eta - 1} \bar{Z}_t^{*1-\eta} \right], \end{aligned} \quad (39)$$

the bond market clearing implies

$$\lambda_t (1 - \Phi(\underline{Z}_t^*)) = 1, \quad (40)$$

which is identical to that obtained by Moll (2010). Equations (12), (38), (36) and (37) imply that

$$p_{ht}^* M_{ht}^* = p_{ft} M_{ft}, \quad (41)$$

so trade is balanced. Since our model is financial autarky, we should expect this result.

### 3 Aggregate Dynamics

#### 3.1 Aggregation

**Proposition 3** *The general equilibrium of the model is characterized by the sequences of 14 variables,  $\{\underline{Z}_t^*, r_t, \bar{Z}_t^*, C_t, M_{ht}, M_{ht}^*, K_{t+1}, P_t, M_{ft}, p_{ht}, Y_t, w_t, H_t, S_t\}_{t=0}^{\infty}$ , which can be solved uniquely by the following system of 14 equations:*

$$\lambda_t \underline{Z}_t^{*-\eta} = 1 \quad (42)$$

$$p_{ht} A_t \underline{Z}_t^* \pi_{d,t} = P_t (r_t + \delta) \quad (43)$$

$$(p_{ht}^* A_t \pi_{x,t} - p_{ht} A_t \pi_{d,t}) \bar{Z}_t^* \lambda_t s_{t-1} = P_t f_t \quad (44)$$

$$\frac{1}{C_t} = \beta \frac{1}{C_{t+1}} \left[ (1 + r_{t+1}) + \frac{1}{\eta - 1} (r_{t+1} + \delta) + \frac{\eta}{\eta - 1} \frac{f_{t+1}}{S_t} \bar{Z}_{t+1}^{*-\eta} \right] \quad (45)$$

$$M_{ht} = A_t \lambda_t s_{t-1} \frac{\pi_{d,t}}{\alpha} (\underline{Z}_t^{*1-\eta} - \bar{Z}_t^{*1-\eta}) \frac{\eta}{\eta - 1} \quad (46)$$

$$M_{ht}^* = A_t \lambda_t s_{t-1} \frac{\pi_{x,t}}{\alpha} \bar{Z}_t^{*1-\eta} \frac{\eta}{\eta - 1} \quad (47)$$

$$Y_t = C_t + f_t \int_{\bar{Z}_t^*}^{\infty} d\Phi(x) + K_{t+1} - (1 - \delta) K_t \quad (48)$$

$$P_t Y_t = p_{ht} M_{ht} + p_{ht}^* M_{ht}^* \quad (49)$$

$$\frac{Y_t}{M_{ft}} = \left( \frac{p_{ft}}{P_t} \frac{1}{1 - \varphi} \right)^\mu \quad (50)$$

$$\frac{Y_t}{M_{ht}} = \left( \frac{p_{ht}}{P_t} \frac{1}{\varphi} \right)^\mu \quad (51)$$

$$Y_t = \left[ \varphi (M_{ht})^{\frac{\mu-1}{\mu}} + (1 - \varphi) (M_{ft})^{\frac{\mu-1}{\mu}} \right]^{\frac{\mu}{\mu-1}} \quad (52)$$

$$w_t H_t = (1 - \alpha) (p_{ht} M_{ht} + p_{ht}^* M_{ht}^*) \quad (53)$$

$$H_t^\gamma = \frac{w_t}{P_t C_t} \quad (54)$$

$$K_{t+1} = S_t. \quad (55)$$

**Proof.** See Appendix. ■

In the proposition, equation (42) determines the production cutoff, equation (43) the user’s cost of capital (the interest rate), equation (44) the export cutoff, equation (45) the optimal consumption path—where the expression inside the brackets on the right-hand side is the expected rate of return to equity investment, which equals firms’ marginal cash flows of one unit of capital  $\frac{\partial x_{t+1}}{\partial s_t}$ ), equation (46) the demand for home intermediate goods, equation (47) the exports, equation (48) the optimal capital stock, equation (49) the final-goods price, equation (50) the imports, equation (51) the domestic price of intermediate goods, equation (52) the aggregate output, equation (53) the real wage, equation (54) the hours worked, and equation (55) the aggregate savings.

### 3.2 Calibration

We set the following exogenous variables to constant,  $f_t \equiv f$ ,  $p_{ht}^* \equiv p_h^*$ ,  $p_{ft} \equiv p_f$ , and set the time period to be one quarter, capital share  $\alpha = 0.35$ , the discount rate  $\beta = 0.985$ , capital depreciation rate  $\delta = 0.025$ , and the inverse labor supply elasticity  $\gamma = 1/3$  so that the implied hours worked per week is approximately 40 (Table 1).<sup>12</sup> We let the home-bias weight parameter  $\varphi = 0.80$  (Kose and Yi, 2005, estimate this weight parameter as 0.792 for France, 0.83 for Australia, and 0.899 for the United States) and the elasticity of substitution parameter  $\mu = 8$ , which falls into the interval of the estimations in the literature. Following Moll (2010), we choose collateral requirement parameter  $\lambda = 4.15$ , which implies a loan-to-collateral ratio of 0.759 and a leverage ratio of 3.15. The shape parameter of the Pareto distribution is set to  $\eta = 4.0$  (Table 1). The existing trade literature assigns larger values to  $\eta$ . In particular, Eaton, Kortum, and Sotelo (2011) set  $\theta/(\sigma - 1) = 2.46$ , where  $\sigma$  is the elasticity of substitution among differentiated goods, which ranges from 3 to 10; so the median value of  $\theta$  is 13.5, which would correspond to  $\eta = 4.7$  in our model. A larger value of  $\eta$  would favor our results because it implies a larger number of low-productivity firms in the distribution and a higher level of lending in the steady state, so a negative financial shock

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<sup>12</sup>The estimates of labor supply elasticity are imprecise in the macro and micro literature. We explore the log-linear equivalence between the leisure function adopted in this paper ( $-\frac{H^{1+\gamma}}{1+\gamma}$ ) and an alternative leisure function,  $a \log(1 - H)$ . The elasticity of labor supply in our model is  $\gamma$  while in the alternative specification is  $\frac{\bar{H}}{1-\bar{H}}$ , where  $\bar{H}$  is the steady-state fraction of hours worked. If the endowment of total hours per week is normalized to 1, then 40 hours of working time implies  $\bar{H} \simeq 0.25$ . Hence, the implied elasticity of labor supply is  $\frac{1}{3}$ . These two specifications of leisure function give identical first and second moments of the model when setting  $\gamma = \frac{\bar{H}}{1-\bar{H}}$ .

will have a larger effect on the bond market since more low-productivity firms will opt to withdraw their funds from the credit market, thus creating a larger fall in trade finance and exporters' output.

Table 1. Parameter Values

Parameter	$\alpha$	$\beta$	$\gamma$	$\delta$	$\eta$	$\varphi$	$\mu$	$\lambda$
Value	0.35	0.985	0.333	0.025	4.0	0.80	8.0	4.15

To calibrate the exogenous prices  $p_f$  and  $p_h^*$ , we normalize the steady-state value of the real wage  $w = 1$ , set the exports-to-GDP ratio to 25% (which is consistent with the data for many countries), and choose the value of the fixed cost  $f$  so that the implied ratio of total fixed costs-to-total output is 2%. The implied steady-state values of the model are reported in Table 2, where  $F \equiv f \left[ 1 - \Phi \left( \bar{Z}^* \right) \right]$  is the total fixed costs paid by exporters. Table 2 shows that the model-implied capital-to-output ratio ( $K/Y$ ) is 8.7, the investment-to-output ratio ( $I/Y$ ) is 0.22, and the consumption-to-output ratio ( $C/Y$ ) is 0.76, which are comparable to those in a standard RBC model.

Table 2. Steady-State Values

Price	$p_f$	$p_h^*$	$P$	$p_h$	$w$	$r$				
	0.088	0.414	0.452	0.365	1.00	0.0029				
Quantity	$Y$	$C$	$I$	$F$	$K$	$M_h$	$M_f$	$M_h^*$	$\underline{Z}^*$	$\bar{Z}^*$
	3.02	2.30	0.66	0.06	26.27	2.81	3.90	0.82	1.43	2.49
Ratio	$C/Y$	$K/Y$	$I/Y$	$F/Y$	$EX/Y$					
	0.76	8.7	0.22	0.02	0.25					

The implied firm distributions are reported in Table 3. The predicted fraction of exporters is 2.6%, their share of capital stock in the economy is 12%, share of employment is 25%, share of cash flows is about 3%, and share of debts is 12%. The fraction of exporters in our model may appear too small, accounting for only 2.6% of all firms and 12% of the active firms. In the data, about 21% of U.S. manufacturing plants engage in export (see Bernard et al., 2003). However, this discrepancy arises for several reasons. First, the Pareto distribution is long-tailed, so a very small number of the most productive firms is sufficient to generate enough exports in our model. Suppose we assume the uniform distribution instead, then the share of exporters would be much larger. Second, exporters in our model do not serve the domestic market. In the data, most exporters export only a small fraction of output. We expect that the share of exporters in our model can be significantly increased if we assume monopolistic competition so that exporters will also serve the domestic market.

Table 3. Firm Distribution

	Inactive Firms	Domestic Firms	Exporters
Number of Firms	75.90%	21.50%	2.60%
Share of Rented Capital	0	87.92%	12.08%
Share of Employment	0	75%	25%
Share of Cash Flow	75.15%	21.81%	3.04%
Share of Debt	-100%	87.92%	12.08%

Third, and more importantly, we believe that the value of 21% reported in the literature is an overestimation of the fraction of exporters because the samples in the existing literature do not include all firms, especially small firms (yet small firms are generally non-exporters). For example, according to Bernard et al. (2007, p.2), "[O]f the 5.5 million firms operating in the United States in 2000, just 4 percent were exporters. Among these exporting firms, the top 10 percent accounted for 96 percent of total U.S. exports." As another example, the data used by Lu (2010) include only the state-owned enterprise (SOE) and non-SOEs with sales over 5 million RMB (about 600,000 U.S. dollars), yielding 162,855 firms in the 2000 survey. This number rises to 336,768 in 2007, and 29.6% of these firms are exporters in 2005. However, if small firms are included, there were actually 9,978,800 firms in China in 2009. Suppose exporters are all included in the data used by Lu (2010), then the true fraction of exporters is roughly  $\frac{336768 \times 29.6}{9978800} = 1\%$ . Even if we double the number of exporters in Lu's data, the implied fraction of exporters is only 2%. This makes our result of 2.6% look reasonable.

### 3.3 Financial Development and International Trade

Figure 3 shows the predicted relationship between financial development and three important indicators of economic performance: total factor productivity (TFP), GDP, and the trade volume-to-GDP ratio. The charts show that financial development in our model (represented as increases in the loan-to-value ratio  $\theta$ ) raises both GDP and the share of trade in GDP in the steady state (along a balanced growth path). For example, if the loan-to-collateral ratio increases from 40% to 90% in the steady state, the level of GDP in our model would be nearly 1.5 times higher and the ratio of trade volume to GDP would increase by 2.6 times. This dramatic expansion in output and international trade is attributable to improved aggregate productivity through financial development—the measured aggregate TFP in our model increases by 20% when the loan-to-collateral ratio increases from 40% to 90%. Financial intermediation facilitates capital to flow from low-productivity firms to high-productivity firms

(exporters); hence a rising loan-to-collateral ratio (due to improved contract enforceability or costly verification technology) can raise the aggregate productivity of the economy (as shown by Greenwood et al., 2010). Thus financial development promotes international trade and can indeed be a great source of comparative advantage, as emphasized by the recent literature (see, e.g., Kletzer and Bardhan, 1987; Beck, 2002; Matsuyama, 2005; Ju and Wei, 2005, 2011; Becker and Greenberg, 2007; and Manova, 2011).

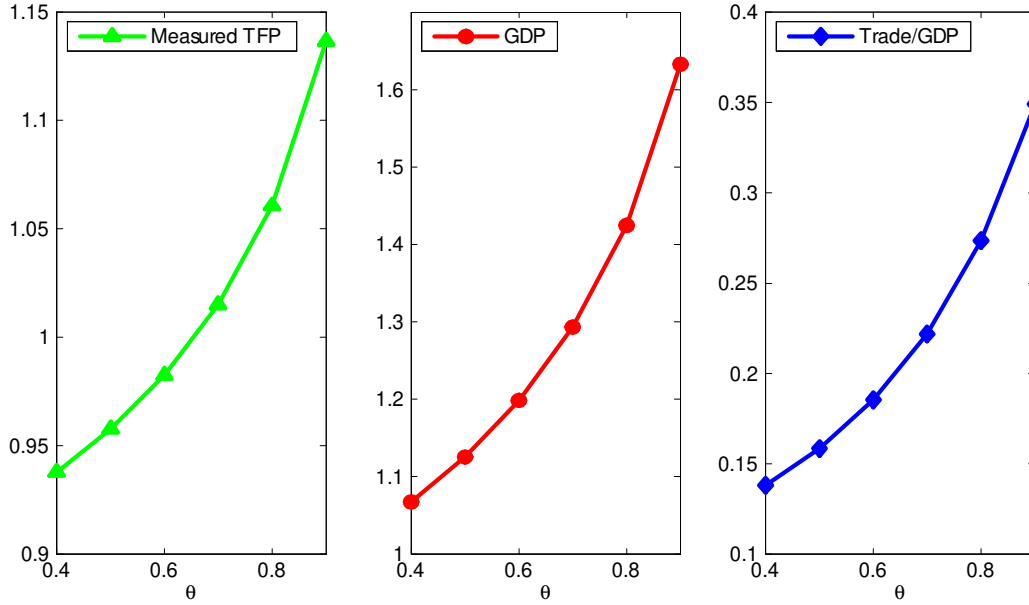


Figure 3. Effects of Financial Development ( $\theta$ ) on TFP, GDP, and Trade.

### 3.4 Explaining the Volatility of Trade

Assume that productivity shocks and financial shocks both follow an AR(1) process with persistent parameter  $\rho$ :

$$\log(A_{t+1}) = \rho \log(A_t) + \varepsilon_{A,t+1} \quad (56)$$

$$\log(\lambda_{t+1}) - \log(\lambda) = \rho(\log(\lambda_t) - \log(\lambda)) + \varepsilon_{\lambda,t+1} \quad (57)$$

We conduct two comparative experiments. First, we compare the dynamics of our model with a standard closed-economy one-sector RBC model under TFP shocks (e.g., the model of King, Plosser, and Rebelo, 1988). We show that the two models behave quite similarly under TFP shocks despite the substantial difference in the structures of the two models. This suggests that our model can explain the regular business cycle as well as a standard

RBC model. Second, we compare the differential effects of TFP shocks and financial shocks in our model on international trade. We show that under TFP shocks, the volatility of trade volume is on the same order of magnitude as that of output. However, under financial shocks, the volatility of trade volume is an order of magnitude (nearly four times) larger than that of output, consistent with the empirical facts discussed in the Introduction.

Figure 4 shows the impulse responses of aggregate output ( $Y$ ), consumption ( $C$ ), investment ( $I$ ), and labor ( $H$ ) to a  $-1\%$  standard deviation shock (contraction) to TFP ( $A$ ). The left panel shows the predictions of our model and the right panel those of a standard closed-economy one-sector RBC model (King, Plosser, and Rebelo, 1988) with comparable utility function, production function, and parameter values for the shared common parameters. The figure shows that our model can generate larger absolute volatility in output, consumption, hours, and investment than the RBC model. Except for these differences in magnitudes, the dynamics of the two models are virtually indistinguishable.

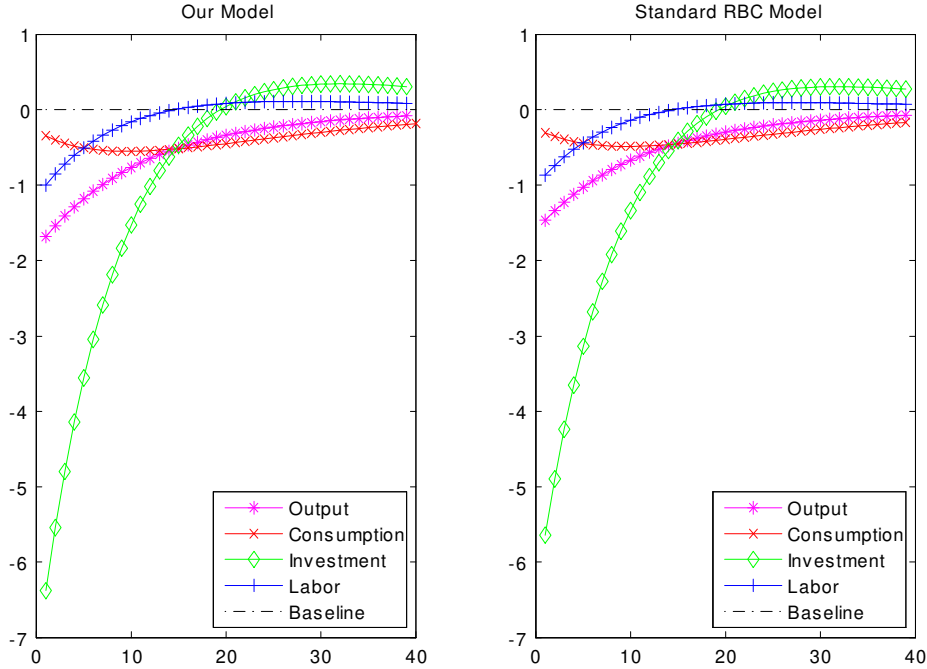


Figure 4. Comparison of RBC and Our Model

Our model can generate a stronger response in aggregate output and investment to TFP shock than a standard RBC model because of the adjustment of the number of exporters in our model. A negative TFP shock reduces the output of all firms; hence the aggregate income level decreases. This intensive margin effect is the same as in the RBC model. However,

there is also an extensive margin effect in our model—the number of exporters declines under a negative TFP shock. Because exporters are relatively more productive firms, this extensive margin effect exacerbates the fall in aggregate income.

Similarly, an adverse TFP shock reduces the demand for capital by all intermediate-goods firms, which drives down aggregate investment, as in the RBC model. In addition, the demand for capital is stronger for exporters than for non-exporters. Hence, when the number of exporters declines, the aggregate demand for capital (investment) decreases more significantly than in an RBC model without exporters.

Table 4. Selected Business Cycle Moments

$x$	relative SD ( $\frac{\sigma_x}{\sigma_Y}$ )				
	$Y$	$C$	$I$	$H$	$EX$
Data	1	0.60	2.98	0.98	<b>3.30</b>
RBC Model	1	0.64	3.00	0.45	N/A
Trade Model ( $A$ )	1	0.64	2.97	0.45	<b>1.44</b>
Trade Model ( $\theta$ )	1	0.65	2.99	0.45	<b>3.71</b>
$x$	$Corr(x, Y)$				
	$Y$	$C$	$I$	$H$	$EX$
Data	1	0.78	0.77	0.83	0.46
RBC Model	1	0.82	0.90	0.80	N/A
Trade Model ( $A$ )	1	0.82	0.90	0.80	1.0
Trade Model ( $\theta$ )	1	0.82	0.90	0.79	1.0
$x$	$Corr(x_t, x_{t-1})$				
	$Y$	$C$	$I$	$H$	$EX$
Data	0.83	0.81	0.84	0.90	0.80
RBC Model	0.92	0.99	0.86	0.85	N/A
Trade Model ( $A$ )	0.92	0.99	0.86	0.85	0.92
Trade Model ( $\theta$ )	0.92	0.99	0.86	0.84	0.91

Y: output, C: consumption, I: investment, H: hours, EX: exports.

However, the standard business-cycle statistics of our model (as measured by relative volatility and correlations with output) are nearly identical to that in the standard RBC mode. Table 4 reports the business-cycle moments of the mode under TFP shocks (labeled "Trade Model  $A$ "), along with their counterparts in the data and the RBC model. Our model is virtually indistinguishable to the RBC model except that investment volatility (relative to output) in our model is slightly smaller. To understand this, notice that equations (42)-(47) and (49) imply  $\frac{1}{C_t} = \beta E_t \frac{1}{C_{t+1}} \left[ 1 - \delta + \alpha \frac{Y_{t+1}}{K_{t+1}} \right]$ , which is identical to the consumption Euler equation in a standard representative-agent RBC model. The intuition is that the rate of



return to household saving (equity holdings) equals the aggregate rate of return to capital, which is the expected marginal cash flows of one unit of capital. Since all firms have the same expected cash flows under i.i.d shocks, the rate of return to household saving depends only on the aggregate output-to-capital ratio and the distribution of firms is irrelevant here. Equation (48) is similar to the aggregate resource constraint in a standard RBC model except for the fixed export costs. In addition, equations (53)-(55) are identical to their counterparts in a standard RBC model when the right-hand side of equation (53) is substituted by equation (49). Hence, our model has the same reduced-form first-order conditions on the household side as in a representative-agent RBC model. In other words, from the household's viewpoint, the return to work is proportional to the aggregate output-to-labor ratio and the return to saving is proportional to the aggregate output-to-capital ratio. The only difference is the small fixed export cost paid for production. Therefore, ignoring the fixed cost, the aggregate consumption-to-output ratio, labor-to-output ratio, and capital-to-output will behave in the same way as in a standard representative-agent RBC model.<sup>13</sup>

The last column of the table also reports the second moments of exports. The predicted volatility of exports relative to output is significantly smaller than that in the data, accounting for only 45% of the U.S. data. This reveals the "trade elasticity puzzle" emphasized by the existing literature on international trade and international finance. Ahn, Amiti, and Weinstein (2011), among others, argue that financial frictions hold the key for solving the trade elasticity puzzle.

The rows labeled "Trade Model  $\theta$ " in Table 4 report the predicted business-cycle moments of our model under financial shocks. In many dimensions, the model under financial shocks behaves similarly to the case under TFP shocks, but with one important exception: The volatility of exports is now nearly four times as large as that of output. To illustrate this sharp difference, Figure 5 shows the impulse responses of output and exports to a negative TFP shock and a negative financial shock. We control the size of the two shocks so that the implied drop in output is 5% in both models (which captures the average magnitude of recession in Figure 1).<sup>14</sup> The left panel in Figure 5 shows that under TFP shocks, output

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<sup>13</sup>Since trade is always balanced in our model, movements in the cutoffs (the distribution of firms) affect aggregate consumption, investment, and output proportionately. Hence, when output is used as the reference point, the dynamics of the model appear not affected by trade or the distribution of firms. However, the absolute magnitude of the business cycle and the dynamics of the total volume of trade are different from RBC models—precisely because the absolute movements of the variables depend on the cutoffs  $\{Z_t^*, \bar{Z}_t^*\}$  and the distribution of firms.

<sup>14</sup>Our model under financial shocks is able to generate this magnitude of drop in output. For example, aggregate output will drop by 5% if we assume that  $\lambda_t$  decreases by 20.0%. This magnitude of financial shock can be easily justified by real-world data. For example, during the recent financial crisis, U.S. corporate loans

declines by 5% and trade volume declines by 7% on impact. This near unit elasticity of exports with respect to changes in output is a well-known result for standard business cycle models in the literature (see Ahn, Amiti, and Weinstein, 2011, for a literature review). In the data, however, this elasticity is 3.3 for the postwar United States (including the recent financial crisis). A major reason for the smaller predicted elasticity is that the existing theoretical models have largely ignored the important role of finance in international trade, as argued by Ahn, Amiti, and Weinstein (2011). However, here we show that despite the existence of a financial market and its importance in facilitating trade, the elasticity of trade is still small, only 1.4, under non-financial shocks.

Therefore, the issue is subtler than thought. This is why we need a DSGE trade model that can differentiate non-financial shocks from financial shocks. This argument is supported by our model in the right panel in Figure 5, which shows that under financial shocks, trade volume in our model declines by more than 15% on impact—more than 3 times larger than the initial drop in output. This implies that the trade elasticity in our model is larger than 3, fully consistent with the data.

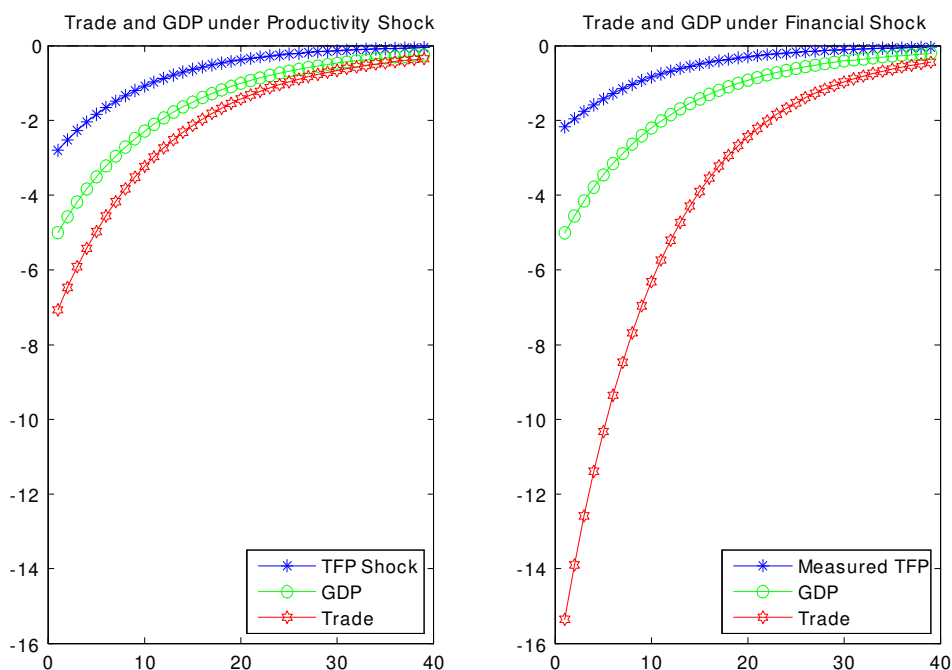


Figure 5. Differential Effects of TFP and Financial Shocks on Trade.

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dropped by 69.7% based on the quarter-to-quarter growth rate between 2007:Q4 and 2008:Q4, and by 78.6% from the peak in 2007Q2 to the trough in 2008Q4 (Source: Ivashina and Scharfstein, 2010).

The significantly larger decline in trade volume relative to output under financial shocks than under TFP shocks is the result of the effect of a rising credit standard (or tightening borrowing limit) on the demand for capital by high-productivity firms and the consequent adverse reallocation of capital from exporters to non-exporters. When the demand for capital in the export sector declines, the excess supply of capital flows back to the domestic sector. As a result, the output of the export sector drops disproportionately more than the output of the domestic sector. In other words, since exporters are more productive and rely more heavily on outside credit to finance working capital than non-exporters, the drop in borrowing limit hurts the exporters disproportionately more than non-exporters in terms of sales. Consequently, total trade volume experiences a disproportionately larger decrease than does aggregate output. In contrast, under TFP shocks, the negative effect on firms' productivity is the same across all firms; hence, output in the export and the domestic sectors decreases almost proportionately, leading to a nearly proportionate drop in aggregate output.<sup>15</sup>

## 4 Conclusion

This paper proposes a highly stylized international trade model with capital accumulation and financial intermediation by embedding the Melitz (2003) model into an incomplete-market neoclassical framework with heterogeneous firms. The model preserves the analytical tractability of the original Melitz model despite well-defined distributions of firm wealth and a non-trivial form of borrowing constraints. A calibrated version of the model is applied to examine the differential effects of financial shocks and non-financial shocks on the economy. The results show that financial shocks can generate a much sharper and deeper decline in trade volume relative to aggregate output than non-financial shocks (e.g., productivity shocks). The intuition is that (i) exporters are more productive and thus able to enter the foreign market by paying a higher fixed cost; (ii) financial intermediation is able to channel capital from low-productive agents to productive agents, which means that exporters are able to rely more heavily on outside credit to finance their operations than non-exporters; (iii) consequently, a financial crisis or credit crunch that hinders the flow of funds to productive firms will thus have an asymmetric effect on exporters and non-exporters, resulting in a larger fall in trade volume than aggregate output. This prediction of our model offers a theoretical explanation for the well-documented empirical puzzle that many countries that

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<sup>15</sup>The presence of the fixed costs in the export sector causes output in the export sector to drop slightly more because of increasing returns to scale. So the trade elasticity is slightly larger than 1 instead of equal to 1 under TFP shocks.

had financial crises also experienced sharp contractions in trade volume relative to output (such as the Great Trade Collapse during the recent financial crisis).

Our model also shows that in the long run countries with deeper financial markets are able to achieve a higher output level and a larger share of exports in output. Therefore, financial development appears to be a great source of "comparative advantage," enabling firms to enter and stay in the foreign markets even though making them more vulnerable to financial shocks.

As a highly stylized model, our model still has many shortcomings. For example, in our model firms change their export status too frequently due to the i.i.d nature of firm-specific productivity shocks. In the data, although most firms exit the foreign product market after entering for just one year, the median length of stay is about 3 years.<sup>16</sup> Nonetheless, our model can be extended in many ways. For example, we can introduce permanent productivity differences across firms so that some firms are endowed with better technology than others. In this case, the high-productivity firm is more likely to enter and stay in the foreign market under i.i.d productivity shocks than the low-productivity firm. We can also introduce monopolist competition to the intermediate-goods sector. This extension will make our model more realistic, especially regarding the share of exporters' output in the domestic market and the distribution of firm wealth. We can also extend our model to a two-country framework, which will enhance our results because financial crisis in the home country reduces the demand for foreign goods, which can act as a demand shock to the foreign country's output (as emphasized by Eaton et al., 2011). A recession in the foreign country will then feed back to the home country, reinforcing the financial crisis. Thus, we expect that a two-country version of our model is able to explain the cross-country business-cycle comovements by relying on financial shocks alone. Extensions such as these are left as our future projects.

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<sup>16</sup>For example, based on highly disaggregated U.S. import data for 1972-2001, Besedes and Prusa (2006) found that trade duration is rather short lived with a median of 2 to 4 years, and 67% trade relationships hold only one year. Notice that in the original Melitz (2003) model, firms never change their export status once entering the foreign market unless hit by a death shock. Hence, our model is already a significant improvement over the Melitz model in accounting for the observed transition probability of exporters and non-exporters.

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## Appendix A: Proof of Proposition 2

First, we group all firms into two types: inactive and active. If a firm is inactive, it only saves and does not produce. So its real profit is

$$\frac{x_{t+1}}{P_{t+1}} = (1 + r_{t+1})s_t. \quad (58)$$

If a firm chooses to be active, it can sell domestically or export. A domestic firm solves

$$\frac{x_{t+1}}{P_{t+1}} = \max \left\{ \frac{p_{h,t+1}}{P_{t+1}} (A_{t+1} z_{t+1} k_{t+1})^\alpha l_{t+1}^{1-\alpha} - \frac{w_{t+1}}{P_{t+1}} l_{t+1} + (1 - \delta)k_{t+1} - (1 + r_{t+1})b_{t+1} \right\}, \quad (59)$$

subject to

$$0 < k_{t+1} \leq \lambda_{t+1} s_t. \quad (60)$$

The firm's labor demand is given by

$$l_{t+1} = \left[ (1 - \alpha) \frac{p_{h,t+1}}{w_{t+1}} \right]^{\frac{1}{\alpha}} A_{t+1} z_{t+1} k_{t+1}. \quad (61)$$

Substituting the labor demand function into the objective function gives

$$\frac{x_{t+1}}{P_{t+1}} = \max \left\{ (1 + r_{t+1})s_t + \left[ \frac{p_{h,t+1}}{P_{t+1}} A_{t+1} z_{t+1} \pi_{t+1} - (r_{t+1} + \delta) \right] k_{t+1} \right\}. \quad (62)$$

Optimality means that if a firm chooses to be active, it must be true that  $P_{t+1} A_{t+1} z_{t+1} \pi_{t+1} - (r_{t+1} + \delta) \geq 0$ . Since the objective function is linear in  $k_{t+1}$ , an active firm will borrow to the upper limit by setting  $b_{t+1} = (\lambda_{t+1} - 1) s_t$ . So we have  $k_{t+1} = \lambda_{t+1} s_t$ . Consequently, the optimal labor demand  $l_{t+1}$  and cash flow  $x_{t+1}$  can be solved in closed form.

Similarly, if a firm chooses to sell in the foreign market, it solves

$$\frac{x_{t+1}}{P_{t+1}} = \max \left\{ \frac{p_{h,t+1}^*}{P_{t+1}} (A_{t+1} z_{t+1} k_{t+1})^\alpha l_{t+1}^{1-\alpha} - f_{t+1} - \frac{w_{t+1}}{P_{t+1}} l_{t+1} + (1 - \delta)k_{t+1} - (1 + r_{t+1})b_{t+1} \right\}, \quad (63)$$

subject to equation (60). The firm's optimal demand for labor is simpler:

$$l_{t+1} = \left[ (1 - \alpha) \frac{p_{h,t+1}^*}{w_{t+1}} \right]^{\frac{1}{\alpha}} A_{t+1} z_{t+1} k_{t+1}, \quad (64)$$

Substituting the above equation into the objective function, we obtain

$$\frac{x_{t+1}}{P_{t+1}} = \max \left\{ (1 + r_{t+1})s_t + \left[ \frac{p_{h,t+1}^*}{P_{t+1}} A_{t+1} z_{t+1} \pi_{x,t+1} - (r_{t+1} + \delta) \right] k_{t+1} - f_{t+1} \right\}. \quad (65)$$

Similar to a domestic firm, an exporter will also borrow to its upper limit. Consequently,  $\{k_{t+1}, b_{t+1}, l_{t+1}, x_{t+1}\}$  can all be solved in closed form. Note if  $p_{h,t+1}^* \leq p_{h,t+1}$ , no firm wants to export because of the additional fixed cost involved. However, our model is financial autarky, so trade is always balanced. No exports means no imports and no final goods at all. We rule out this uninteresting case by assuming  $p_{h,t+1}^* > p_{h,t+1}$  in equilibrium. Only when a firm's profit is high enough to cover the fixed cost, will it export. So the export condition is

$$\frac{p_{h,t+1}^*}{P_{t+1}} A_{t+1} z_{t+1} \pi_{x,t+1} s_t - \frac{p_{h,t+1}}{P_{t+1}} A_{t+1} z_{t+1} \pi_{t+1} s_t > f_{t+1}. \quad (66)$$

From above, we have two cutoff conditions:

$$\frac{p_{h,t+1}}{P_{t+1}} A_{t+1} \underline{Z}_{t+1}^* \pi_{d,t+1} = r_{t+1} + \delta \quad (67)$$

$$p_{h,t+1}^* A_{t+1} \bar{Z}_{t+1}^* \frac{\pi_{x,t+1}}{P_{t+1}} \lambda_{t+1} s_t - f_{t+1} = p_{h,t+1} A_{t+1} \bar{Z}_{t+1}^* \frac{\pi_{t+1}}{P_{t+1}} \lambda_{t+1} s_t \quad (68)$$

Assume  $f_{t+1}$  is large enough, we have  $\bar{Z}_{t+1}^* \geq \underline{Z}_{t+1}^*$ . If the fixed cost is too small, then we may have  $\bar{Z}_{t+1}^* < \underline{Z}_{t+1}^*$ , which means that no firms want to serve the domestic market, given that  $p_{h,t+1}^* > p_{h,t+1}$ . We also rule out this possibility.

## Appendix B: Proof of Proposition 3

Equation (42) is implied by equation (40) under Pareto distribution. Equation (43) and (44) are the two cutoff conditions in Proposition 2. Equation (45) is implied by equation (5), (19), and (30). Note  $\lambda_t \underline{Z}_t^* = 1$  by equation (42). Equation (46) and (47) correspond to equation (33) and (34). Equation (48) is simply equation (37). Equation (49) gives GDP components, which can be derived from equations (12) and (41). Equation (50), (51), and (52) come from the final-goods producer's problem. Equation (53) is labor's income share, inferred from equations (39), (33), and (34). Equation (54) is indicated by equations (5) and (6). Equation (55) is the rental market-clearing condition.