Financial Frictions and Trade Dynamics

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Abstract

This paper demonstrates theoretically that a financial shock can have very persistent effects on international trade. Motivation is taken from the aftermath of the dramatic trade collapse in 2008-9, which despite a substantial recovery, has left a persistently slower growth rate in trade. We find that firm dynamics at the extensive margin of trade can be a potent propagation mechanism to help explain persistence. Under certain conditions a transitory financial shock can significantly reduce the investment by firms in entering the export market, which can have long-lasting effects on the range of goods exported and hence overall trade. Important to our explanation are endogenous capital structure decisions by firms in response to the financial shock, and firm entry investment that requires traded goods.

JEL classification:
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1. Introduction

While the level of international goods trade largely has recovered from the dramatic collapse in 2008-9, there appears to be a longer run impact in the form of a persistently slower growth rate in trade compared to the trend before the crisis. As seen in Table 1, the average annual growth rate in US exports for 2012-14 was less than a third of the average annual growth rate for the five years preceding the crisis (3.1% versus 10.1%). This paper will study the role that extensive margin dynamics can play as a mechanism translating a transitory financial shock into a longer-run decline in trade. Previous empirical research on the trade collapse has downplayed the role of the extensive margin, finding it contributed ten percent or less of the fall in trade in 2009 (see Behrens et al. 2013, and Bricongne et al. 2012). Column two of Table 1 confirms this impression, where the fall during 2009 for two measures of extensive margin, the number of goods-country combinations with positive exports and the number of exporters, respectively, are a tenth and a quarter of the fall in export value. However, Table 1 also considers a data set extended to more recent years, and column four shows that the shortfall in growth rate (comparing post-crisis to pre-crisis averages) in the extensive margin is up to one-half of the magnitude of the shortfall in export growth. We conclude that, while firm dynamics and changes in the extensive margin may move modestly in the short run, they appear to be persistent, and in the medium to long run these persistent effects in the extensive margin are a significant component of the fall in overall exports.

In some respects this relationship is surprising. Paravisini et al. (2015) claims that the financial crisis involves shocks to working capital not sunk entry costs, as this is what is needed to explain the given effect on overall trade volume, and further, shocks to short term capital directly affect the intensive rather than extensive margin.

However, Bergin et al. (2016) showed in a closed economy model that a shock to short term working capital costs can have strong implications for the financing of firm sunk entry costs through endogenous changes in firm capital structure. This paper will develop a two-country dynamic stochastic general equilibrium (DSGE) model with endogenous capital structure to study how a financial shock can lead to both a large temporary fall in trade volume and a drop in extensive margin of trade that has long-lasting effects on trade volume.

We draw additional empirical motivation from an empirical vector autoregression, identifying the dynamic effects of financial shocks on the margins of trade in recent historical data. Using multiple measures of trade and of the financial shock, the impulse response point estimates indicate a sharp downturn in trade, followed by a partial recovery but protracted shortfall in trade relative to the original level. Impulse responses for the extensive margin indicate a similar downturn and lingering effect. Our theoretical model will generate this pattern of responses, and will offer an explanation of how they are related to each other, in particular, how the persistent effect on the stock of exporting firms can act as a propagation mechanism for trade volume.

Two key mechanisms drive the theoretical result. The first is that shocks to costs of financing working capital lead firms to alter their capital structure from debt to more expensive equity financing. Evidence for such capital restructuring during the financial crisis has been provided by Jermann and Quadrini (2012), and Bergin et al. (2016) has shown it has important implications for firm entry. An adverse financial shock takes the usual form of a tightening of the collateral constraint for borrowing working capital during a period, which reduces the scale of firm production. Since equity is used as collateral, the shock creates an incentive for firms to reallocate firm financing away from intertemporal debt toward equity financing. Because equity is a more costly form of firm financing, this capital structure reallocation raises the effective cost of financing the sunk investment cost of entering the export market, and hence deters potential entrants. This mechanism thus addresses the problem in past research that a transitory shock affecting short run profits does not sufficiently reduce the overall present value of the stream of all future profits in order to have a significant effect on the level of firm entry. By translating this short-run financing shock to raise instead the effective sunk cost, the shock is able to significantly discourage new entry. Due to the fairly slow dynamics in the stock of firms, such a fall in new entry can have long-lasting effects on the number of exporters. A drop in the number of home export varieties available to foreign consumers, relative to the number of foreign domestic varieties, reduces demand for home exports in our model, leading to a long-lasting drop in export volume.

The second key mechanism is that entry investment includes a substantial share of traded goods. The literature has long recognized that capital goods represent a substantial portion of trade flows, and that the volatility of investment helps explain the high volatility in trade flows, including in the recent financial crisis. (See Boileau 1999, Eaton and Kortum 2001, Engel and Wang 2011, and Alessandria et al. 2010.) In the context of our model, including entry investment in the trade volume allows the change in extensive margin to contribute to trade dynamics in two ways. First, it adds to the initial fall in trade on impact of the shock. This fact is something that was appreciated in past work noted above studying the initial trade collapse. But a second effect, novel to our work, is that it also can have a powerful impact on the persistence of trade dynamics through a vicious circle. A drop in the extensive margin of trade lowering the number of varieties of imported goods available for investment raises the cost of investment, which lowers entry in future periods, which in turn raises the cost of future investment, etc. This persistent drop in the extensive margin of trade then translates into a persistent effect on trade volume.

Results from model simulation imply a large impact effect on trade, which partly dies away quickly, but leaves a persistent component that dies away very slowly. Simulations show this persistence in trade volume is related to an extensive margin that gradually worsens and is quite persistent. They also show the worsening price index of imports and hence for investment noted above. Experiments confirm that both mechanisms, capital restructuring to raise entry cost, and entry costs in units of traded goods, are necessary for our model to generate theoretical impulse responses that look like the empirical responses, in terms of impact effect and persistence. A calibration exercise indicates that this mechanism potentially could explain a substantial share of the persistent effect on trade observed in our empirical VAR.

The remainder of this paper is structured as follows. Section 2 documents some new stylized facts regarding the extensive margin of trade during the financial crisis. Section 3 explains the mechanics of the DSGE model. Section 4 calibrates the model, interprets simulation results, and conducts sensitivity analyses to identify key channels of the mechanism. Section 5 concludes.

2. Empirical Motivation

We characterize the dynamic responses of the margins of trade to a financial shock by estimating a 7-variable vector autoregression model. A VAR is useful in that it can control for other shocks, such as shocks to monetary policy. It also characterizes dynamics in terms of impulse responses that are directly comparable to those produced by our theoretical DSGE model.

The VAR includes monthly 6-digit HS disaggregate U.S. export and import flow data running from 2002:1 to 2016:11 to measure trade flows, and permit computation of the extensive margin of trade as the number of different categories traded with a given country in a month. This sample period includes the recent crisis and recovery. Given the short time span, we procured export and import data at a monthly frequency in order to maximize the level of statistical significance. The VAR model is estimated with variables in the following order: the logarithm of industrial production, logarithm of CPI, the federal funds rate, the 3-month interbank lending rate, the logarithm of the extensive margin of trade, the logarithm of total trade, and the logarithm of S&P500 index. For robustness, we will also run VARs for exports and imports separately, in place of the trade variable.

As in Bergin et al. (2016), an exogenous financial shock is represented as an innovation to the interbank lending rate. The impulse responses are reported in Fig. 1, along with two-standard error bands. These show that the lending rate has negative and significant impacts on the extensive margin of trade and total trade. The effect on the extensive margin of trade is delayed, with the peak response coming 3 months after the shock. The effect on the total exports is larger in magnitude and later in timing, with the peak effect at 8 to 9 months after the shock. The impulse response is consistent with a highly persistent effect on trade, in that the point estimates of the impulse responses do no fully return to the starting point, even when the horizon of the impulse responses is doubled to 120 months. (However, wide confidence bands preclude claims of statistical significance in the long run.)

Figs. 2 and 3 present robustness checks by estimating the impacts of financial shock on the exports and imports separately. The impulse responses of the extensive margins of exports and imports are both very persistent, however, the significance of impacts on the extensive margin of imports is longer-lasting than that on the extensive margin of exports. For robustness, we also consider VARs that replace innovations in the interbank rate with an innovation in the Chicago Fed National Financial

Conditions Index as an indicator of the financial shock. The results shown in Appendix Fig. A1 to A3 are very similar to our benchmark model. However, the impacts of financial shock on the extensive margin of trade and total trade are even somewhat more persistent than the benchmark. Finally, we note that the impulse responses are almost identical when we change the ordering which lists the extensive margin after trade.

3. Model

The theoretical model considers two symmetric countries, Home and Foreign. In each country there are five sectors: (1) a perfectly competitive final goods sector whose goods will be consumed domestically, (2) a perfectly competitive investment goods sector whose goods will be used for export market entry investment, (3) a monopolistically competitive intermediate goods sector where some producers are exporters and the rest are non-exporters, (4) a representative investor who finances domestic intermediate firms through equity purchases, and (5) a representative worker who supplies labor to domestic intermediate firms and purchases bonds from these firms.

The intermediate firms are financially constrained as they may default on their borrowing for wage payments. To smooth production, the intermediates may change their capital structure through equity and bond issuance as described in Jermann and Quadrini (2012). Non-exporters may choose to become exporters after paying a sunk entry cost. For simplicity we assume that for a given country the total mass of firms in the intermediate goods sector is constant, fixed at a mass of unity, but that the number of these firms that engage in export activity varies endogenously.

Below we describe the economy in the Home country; the economy in the

Foreign country is analogous. All foreign variables are indicated by a superscript '*'. For a given country, we denote exporters and non-exporters with a subscript 'x' or 'nx' respectively. Prices are in common currency. As our focus is on real variables, the model abstracts from money and nominal exchange rates.

3.1 Timeline

The timeline of the economy is shown in Table 2. Each period starts with four aggregate state variables: the technology shocks (A_t, A_t^*), and the financial shocks (ξ_t, ξ_t^*). We will describe the financial shocks (ξ_t) in more detail in the next section.

There is a unit mass of firms in the intermediate goods sector, with fraction n_{xt-1} that are exporters, and fraction $1-n_{xt-1}$ that are non-exporters at the end of period $t-1$. In period t, after paying a sunk entry cost, ne_{xt} non-exporters enter the export market, so the mass of exporters becomes $n_{xt-1}+ne_{xt}$, and the mass of non-exporters are $n_{nxt}^{begin}=1-\left(n_{xt-1}+ne_{xt}\right)$, where n_{nxt}^{begin} represents the non-exporter number at the beginning of period t. Following Bergin et al. (2016), we assume that new exporters hire labor, produce goods and issue corporate bonds in the initial period of entry. As in Bergin et al. (2016), this specification preserves the property that all firms, both incumbents and new entrants, are homogeneous and face the same enforcement constraint. New exporters differ from incumbent exporters in that they have a matured debt position like their non-exporter counterparts, since new exporters existed as non-exporters in the preceding period. New exporters also differ from incumbent exporters in that they must pay a sunk entry cost.

At this point in time, all firms make production and financial decisions. They hire labor and make wage payments before revenue realization, issue corporate bonds and equities and produce goods. The household receives wage income and bond repayment, and the investor receives equity returns from the ne_{nxt-1}^{end} surviving non-exporters and the n_{xt-1} surviving exporters; in the mean time they make financial investment over the n_{nxt}^{begin} non-exporters and the $n_{xt-1}+ne_{xt}$ exporters.

At the end of period t, after all markets have cleared, an exogenous death shock applies to the firms with a probability of λ. So now there are $n_{xt}=(1-\lambda)(n_{xt-1}+ne_{xt})$ surviving exporters and $n_{nxt}^{end}=(1-\lambda)n_{nxt}^{begin}$ surviving non-exporters, each of which will enter period $t+1$ with a matured debt repayment b_{xt} or b_{nxt} respectively. To maintain the assumption of a unit mass of firms, after the death shock at t a mass of $1-n_{xt}-n_{nxt}^{end}$, that is, λ firms are born into the domestic market as non-exporters automatically without incurring any additional cost.[1]

So the dynamics of exporters and non-exporters in the home country is as follows:

$$n_{xt}=(1-\lambda)(n_{xt-1}+ne_{xt}) \tag{1}$$

$$n_{nxt}^{begin}=1-(n_{xt-1}+ne_{xt}) \tag{2}$$

$$n_{nxt}^{end}=(1-\lambda)n_{nxt}^{begin} \tag{3}$$

3.2 Final goods sector: Consumption and Investment

[1] It is assumed that newly born non-exporting firms inherit the debt position of the dying non-exporting firms they replace.

3.2.1 Consumption

The overall consumption goods index (C_t) is a CES aggregator of home and foreign varieties:

$$C_t \equiv \left[\int_0^{n_{xt-1}+ne_{xt}} c_{dxit}^{\frac{\sigma-1}{\sigma}} di + \int_{n_{xt-1}+ne_{xt}}^{1} c_{nxit}^{\frac{\sigma-1}{\sigma}} di + \int_0^{n^*_{xt-1}+ne^*_{xt}} c_{fxit}^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}},$$

where c_{dxit} denotes the varieties produced by the home exporter hx_{it} consumed domestically by the home consumers, representing fraction $n_{xt-1} + ne_{xt}$ of all home varieties. Likewise c_{nxit} is the goods produced by domestic non-exporter nx_{it}, representing fraction $1-\left(n_{xt-1} + ne_{xt}\right)$ of home varieties. And c_{fxit} denotes the varieties produced by the foreign exporter fx_{it} consumed by the home country, representing fraction $n^*_{xt-1} + ne^*_{xt}$ of all foreign varieties. For reference, we can write this overall consumption index in terms of sub-aggregates:

$$C_t = \left[C_{Ht}^{\frac{\sigma-1}{\sigma}} + C_{Ft}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}},$$

where C_{Ht} is a CES aggregator of all home varieties,

$$C_{Ht} \equiv \left[\int_0^{n_{xt-1}+ne_{xt}} c_{dxit}^{\frac{\sigma-1}{\sigma}} di + \int_{n_{xt-1}+ne_{xt}}^{1} c_{nxit}^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}},$$

and C_{Ft} is a CES aggregator of imported foreign varieties,

$$C_{Ft} \equiv \left[\int_0^{n^*_{xt-1}+ne^*_{xt}} c_{fxit}^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}} = \left(n^*_{xt-1} + ne^*_{xt} \right)^{\frac{\sigma}{\sigma-1}} c_{fxit} .$$

where the second equalities are from the symmetric equilibrium as shocks in the economy are at the aggregate level and common to all firms of the same type.

The corresponding consumer price indices are thus given by:

$$P_t = \left[P_{Ht}^{1-\sigma} + P_{Ft}^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{4}$$

where
$$P_{Ht} \equiv \left[\int_0^{n_{xt-1}+ne_{xt}} p_{\mathrm{dx}it}^{1-\sigma} di + \int_{1-(n_{xt-1}+ne_{xt})}^{1} p_{nxit}^{1-\sigma} di \right]^{\frac{1}{1-\sigma}}, \tag{5}$$

or equivalently $P_{Ht}^{1-\sigma} \equiv \left(n_{xt-1} + ne_{xt} \right) p_{\mathrm{dx}it}^{1-\sigma} + \left(1 - n_{xt-1} - ne_{xt} \right) p_{nxit}^{1-\sigma}$,

and
$$P_{Ft} \equiv \left[\int_0^{n_{xt-1}^{*}+ne_{xt}^{*}} p_{fxit}^{1-\sigma} di \right]^{\frac{1}{1-\sigma}} = \left(n_{xt-1}^{*} + ne_{xt}^{*} \right)^{\frac{1}{1-\sigma}} p_{fxit} \tag{6}$$

for homogeneous firms. Here, P_t is the domestic aggregate consumer price level, P_{Ht} is the price level of the home composite, P_{Ft} is the price of the imported foreign composite, and p_{hxit}, p_{nxit} and p_{fxit} are the prices (faced by home consumers) of individual varieties produced by home exporers, home non-exporters and foreign exporters.

The implied relative demand functions for home country are

$$C_{Ht} = \left(\frac{P_{Ht}}{P_t} \right)^{-\sigma} C_t \tag{7}$$

$$C_{Ft} = \left(\frac{P_{Ft}}{P_t} \right)^{-\sigma} C_t \tag{8}$$

$$c_{nxit} = \left(\frac{p_{nxit}}{P_{Ht}} \right)^{-\sigma} C_{Ht} \tag{9}$$

$$c_{dxit} = \left(\frac{p_{dxit}}{P_{Ht}} \right)^{-\sigma} C_{Ht} \tag{10}$$

$$c_{fxit} = \left(\frac{p_{fxit}}{P_{Ft}} \right)^{-\sigma} C_{Ft} = \left(n_{xt-1}^{*} + ne_{xt}^{*} \right)^{\frac{\sigma}{1-\sigma}} C_{Ft} \tag{11}$$

Analogous conditions apply to the foreign country.

3.2.2 Investment

In period t, each of the ne_{xt} new exporters must pay an entry cost, K_t^E, to enter the export market. So the total investment expenditure on entry in Home country is given by

$$I_t \equiv ne_{xt} K_t^E . \tag{12}$$

Analogous to the aggregate consumption index above C_t, we assume the production of investment good for entry is a CES aggregator of home and foreign varieties, given by

$$I_t = \left[\theta^{\frac{1}{\phi}} I_{Ht}^{\frac{\phi-1}{\phi}} + (1-\theta)^{\frac{1}{\phi}} I_{Ft}^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}},$$

where $1-\theta$ is the degree of bias to imported foreign goods, reflecting the dependence of home firms on local inputs when entering foreign market. Here, I_{Ht} is a CES aggregator of all home varieties,

$$I_{Ht} \equiv \left[\int_0^{n_{xt-1}+ne_{xt}} i_{dxit}^{\frac{\phi-1}{\phi}} di + \int_{n_{xt-1}+ne_{xt}}^{1} i_{nxit}^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}},$$

and I_{Ft} is a CES aggregator of imported foreign varieties,

$$I_{Ft} \equiv \left[\int_0^{n_{xt-1}^*+ne_{xt}^*} i_{fxit}^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}} = \left(n_{xt-1}^* + ne_{xt}^* \right)^{\frac{\phi}{\phi-1}} i_{fxit} .$$

The corresponding investment price index is thus given by

$$P_{It} = \left[\theta P_{Ht}^{1-\phi} + (1-\theta) P_{Ft}^{1-\phi} \right]^{\frac{1}{1-\phi}} . \tag{13}$$

The implied relative demand functions for home country are

$$I_{Ht} = \theta \left(\frac{P_{Ht}}{P_{It}} \right)^{-\phi} I_t \tag{14}$$

$$I_{Ft} = (1-\theta)\left(\frac{P_{Ft}}{P_{It}}\right)^{-\phi} I_t \tag{15}$$

$$i_{nxit} = \left(\frac{p_{nxit}}{P_{Ht}}\right)^{-\phi} I_{Ht} \tag{16}$$

$$i_{dxit} = \left(\frac{p_{dxit}}{P_{Ht}}\right)^{-\phi} I_{Ht} \tag{17}$$

$$i_{fxit} = \left(\frac{p_{fxit}}{P_{Ft}}\right)^{-\phi} I_{Ft} = \left(n^*_{xt-1} + ne^*_{xt}\right)^{\frac{\phi}{1-\phi}} I_{Ft} \tag{18}$$

Analogous conditions apply to the foreign country.

3.2 Worker preferences and optimization

The representative worker derives utility from consuming the basket of final goods (C_{wt}), and disutility from labor supply (L_t) in each period, and maximizes expected lifetime utility,

$$\max\ E_0 \sum_{t=0}^{\infty} \beta^t U(C_{wt}, L_t), \quad with \quad U(C_{wt}, L_t) = \frac{C_{wt}^{1-\rho}}{1-\rho} - \kappa \frac{L_t^{1+\varphi}}{1+\varphi},$$

where $\rho > 0$ is the worker's degree of risk aversion, $\beta \in (0,1)$ is the worker's discount factor, and κ is the relative weight of labor in the utility function.

The worker receives income from providing labor services (L_t) at the real wage rate (w_t), and holding matured corporate bonds of the (n_{xt-1}) domestic exporters (b_{xit-1}) and of the ne^{end}_{nxt-1} non-exporters (b_{nxit-1}), respectively. The worker then purchases consumption (C_{wt}), and updates its corporate bond investment to the ($n_{xt-1} + ne_{xt}$) domestic exporters and n^{begin}_{nxt} domestic non-exporters with a price at $\frac{1}{R_t}$. Note that, workers are indifferent to the bonds issued by non-exporters or exporters as these two types of bonds bear identical risks and identical prices. Later we will explain more about this.

The period budget constraint may thus be written as

$$C_{w,t} + \frac{\left(n_{xt-1} + ne_{xt}\right) b_{xt}}{R_t} + \frac{n_{nxt}^{begin} b_{nxt}}{R_t} \leq w_t \mathrm{L}_t + n_{xt-1} b_{xt-1} + n_{nxt-1}^{end} b_{nxt-1} \; .$$

From the constraint, we see that worker receives financial income from the n_{xt-1} surviving exporters and n_{nxt-1}^{end} surviving non-exporters from last period, but purchases corporate bonds from the n_{xt-1} surviving exporters, the ne_{xt} new exporters and the n_{nxt}^{begin} non-exporters.

The worker maximizes his expected lifetime utility subject to the budget constraint, leading to the following first-order conditions:

$$U_{C_{wt}} w_t + U_{Lt} = 0 \tag{19}$$

$$\beta(1-\lambda) E_t \left[U_{C_{wt+1}} R_t \right] = U_{C_{wt}} \tag{20}$$

where Eq. (19) is the labor-consumption tradeoff condition, and Eq. (20) is the Euler equation for holding exporter and non-exporter bonds. As household is indifferent between the bonds issued by exporter and non-exporter, Eq. (20) applies to both types of home firms.

3.3 Investor preferences and optimization

The representative investor derives utility from consuming the basket of final goods (C_{It}) in each period, and maximizes his expected lifetime utility:

$$\max\ E_0 \sum_{t=0}^{\infty} \beta_I^t U(C_{It}), \qquad with \qquad U(C_{I,t}) = \frac{C_{It}^{1-\rho_I}}{1-\rho_I},$$

where $\rho_I > 0$ is the investor's degree of risk aversion, and $\beta_I \in (0,1)$ is the investor's discount factor.

The investor makes equity investment in domestic intermediate firms. He purchases equities of the n_{xt-1} surviving exporters, the ne_{xt} new exporters and the n_{nxt}^{begin} non-exporters, and receives incomes from last period equity investment on the n_{xt-1} surviving exporters and the n_{nxt-1}^{end} surviving non-exporters. The period budget constraint may thus be written as:

$$C_{It} + \left(n_{xt-1} + ne_{xt}\right) q_{xt} s_{xt} + n_{nxt}^{begin} q_{nxt} s_{nxt} \le n_{xt-1} s_{xt-1} \left(q_{xt} + d_{xt}\right) + n_{nxt-1}^{end} \left(q_{nxt} + d_{nxt}\right) \quad (21)$$

where s_{xt} and s_{nxt} are the stock shares purchased from exporters and non-exporters respectively, q_{xt}, q_{nxt}, are the market stock prices, and d_{xt} and d_{nxt} are the dividends received from owning shares issued by domestic exporters and non-exporters respectively, all in units of final goods. As intermediate firms are fully owned by domestic investor, $s_{xt} = s_{nxt} = 1$ in equilibrium.

The optimization implies the following first-order conditions:

$$\beta_I (1-\lambda) E_t \left[U_{C_{It+1}} \left(q_{xt+1} + d_{xt+1} \right) \right] = U_{C_{It}} q_{xt} \quad (22)$$

$$\beta_I (1-\lambda) E_t \left[U_{C_{It+1}} \left(q_{nxt+1} + d_{nxt+1} \right) \right] = U_{C_{It}} q_{nxt} \quad (23)$$

where Eqs. (22-23) are the Euler equations for holding shares issued by domestic exporters and non-exporters.

As in Perri and Quadrini (2016), we assume that the investor is less patient than worker, $\beta_I < \beta$. Because firms are owned by the investor, the higher discounting rate of investor implies that in equilibrium firms borrow from the worker.

3.4 Intermediate goods sector

3.4.1 Enforcement constraint

Each intermediate firm issues one-period corporate bonds (denoted by b_{xit} for exporters, or b_{nxit} for non-exporters) or adjusts their dividend payouts (denoted by d_{xit}, or d_{nxit}) to maximize their firm values. As the investor (equity holder) is less patient than the worker (debt holder), firms prefer debt financing to equity financing (in steady state) because the cost of external financing through bond issuance is lower than the cost through equity issuance.

In addition to the inter-period corporate bonds, each firm also borrows an intra-period loan at the amount of $w_t l_{xit}$ or $w_t l_{nxit}$ as labor market requires working capital being paid before the realization of revenue. The intra-period loan is repaid at the end of the period and there is no interest. As firms may default on the intra-period loan repayments, their borrowing is restricted by the firm's end-of-period equity value perceived by the credit market:

$$\xi_t E_t(m_{t+1} V_{xit+1}(b_{xit})) \geq w_t l_{xit} \tag{24}$$

$$\xi_t E_t(m_{t+1} V_{nxit+1}(b_{nxit})) \geq w_t l_{nxit} \tag{25}$$

where $m_{t+1} = \beta_I (1-\lambda) \frac{U_{CI,t+1}}{U_{CI,t}}$ is the discount factor as the firms are essentially owned by the investor through equity purchases, and $E_t(m_{t+1} V_{xit+1})$ (or $E_t(m_{t+1} V_{nxit+1})$) is the firm's end-of-period equity value.[2] The lenders are willing to lend only if the perceived liquidation value of the equity asset ($\xi_t E_t(m_{t+1}V_{xit+1})$ or $\xi_t E_t(m_{t+1}V_{nxit+1})$) in case of default is sufficient to cover the loaned amount ($w_t l_{xit}$ or $w_t l_{nxit}$). Note that, the liquidation value of equity asset is determined not only by the firm's end-of-period equity value but also by the liquidity of the credit market, captured by the stochastic variable ξ_t and $\xi_t < 1$ due to liquidation loss. When the credit market condition worsens (ξ_t falls), lenders might have difficulty in liquidating the firm asset and consequently impose tighter constraints on firm borrowing.

3.4.2 Incumbents' production and pricing

The variety (y_{nxit}) produced by non-exporters will be used domestically for consumption (c_{nxit}) and for entry investment (i_{nxit}). The resource constraint for non-exporters is thus given by:

$$y_{nxit} = c_{nxit} + i_{nxit} . \tag{26}$$

The variety (y_{xit}) produced by exporters will serve two markets for two purposes, the domestic market (y_{dxit}) for consumption (c_{dxit}) and for entry investment (i_{dxit}), and the foreign market (y^*_{hxit}) for consumption (c^*_{hxit}) and for entry investment (i^*_{hxit}). When shipping abroad, only a fraction $1-\eta \in [0,1]$ of the exports will arrive at the destination. The resource constraint for exporters is thus

[2] The idea with financially constrained working capital needs is not new, and can be widely seen in literature, such as in Jermann and Quadrini (2009, 2012). The collateral constraint is not derived from an optimal credit contract. Instead, it may come from the limited enforcement that prevents lenders from collecting more than a certain fraction of the firm's collateral asset value.

given by:

$$y_{xit} = y_{dxit} + y^*_{hxit}. \tag{27}$$

where

$$y_{dxit} = c_{dxit} + i_{dxit}. \tag{28}$$

$$y^*_{hxit} = \frac{c^*_{hxit} + i^*_{hxit}}{1-\eta}. \tag{29}$$

Each firm produces a unique variety, requiring only one factor, labor. The production functions are thus:

$$y_{xit} = A_t l_{xit}, \tag{30}$$

$$y_{nxit} = A_t l_{nxit}, \tag{31}$$

where A_t is the aggregate productivity common to all firms, and l_{xit} (or l_{nxit}) is the input of labor by exporter (or non-exporter) i.

Firm dividends are given by:

$$d_{xit} = \pi_{dxit} + \pi^*_{hxit} - \left(b_{xit-1} - \frac{b_{xit}}{R_t} \right), \tag{32}$$

$$d_{nxit} = \pi_{nxit} - \left(b_{nxit-1} - \frac{b_{nxit}}{R_t} \right), \tag{33}$$

where the operation profits π_{dxit}, π^*_{hxit}, π_{nxit} are defined as:

$$\pi_{dxit} = \frac{p_{dxit}}{P_t} y_{hxit} - w_t \frac{y_{dxit}}{A_t}, \tag{34}$$

$$\pi^*_{hxit} = \frac{p^*_{hxit}}{P_t} y^*_{hxit} (1-\eta) - w_t l^*_{hxit}, \tag{35}$$

$$\pi_{nxit} = \frac{p_{nxit}}{P_t} y_{nxit} - w_t l_{nxit}. \tag{36}$$

The value functions of the firms, representing the beginning of period firm value before dividends are paid, are thus,

$$V_{xit}\left(b_{xit-1}\right) = \max_{p_{dxut},\, p^*_{hxit},\, b_{xit}} \{d_{xit} + E_t(m_{t+1}V_{xit+1}\left(b_{xit}\right))\}\,, \qquad (37)$$

$$V_{nxit}\left(b_{nxit-1}\right) = \max_{p_{nxit},\, b_{nxit}} \{d_{nxit} + E_t(m_{t+1}V_{nxit+1}\left(b_{nxit}\right))\}\,. \qquad (38)$$

The last term in brackets is the end of period firm value, which is also the measure of equity prices: $q_{xit} = E_t\left(m_{t+1}V_{xit+1}\left(b_{xit}\right)\right)$ and $q_{nxit} = E_t(m_{t+1}V_{nxit+1}\left(b_{nxit}\right))$. Exporter (non-exporter) i chooses the price levels sold in home and in foreign countries, p_{dxit}, p^*_{hxit} (p_{nxit}), and its issue of debt, b_{xit} (b_{nxit}), to maximize its firm value, Eq. (37) (Eq.(38)), subject to the enforcement constraint, Eq. (24) (Eq. (25)), the resource constraint, Eq. (27-29) (Eq. (26)), the production function, Eq. (30) (Eq. (31)), the dividend equation, Eq. (32) (Eq. (33)), and the demand for individual varieties, Eqs. (10-11) and (17-18) (Eqs. (9) and (16)).

The optimization implies the following pricing rules and the multiplier associated with the enforcement constraint:

$$\frac{p_{dxit}}{P_t} = \frac{\sigma}{\sigma-1}\frac{w_t}{A_t}\left(1+\mu_{xit}\right), \qquad (39)$$

$$\frac{p^*_{hxit}}{P_t} = \frac{\sigma}{\sigma-1}\frac{w_t}{\left(1-\eta\right)A_t}\left(1+\mu_{xit}\right) \quad , \qquad (40)$$

$$\frac{p_{nxit}}{P_t} = \frac{\sigma}{\sigma-1}\frac{w_t}{A_t}\left(1+\mu_{nxit}\right), \qquad (41)$$

$$\mu_{xit} = \frac{\dfrac{1}{R_t} - E_t m_{t+1}}{\xi_t E_t m_{t+1}}, \qquad (42)$$

$$\mu_{nxit} = \mu_{xit}\,, \qquad (43)$$

where μ_{nxit} and μ_{xit} are the Lagrange multipliers associated with the enforcement constraint for non-exporters and exporters, respectively. As the investor is indifferent between the bonds issued by exporters and non-exporters, the two multipliers are identical. The multiplier is the shadow price of the intra-period loan on firm value and measures the relative cost of bond financing ($1/R_t$) to equity financing ($E_t m_{t+1}$) for a financially constrained firm adjusted by the financial market condition. When a firm increases its bond issuance, it raises dividend payout today but simultaneously suffers an opportunity cost of tightening financial constraint due to falling equity value.

The enforcement constraint, Eqs. (24-25), shows that a firm can relax its constraint by reducing its bond issuance today. The benefit from bond reduction is two-fold. First, according to the firm value Eqs. (37-38), a one unit drop of debt issuance today would increase the firm's end-of-period value by an amount of $E_t m_{t+1}$. Second, the rise in end-of-period value would increase the firm's borrowing capacity on working capital by an amount of $\xi_t E_t m_{t+1}$.

However, there is also a cost of bond issuance reduction as it reduces the firm's cash flow and hence reduces the firm's beginning-of-period value by an amount of $\frac{1}{R_t}$. To what degree the enforcement constraint would be relaxed relies on the direct benefit and cost of debt reduction on firm value ($\frac{1}{R_t} - E_t m_{t+1}$) and the associated contribution to working capital finance ($\xi_t E_t m_{t+1}$).

The presence of the enforcement constraint adds a wedge term, $1+\mu_{xt}$ (or $1+\mu_{dt}$), to a typical pricing rule, as shown in Eqs. (39-41). The wedge term represents the credit channel introduced by the financing constraint. As shown in Eq. (42), a worsening financing condition (a fall in ξ_t) is associated with a rising μ_t, which implies a rising goods price according to Eqs. (39-41), holding all else constant. In other words, an adverse financial shock lowers liquidation value of a firm and makes its enforcement constraint tighter, thus a firm sets a higher price because its effective marginal costs increase.

3.4.3 New exporters' production and pricing

As we stated in Section 3.1, among the $1-n_{xt-1}$ non-exporters at the beginning of period t, ne_{xt} will become new exporters, so these new exporters have a matured debt position the same as their non-exporter counterparts. To enter the export market, these new exporters must pay a sunk entry cost K_t^E, and then they face enforcement constraints, make production and financing decisions like their incumbent exporter counterparts.

For a marginal non-exporter who decides to become exporters, his/her firm value is as follows:

$$V_{nxit}\left(b_{nxit-1}\right)=\max_{p_{dxit}^{new},p_{xit}^{*new},b_{xit}^{new}}\begin{Bmatrix} d_{nxit}+E_t(m_{t+1}V_{nxit+1}\left(b_{nxit}\right)) \\ d_{xit}^{new}+E_t(m_{t+1}V_{xit+1}\left(b_{xit}^{new}\right)) \end{Bmatrix}$$

where the retained earnings d_{xit}^{new} is given by:

$$d_{xit}^{new}=\pi_{nxit}+\pi_{hxit}^{*new}-b_{nxit-1}+\frac{b_{xit}^{new}}{R_t}-\frac{P_{It}}{P_t}K_t^E . \tag{44}$$

with that $\pi_{hxit}^{*new}=\dfrac{p_{hxit}^{*new}}{P_t}y_{hxit}^{*new}\left(1-\eta\right)-w_t l_{hxit}^{*new}$.

The marginal firm will be indifferent between the choices of being exporter and being non-exporter, implying that:

$$d_{nxit}+E_t(m_{t+1}V_{nxit+1}\left(b_{nxit}\right))=\pi_{nxit}+\pi_{hxit}^{*new}-b_{nxit-1}+\frac{b_{xit}^{new}}{R_t}-\frac{P_{It}}{P_t}K_t^E+E_t\left(m_{t+1}V_{xit+1}\left(b_{xit}^{new}\right)\right)$$

After a few steps of transformation, we have the free entry condition as follows:

$$\frac{P_{It}}{P_t}K_t^E=E_t(m_{t+1}\left(\pi_{hxit+1}^{*new}+\frac{P_{It+1}}{P_{t+1}}K_{t+1}^E\right))+\left(\frac{1}{R_t}-E_t m_{t+1}\right)\left(b_{xit}^{new}-b_{nxit}\right) \tag{45}$$

The value of the new exporter is thus given by:

$$V_{it}^{new}\left(b_{nxit-1}\right) = d_{xit}^{new} + E_t\left(m_{t+1}V_{xit+1}\left(b_{xit}^{new}\right)\right). \quad (46)$$

We allow for the possibility of a congestion externality associated with firm entry[3]:

$$K_t^E = \bar{K}^E\left(\frac{ne_{xt}}{ne_{xt-1}}\right)^{\tau}. \quad (47)$$

Here, $\bar{K}^E$ is the steady state level of sunk entry costs, and ne_{xt} describes the number of new exporters who compete with each other in entering the export market. This functional specification of entry costs has been motivated in terms of an imperfectly elastic supply of a factor specific to product entry such as advertising.

We now turn to the financing and pricing/production decision of the new exporters. Just as for the existing exporters, the new exporters maximize the beginning-of-period firm value (Eq. 46, in this case) subject to the retained earnings equation, (Eq. 44), the enforcement constraint facing exporters, (Eq. 24), and the demand for individual varieties, Eqs. (10-11) and (17-18). Because the enforcement constraint here is not affected by the initial bond position, the first order conditions are the same as for an existing exporter (Eqs. 39-42). We thus conclude that the choice variables of the new exporters are the same as for the incumbents: $b_{xit}^{new} = b_{xit}$, $p_{dxit} = p_{dxit}^{new}$, $\mu_{xit} = \mu_{xit}^{new}$. From the demand equations for individual varieties, that is,

[3]See also Bergin and Lin (2012) and Lewis (2009) for discussions of this model feature. Our functional specification of entry costs more closely resembles that in Lewis (2009) in specifying the rise in entry cost as a function of the number of new entrants, motivated in terms of an imperfectly elastic supply of a factor specific to product entry such as advertising. Bergin and Lin (2012) also allows for the possibility of a congestion externality in entry but specifying the rise in entry cost as a function of total number of active firms. Their specification is in line with Berentsen and Waller (2009), which was motivated using a matching externality found in Rocheteau and Wright (2005) and common in monetary search models.

Eqs. (10-11) and (17-18), we then have that market demand for the goods of new exporters is identical to that of exporters, and hence $y_{xit}^{new} = y_{xit}$, and $l_{xit}^{new} = l_{xit}$. That is, new exporters and existing exporters make identical decisions on production and financing.

3.5 Equilibrium

Shocks are common to all firms from a given country; thus, this study solves the symmetric equilibrium in which firms in the same sector from a given country behave identically. As firms of the same type hire the same amount of labor in production and labor is immobile across countries, the market clearing condition for labor is thus given by:

$$L_t = \left(1-\left(n_{xt-1} + ne_{xt}\right)\right) l_{nxt} + \left(n_{xt-1} + ne_{xt}\right) l_{xt} . \quad (48)$$

Overall consumption combines that of both the investor and worker:

$$C_t = C_{It} + C_{wt} . \quad (49)$$

Balanced trade requires:

$$\left(n_{xt-1} + ne_{xt}\right) p_{hxit}^{*} y_{hxit}^{*} = \left(n_{xt-1}^{*} + ne_{xt}^{*}\right) p_{fxit} y_{fxit} \quad (50)$$

For reference, GDP will be defined:

$$GDP_t = C_t + \frac{P_{It}}{P_t} I_t .$$

The technology and financial shocks are log-normally distributed as follows:

$$\log A_t - \log \overline{A} = \rho_A (\log A_{t-1} - \log \overline{A}) + \varepsilon_{A,t} \quad (51)$$

$$\log \xi_t - \log \overline{\xi} = \rho_{\xi} (\log \xi_{t-1} - \log \overline{\xi}) + \varepsilon_{\xi,t} \quad (52)$$

where $\varepsilon_{A,t}$ and $\varepsilon_{\xi,t}$ are technology and financing innovations, respectively, which are i.i.d. random variables with homoscedastic variances. We don't allow spillovers of shocks across borders.

Equilibrium is a sequence of the following 100 endogenous variables: n_{xt}, ne_{xt}, n_{nxt}^{end}, n_{nxt}^{begin}, P_t, P_{Ht}, P_{Ft}, p_{dxit}, p_{nxit}, p_{fxit}, C_t, C_{Ht}, C_{Ft}, c_{nxit}, c_{dxit}, c_{fxit} I_t, K_t^E, I_{Ht}, I_{Ft}, P_{It}, i_{fxit}, i_{nxit}, i_{dxit}, C_{wt}, w_t, L_t, R_t, C_{It}, q_{xt}, q_{nxt}, d_{xt}, d_{nxt}, V_{xt}, l_{xt}, V_{nxt}, l_{nxt}, y_{xt}, y_{nxt}, y_{dxt}, y_{fxt}, π_{dxt}, π_{fxt}, π_{nxt}, b_{xt}, b_{nxt}, μ_{xt}, μ_{nxt}, V_{xt}^{new}, d_{xt}^{new}, and their foreign counterparts. The 100 equilibrium conditions are Eqs. (1-49) with their foreign counterparts, the balance trade condition Eq. (50), and choice of the home consumption bundle as the numeraire: $P_t = 1$, summarized in Appendix 1.

4 Quantitative analysis

To analyze the full response paths of firm entry, equity prices and other key macroeconomic variables in response to financial shocks, we log-linearize the system around the unique deterministic steady state. We calibrate parameters and numerically solve the log-linearized model for the dynamic responses to exogenous shocks using the method of generalized Schur decomposition.

4.1 Parameter values

Table 3 lists the parameters in the benchmark setting. The two economies are symmetric in terms of parameter values. We set $\beta = 0.995$ and $\beta_I = 0.985$ to capture an annual bond return of 2% and an annual stock return of 6%. The risk aversion of the worker and the investor are set at $\rho = \rho_I = 2$ (Arellano, Bai and Kehoe, 2012). The exogenous death shock probability is set at $\lambda = 0.025$ to match the 10% annual job destruction rate in the U.S. data as documented in the literature (for instance, in Bernard et al. (2010)). We follow Ghironi and Metliz (2005), Bernard et al. (2003) and Bilbiie, Ghironi and Melitz (2012) in setting the elasticity of substitution among all varieties, both domestic and imported, to $\sigma = 3.8$. The same calibration is used for the aggregation of goods for use in investment: $\phi = 3.8$.

The relative utility weight of labor is set at $\kappa = 3.409$ and the inverse of Frisch labor supply elasticity is set at ψ =0.5 to capture an elasticity of 2, which is used in Arellano, Bai and Kehoe (2012) and is in the range commonly estimated in micro- and macroeconomic work as reported by Rogerson and Wallenius (2009).

Sunk entry costs and iceberg costs are set to imply jointly a steady state where 21% of firms export (from Ghironi and Melitz, 2005) and exports represent 18% of GDP, taken from author calculations as the average for OECD counties in the Comtrade data base. This implies $\bar{K}^E = 1.5$ and $\eta = 0.014$. The entry adjustment cost curvature parameter is calibrated at $\tau = 4.2$ as in Bergin and Lin (2012). Given limited evidence on the share of imports in export entry investment expenditure, we will consider the full range of values in sensitivity analysis in Section 4.3.1; the benchmark version will specify international market entry cost takes the form of all imported goods.

As our focus is on the impact of financial shocks on trade persistence, we fix the technology shock at its mean level, that is, $\bar{A} = 1$ without loss of generality. Parameter values for financial shocks are taken from Jermann and Quadrini (2012). A period is identified as a quarter, and the mean and the persistence of financial shock are set at $\bar{\xi} = 0.1634$, and $\rho_{\xi} = 0.1634$, respectively. For purposes of simulation, $\sigma_{\xi} = 0.05$ in order to replicate the drop in real US GDP during the 2007-9 financial crisis.

4.2 Impulse responses for the benchmark model

The impulse responses for a global financial shock impacting the home and foreign country in the benchmark model specification are reported in Fig. 4. The magnitude of the shock is set to replicate the approximately 5% fall in US GDP. following the 2007-9 financial crisis. Falling collateral value due to the worsening credit makes it harder for firms to finance working capital to hire workers for production. As a result, labor demand falls, lowering wages and employment, as seen in the figure. Since workers invest in corporate bonds, the drop in their income also raises firms' financing cost through bond issuance. As market demand for individual varieties falls, firms' production and sales drop as well. Although the falling wage to a certain degree compensates firms' market stance in terms of reducing their production cost, firms expect less profit from worse aggregate economy, which is reflected in falling equity values, reported in the figure as an average over all home firms. All these variables return fairly quickly to their long run steady states as the shock dissipates.

The figure shows a pronounced fall in exports in the initial periods, larger in magnitude than the fall in GDP. The ratio of the change in exports to that in GDP is 3.0, which is quite close to the ratio of 3.8 observed for U.S. data during the financial crisis. The other striking feature of the impulse response in exports is that its fall is also much more persistent than that in GDP. In fact, after a fairly quick partial recovery, exports linger below the steady state for a very long period of time. This behavior is similar to that observed in the empirical VAR above. To understand the model's ability to generate this particular combination of short run and long run dynamics, we must first explain the dynamics of firm financing and firm entry, which we turn to next.

Important to our argument, firms respond to the worsening credit market with a strategy of capital restructuring. They reduce bond issuance and postpone dividend payouts today, as observed in the figure. This moderates the fall in equity value and hence helps ease the tightening financial constraint. Given that firms are switching from previously cheaper bond financing to relatively more expensive equity financing, this capital restructuring increases the effective entry cost in the export entry condition faced by potential non-exporters who are otherwise willing to become exporters. This leads to the substantial fall in entry to the export market observed in Fig. 4, which is consistent with what was observed in the empirical VAR for the extensive margin of trade. Previous work in Bergin et al. (2016) has shown that a transitory fall in expected future firm profits is not sufficient to generate the large fall in firm entry observed during the financial crises, as it has too small effect on the total present discounted value of all future firm profits in the entry condition, Eq. (45). Our model reproduces the large fall in firm entry instead by explaining how the shock affects the effective sunk entry cost, which also appears in the entry condition.

A prominent feature observed in the empirical impulse responses in section 2 was a gradual but persistent fall in the extensive margin. This persistence is consistent with what we see in Fig. 4. While persistence arises in part from the congestion externality noted above, it also arises from the fact that the investment price index rises progressively over time, as seen in the figure. In the benchmark model the investment price index, which is the same as the import price index, rises due to the fall in the number of traded varieties available as imports, akin to a love of variety effect. We thus see a vicious circle in which a fall in export entry in both countries resulting from the global financial shock makes the cost of entry higher, which further reduces entry for future periods, which raises the entry cost further, etc. The figure demonstrates that this mechanism can be a powerful propagation channel.

These dynamics of the extensive margin of trade now help us understand the dynamics of total exports in the model. First, the short run fall in trade in the periods after the shock is particularly steep in part due to the dramatic fall in investment demand for imports coming from the dramatic fall in firm entry investment. This reflects the common mechanism in intertemporal models that investment, due to its volatility and greater concentration in traded goods, tends to be a prominent source of trade dynamics.[4] In the present model, investment takes the form of firm entry costs. In addition, as the number of imported varieties shrinks relative to domestic varieties in the overall consumption index, given that our elasticity of substitution between all varieties is the same regardless of country of origin, a fall in extensive margin translates into a nearly proportionate fall in trade as a share of consumption expenditure. For both these reasons, the fall in investment and consumption demand for imports, the fall in extensive margin contributes to the short run fall in trade.

Second, the fact that the extensive margin remains below its steady state value for a very long time explains the very persistent effect on trade in the long run. Again, the fact that firm entry remains below its steady state for a long time means there is prolonged shortfall in investment demand for imports and progressively rising investment price. And again, the fact the number of firms remains below steady state for a very protracted time means the share of import varieties in the overall consumption bundle remains low, so trade remains low as a share of overall consumption.

While the benchmark experiment focuses on a global shock impacting both countries symmetrically, Fig. 5 reports dynamics for a shock hitting just the home country. The persistence in exports is even more extreme in this case, with almost no

[4] See Boileau 1999, Eaton and Kortum 2001, Engel and Wang 2011, and Alessandria et al. (2010).

tendency for the long run effect to dissipate. However, the magnitude of the effect in the initial periods now is smaller than in the benchmark case and smaller than the change in home GDP in percentage terms. The reason is that the fall in the variety of home exports affects the price index of foreign rather than home investment. Further the shock does not lead to a fall in foreign GDP or foreign firm export entry, as the fall in wages is able to compensate for the loss of variety in the foreign investment price index. This example illustrates that goods market linkages are not enough to strongly transmit a financial shock, and more complex international financial linkages would be required.[5] Given that international transmission is a challenging current research question in its own right and not the purpose of this study, we will continue to focus on a symmetric global shock in the subsequent experiments.

4.3 Sensitivity Analysis

4.3.1 Share of imports in investment goods

As there is no clear evidence to use in calibrating the share of imports in new firm entry investment, θ, it is appropriate to conduct sensitivity analysis for this parameter. Fig. 6 reports impulse responses for a version of the model that makes the opposite assumption to that in our benchmark economy, assuming no imported goods in the investment goods bundle ($\theta = 1$). The fall in exports is smaller in magnitude than in the benchmark model, no more volatile than GDP, and the degree of persistence appears to be less, though exports are still somewhat more persistent than GDP. These export dynamics reflect the smaller magnitudes and persistence in the extensive margin, and the fact that the investment price index now falls, given that it

[5] For example, international banks as in Kollmann et al. (2011)

does not include import prices.

One way to quantify the persistence in exports is to look at the impulse response value at the ten year mark after the shock, given that we are now about ten years after the financial crisis. We take this value as a ratio to the maximum (in absolute value) impulse response value. As a gauge, the empirical VARs in section 2 imply a persistence ratio of either 0.16 or 0.22 for overall trade, depending on what definition of the shock is used. The benchmark model implies a very generous degree of persistence, with a ratio of 0.45 of the impact effect lasting 10 years. The model of Fig. 6 with no imports in investment implies a persistence ratio of 0.15, which is a bit shy of the range implied by the empirical VARs.

To fill in the picture for the middle range, Fig. 7a plots the persistence ratio for versions of the model that calibrate the import share θ for value in between 0 and 1. The figure shows that to achieve the degree of persistence in the empirical VAR the model requires a modest share of imports in the investment bundle ($1-\theta$) of 60% at the upper range, down to as little as 20%. While there is no clear evidence regarding the empirically plausible value for this parameter, Cavallari (2013) chooses a 0.6 ($\theta = 0.4$) as a plausible value for the share of imports in domestic entry investment. This calibration would easily allow our model to replicate the degree of persistence in export responses to a financial shock observed in the empirical VAR. We conclude that the presence of imports in the investment bundle is important for generating the high degree of persistence observed in data, but that the share of imports need not be unreasonably high to achieve the minimum objective.

While persistence is fairly robust to a lower import content of entry investment, the impact volatility of exports is more sensitive. Fig 7b. reports the ratio of the maximum effect on exports to that in GDP, showing that it falls fairly rapidly from the value of 3 in the benchmark calibration $\theta = 0$, to levels around 1.5 for a value of

$\theta = 0.4$. Recall that the empirical VAR implied a ratio of 3.8.

4.3.2 Export goods in investment bundle

While our benchmark model specifies investment goods as a bundle biased toward home imports, one might also conjecture that the investment bundle for entry into a foreign market could alternatively be biased toward foreign imports, that is, home exported goods that the firm takes with them to the foreign destination. In principle, given that our model and shock is symmetric, our mechanism of rising import and export prices should work equally well for this specification.

To implement this idea, suppose production of investment goods for entry needs all home produced varieties, but different weights are given to the goods produced by non-exporters and by exporters, given by

$$I_t = I_{Ht} \equiv \left[\alpha_{dx}^{\frac{1}{\phi}} \int_0^{n_{xt-1}+ne_{xt}} i_{dxit}^{\frac{\phi-1}{\phi}} di + \left(1-\alpha_{dx}\right)^{\frac{1}{\phi}} \int_{n_{xt-1}+ne_{xt}}^{1} i_{nxit}^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}},$$

where α_{dx} is the degree of bias to exporter produced goods. The corresponding investment price index is then given by

$$P_{It} = \left[\alpha_{dx} \left(n_{xt-1} + ne_{xt}\right) p_{dx}^{1-\phi} + \left(1-\alpha_{dx}\right)\left[1-\left(n_{xt-1}+ne_{xt}\right)\right] p_{nx}^{1-\phi} \right]^{\frac{1}{1-\phi}}, \qquad (53)$$

and the implied relative demand functions for home country are

$$i_{nxit} = \left(1-\alpha_{dx}\right)\left(\frac{p_{nxit}}{P_{It}}\right)^{-\phi} I_{Ht} \qquad (54)$$

$$i_{dxit} = \alpha_{dx} \left(\frac{p_{dxit}}{P_{It}}\right)^{-\phi} I_{Ht} \qquad (55)$$

Analogous conditions apply to the foreign country.

Fig. 8 reports the impulse responses where more weight is assigned to goods produced by home exporters with $\alpha_{dx} = 0.75$ and $\alpha_{nx} = 0.25$ (cases with high shares of exports proved numerically difficult to solve). Exports fall more on impact than does GDP, and exports show a greater degree of persistence, but these features are somewhat weaker than in the case of entry costs in units of imported goods. The persistence ratio reported above takes the value 0.28, less than in the benchmark case, but sufficient to match that of the empirical VARs.

4.3.3 Role of capital restructuring and congestion externality

To confirm the importance of capital restructuring to our result, we simulate a case where no intertemporal bonds are traded, and firm financing is by equity issue only. This means that firms do not respond to the financial shock by decreasing reliance on bond financing, and thus do not raise the cost of financing export entry. Fig. 9 shows that our result completely disappears in the absence of capital restructuring.[6] Firm entry now rises upon the shock rather than falling. This leads to a substantial rise in trade, as consumers have access to a wider range of imported goods varieties. This result demonstrates that capital restructuring is an absolutely essential part of our explanation for the persistent fall in trade.

Finally, we investigate the role of entry cost curvature, representing a congestion externality, summarized in the parameter τ. Fig. 10 reports impulse responses for exports for a variety of values for this parameter. The main effect is that a higher value of τ amplifies the fall in trade in the initial period. This is because the fall in new firm entry, ne_x leads to a progressively larger fall in entry cost, K^E. So even if a higher τ mutes the fall in ne_x, the even greater amplification of the fall in K^E leads to a larger fall in investment expenditure, which is the product of the two,

[6] A slightly different calibration of parameters is needed in this case in order to ensure the existence of a steady state.

$ne_x \times K^E$. The larger fall in investment expenditure then leads to a larger fall in trade. In any case, trade falls for all values of τ, and the figure shows that this parameter does not diminish the degree of long-run persistence in the effect of the shock on exports.

5. Conclusions

Recent experience has shown that a transitory financial shock can lead to lingering, persistent effects on international trade. This paper argues that this phenomenon may be understood in terms of persistent dynamics in the extensive margin of trade, arising from the decision of firm to enter the export market. Empirical evidence indicates that while the extensive margin played a small role in the dramatic initial effects of the financial shock on trade volume, it is quantitatively a greater part of the long run effect observed in data and our empirical VARs. One key element to our explanation is an endogenous capital structure decision by firms in response to the financial shock. As firms shift from cheaper bond financing toward more expensive equity financing in order to relax the collateral constraint for short-term borrowing, it raises the cost of long term financing for export entry investment. A reduction in the extensive margin translates to a lower volume of trade, as imported varieties represent a smaller share of the varieties available to consumers. This interacts with a second key element, a bias in the composition of entry investment expenditure toward imported goods. A reduction in imported varieties raises the investment price index, further raising entry cost and reducing the extensive margin in future periods.

A calibration exercise indicates that this mechanism potentially could account for a substantial share of the persistent component of the fall in trade volume observed in the wake of the financial crisis. Even reasonable shares of imports in the investment goods bundle imply a high degree of persistence of the shock on the extensive margin. This finding does not gainsay the potential role of other economic or even political factors in generating persistence. But it does suggest that the extensive margin, viewed as peripheral with regard to the dramatic trade collapse in 2007-9, warrants greater attention with regards to the persistent effects of this crisis on trade.

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Table 1. Average annual growth rates for U.S. exports

	(1) 2003-7	(2) 2009	(3) 2012-14	(4) (3) - (1)
Exports	10.1%	-19.8%	3.1%	-7.0%
Extensive margin (good-country)	2.5%	-2.3%	0.1%	-2.4%
Number of exporters	3.6%	-4.6%	0.2%	-3.4%

Source: annual data from the U.S. Census Bureau and author computations.[1]

[1] Annual exports is measured by adding up export value across all HS-level export goods. The extensive margin of exports is measured as the number of variety exported in HS disaggregated data. The same category of goods but exported to different counties are counted as different varieties. Data on HS-level U.S. exports are from Schott's International Economics Resource Page, which were purchased from the U.S. Census Bureau. Data on the number of exporters are from Profile of U.S. Importing and Exporting Companies provided by the U.S. Census Bureau.

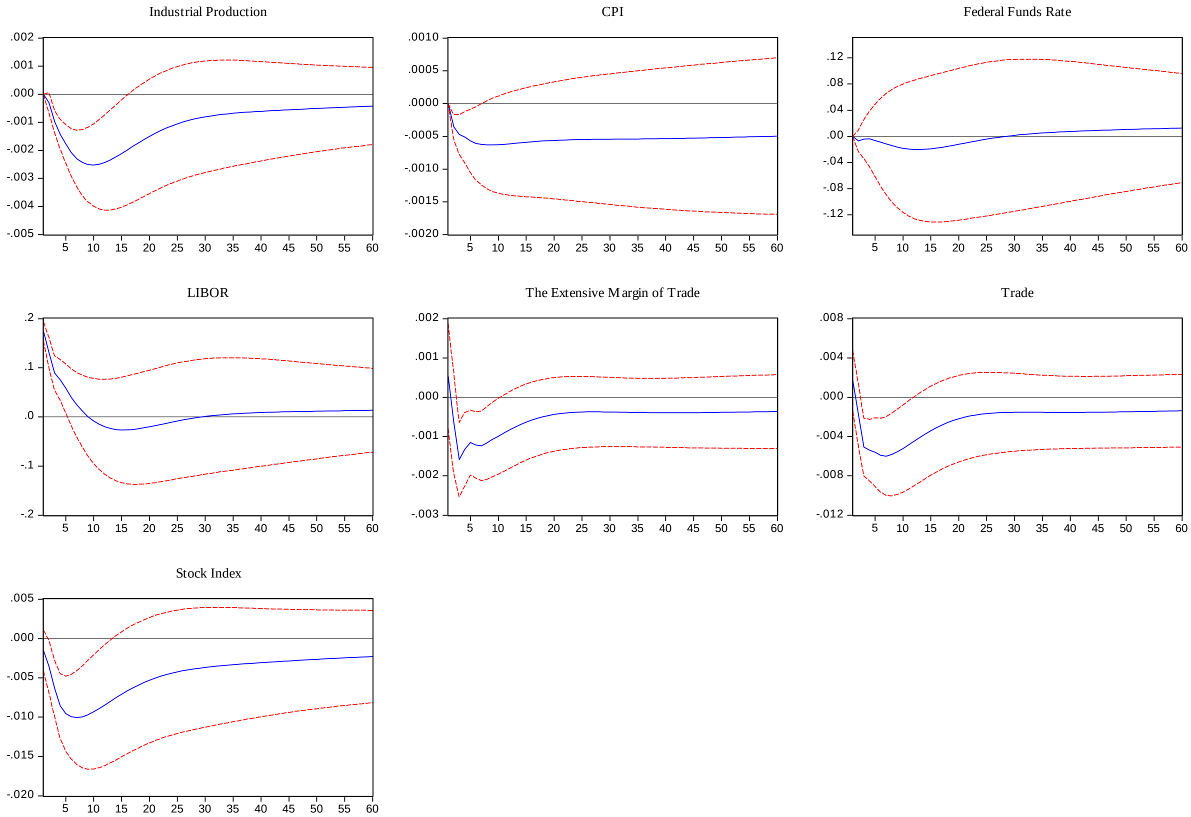
Table 2 Timeline for Home Country

<table>
<tr><th>Beginning of t</th><th>Before death shock</th><th>Death shock</th><th>Beginning of $t+1$</th></tr>
<tr><td rowspan="5">(1) Four shock variables: technology shocks (A_t, A_t^*); financial shocks (ξ_t, ξ_t^*)
(2) n_{xt-1} surviving exporters; $1-n_{xt-1}$ non-exporters among which: n_{nxt-1}^{end} survived, $1-n_{xt-1}-n_{nxt-1}^{end}$ newborns</td><td>n_{xt-1} Incumbent exporters: (1) wage payments made through intra-period loan; (2) financing choice (bond and equity issuance) and revenue realization</td><td rowspan="2">(1) Mass of exporters before death shock: $n_{xt-1}+ne_{xt}$
(2) Mass of exporters after death shock: $n_{xt}=(1-\lambda)(n_{xt-1}+ne_{xt})$</td><td rowspan="5">(1) $1-(n_{xt}+n_{nxt}^{end})$ newborns as non-exporters
(2) Repeating the whole process</td></tr>
<tr><td>ne_{xt} non-exporters becoming exporters: (1) make production and financing decisions as exporters; (2) a matured debt position as exporters</td></tr>
<tr><td>$n_{nxt}^{begin}=1-(n_{xt-1}+ne_{xt})$ non-exporters: make production and financing decisions</td><td>(3) Mass of non-exporters before death shock: $n_{nxt}^{begin}=1-(n_{xt-1}+ne_{xt})$;
(4) Mass of non-exporters after death shock: $n_{nxt}^{end}=(1-\lambda)n_{nxt}^{begin}$</td></tr>
<tr><td>Worker: Consumption and bond investment;</td><td rowspan="2">(5) Mass of all surviving firms: $n_{xt}+n_{nxt}^{end}<1$</td></tr>
<tr><td>Investor: Consumption and equity investment;</td></tr>
</table>

Table 3 Parameterization

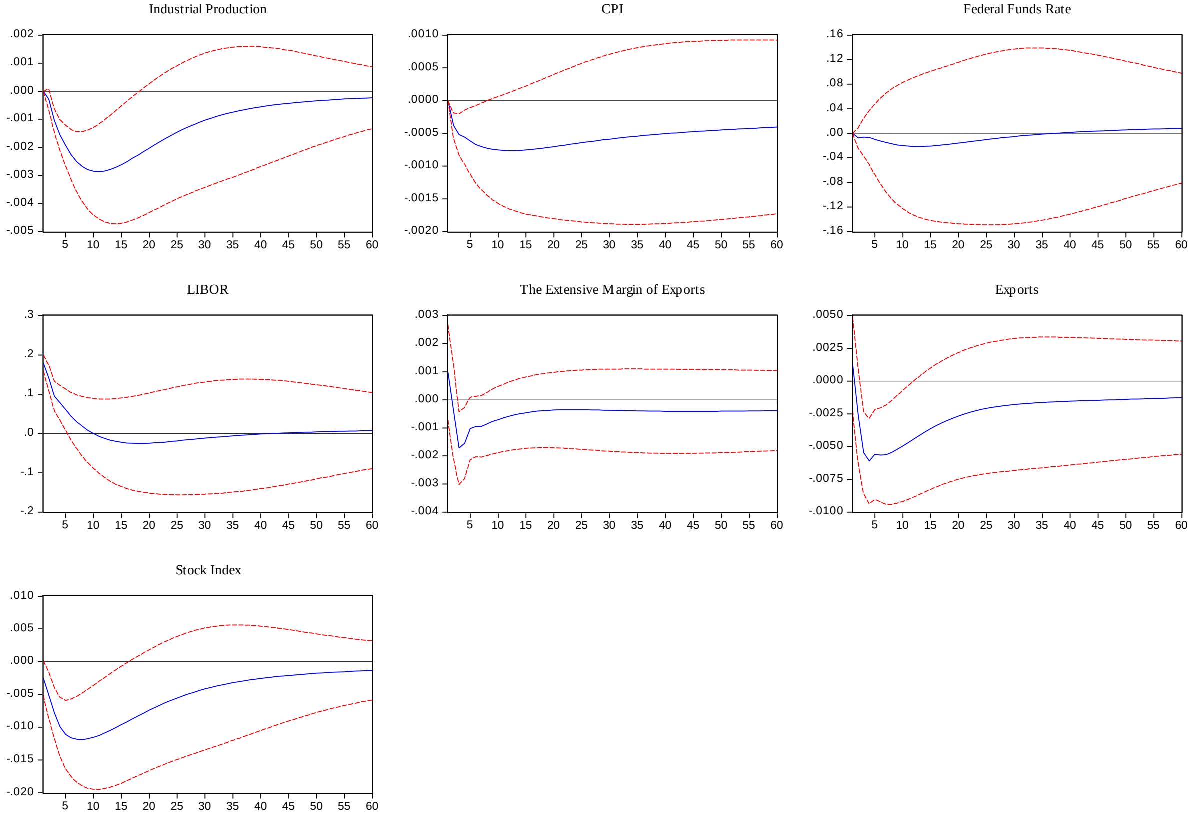
Description	
Worker Relative risk aversion	$\rho = 2$
Investor Relative risk aversion	$\rho_I = 2$
Worker discount factor	$\beta = 0.995$
Investor discount factor	$\beta_I = 0.985$
Substitution elasticity in the consumption bundle	$\sigma = 3.8$
Substitution elasticity in the investment bundle	$\phi = 3.8$
Probability of death shock	$\lambda = 0.025$
Entry costs	$K^E = 1.5$
Congestion Externality in Entry	$\tau = 4.2$
Weight of labor disutility in utility function	$\kappa = 3.409$
Inverse of labor supply elasticity	$\psi = 0.5$
Iceberg trade cost	$\eta = 0.014$
Enforcement parameter	$\bar{\xi} = 0.3$
Persistence: financing shock	$\rho_\xi = 0.97$

Fig. 1. Impulse Responses to Innovation in Interbank Rate : Trade



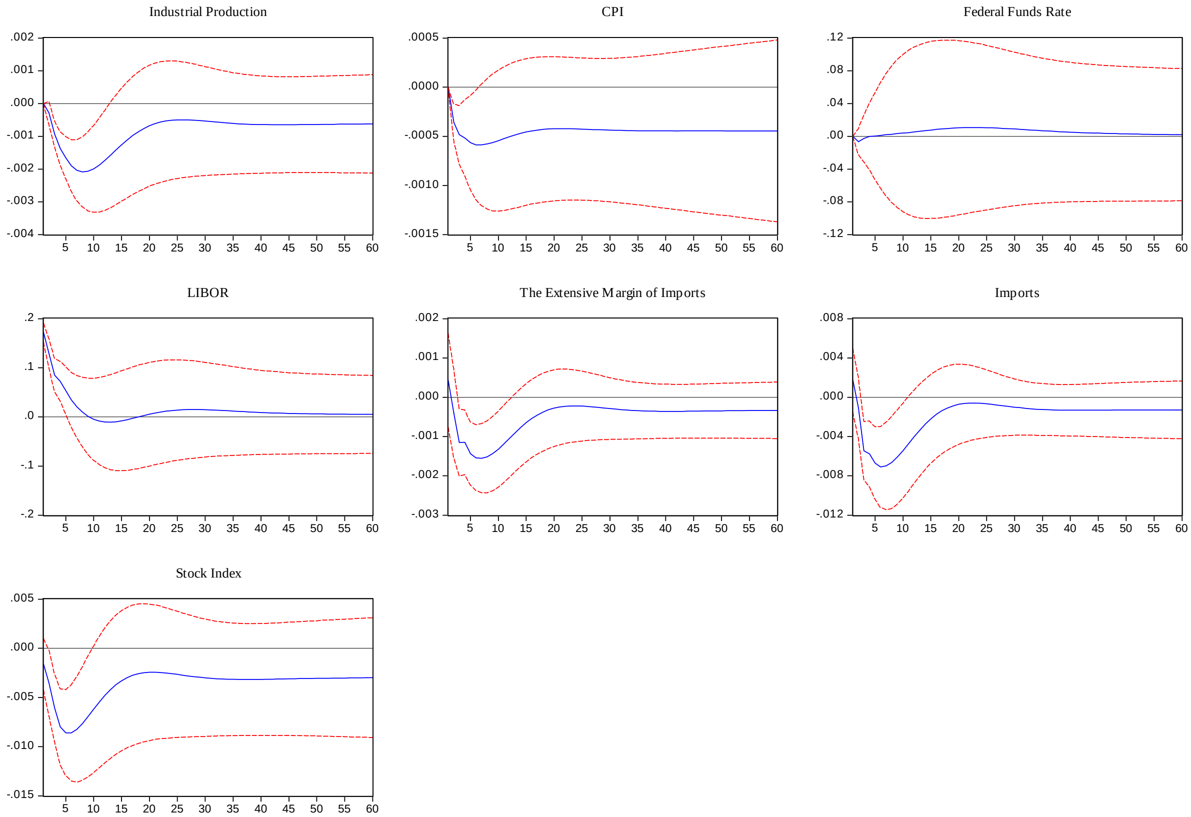
Note: Data are at monthly frequency, based on 6-digit HS disaggregate U.S. export and import flows, running from 2002:1 to 2016:11

Fig. 2. Impulse Responses to Innovation in Interbank Rate: Exports



Note: Data are at monthly frequency, based on 6-digit HS disaggregate U.S. export flows, running from 2002:1 to 2016:11

Fig. 3. Impulse Responses to Innovation in Interbank Rate: Imports



Note: Data are at monthly frequency, based on 6-digit HS disaggregate U.S. import flows, running from 2002:1 to 2016:11.

Fig. 4. Impulse Responses for benchmark theoretical model

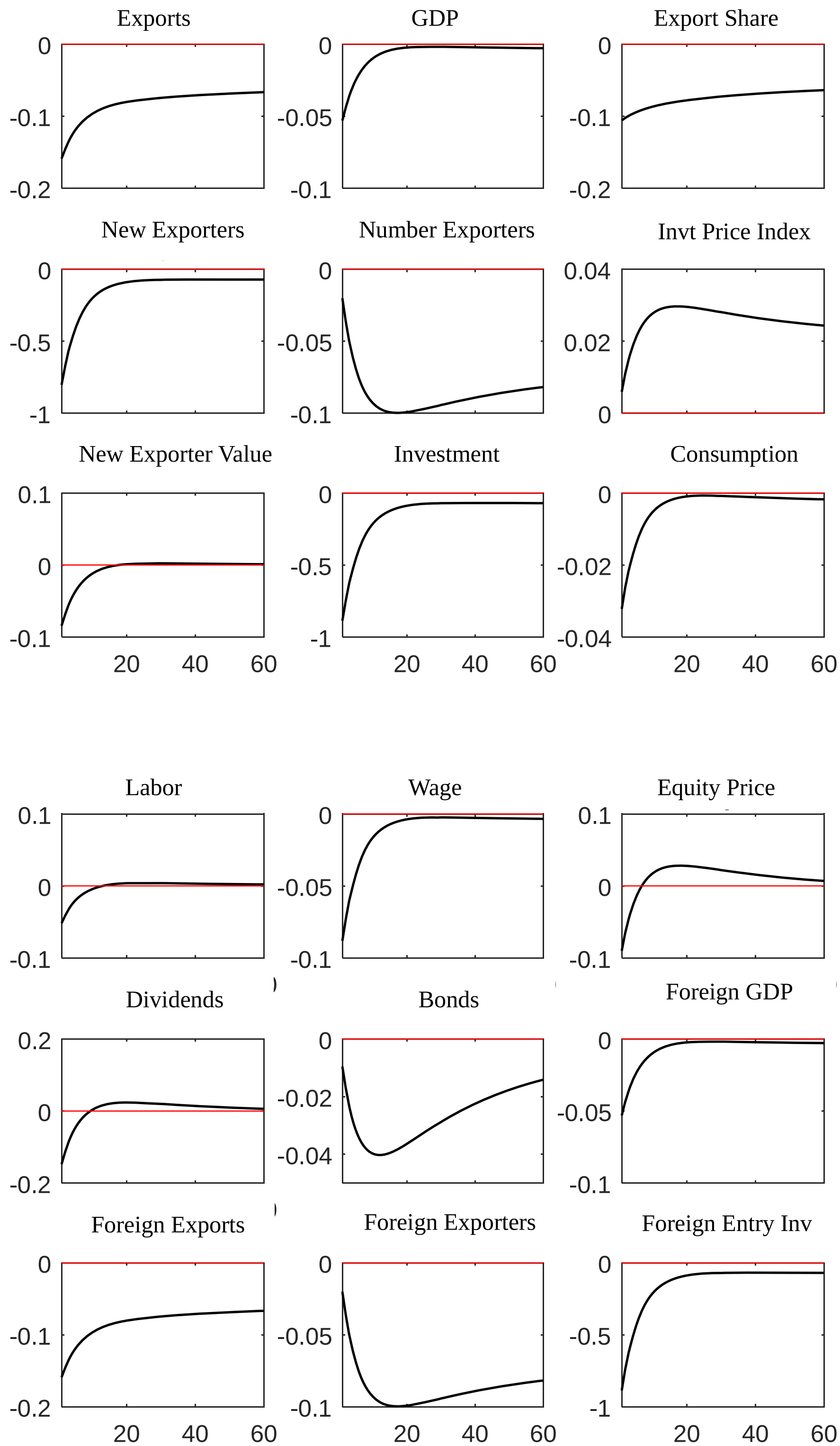


Fig. 5. Impulse Responses for benchmark theoretical model, home country shock

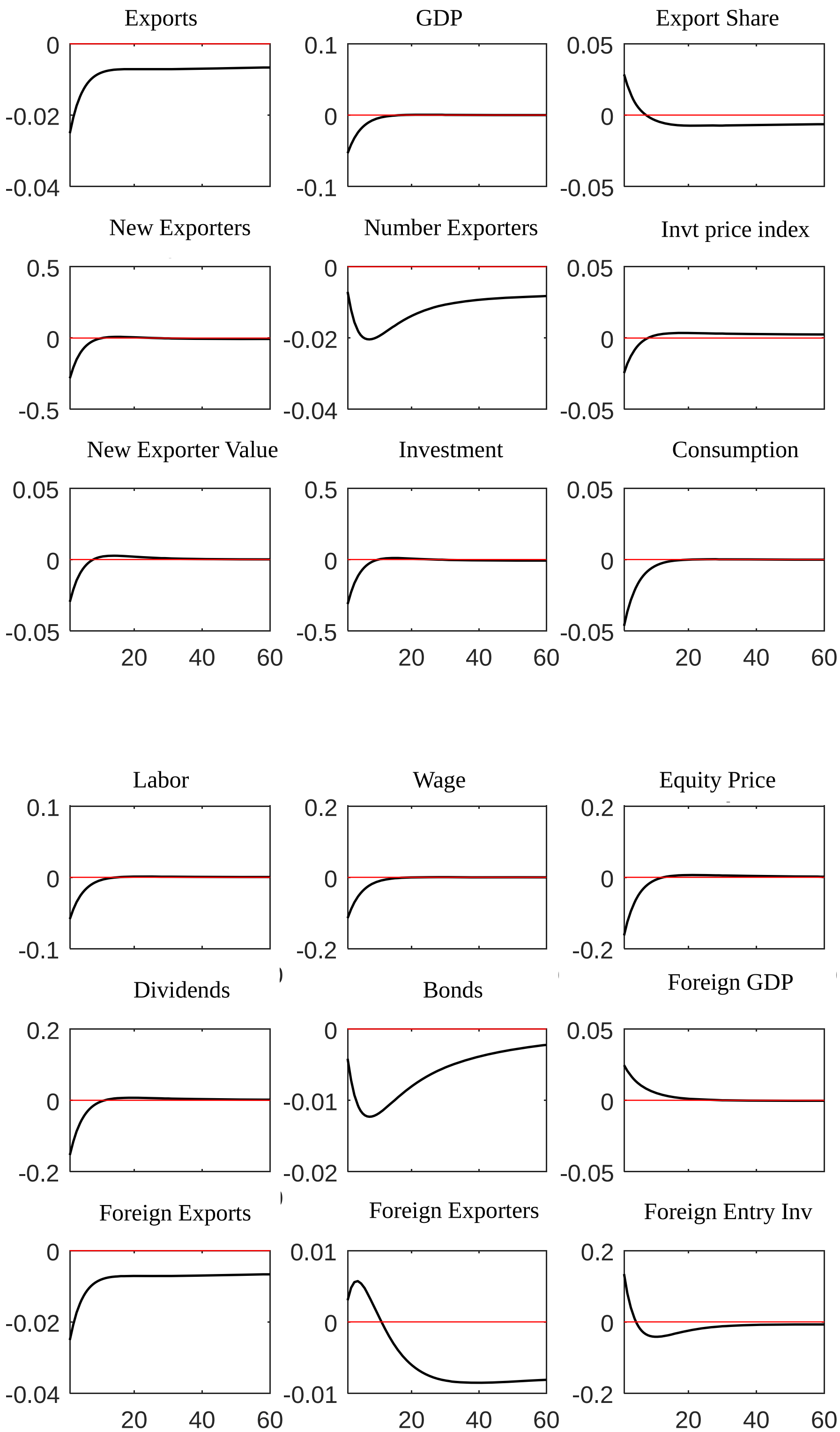


Fig. 6. Impulse Responses for model with no imported goods in investment

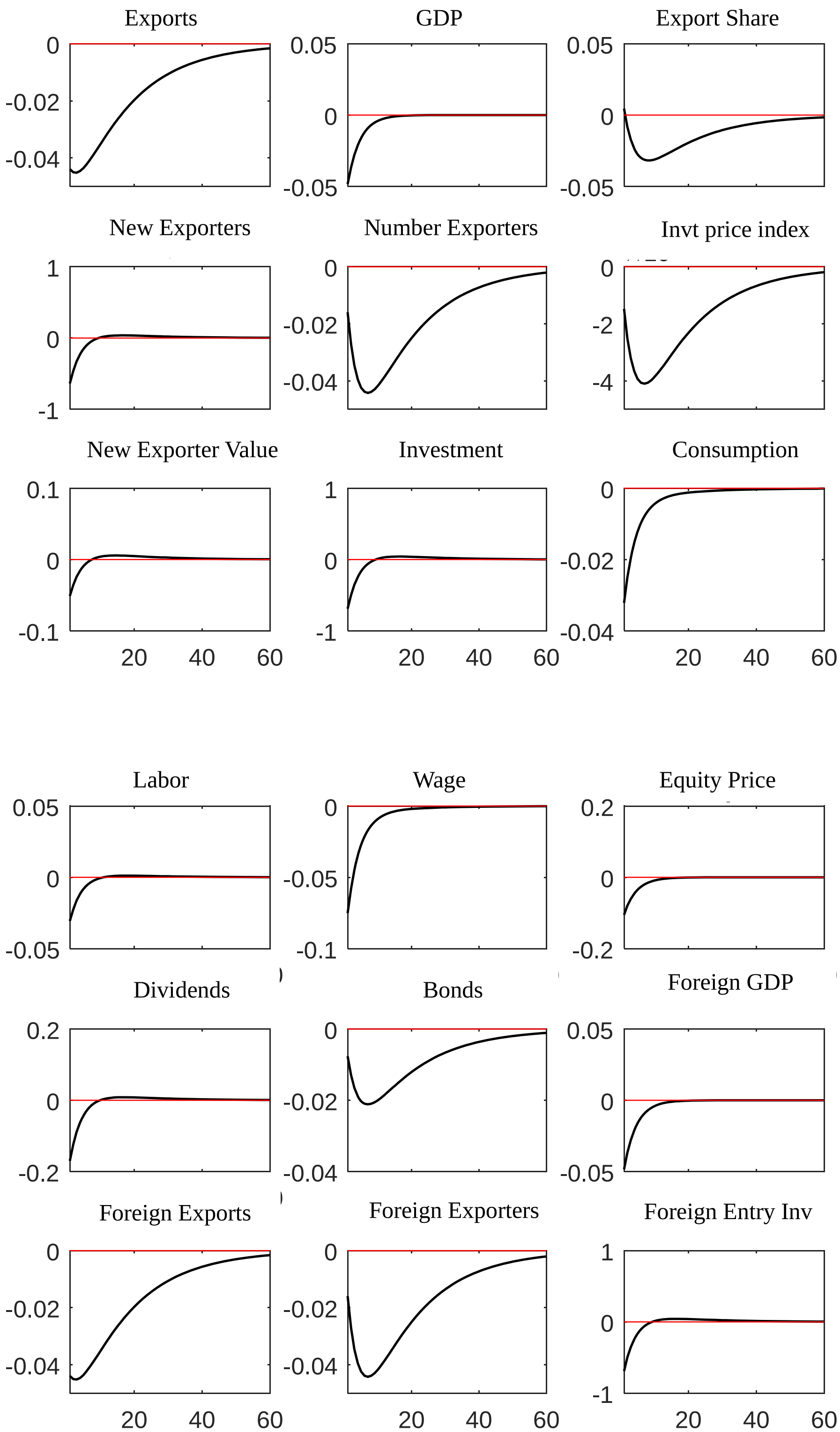


Fig. 7a. How persistence of exports dynamics varies for lower shares of trade in entry cost*

Fig. 7b. How volatility of exports varies for lower shares of trade in entry cost**

* The metric of persistence is the value of the impulse response for exports in year 10 divided by the maximum impulse response.

** The metric for volatility is the ratio of impulse response value in period 1 (the maximum effect) for exports divided by that for GDP.

Fig. 8. Impulse Responses for model with exported goods in entry investment

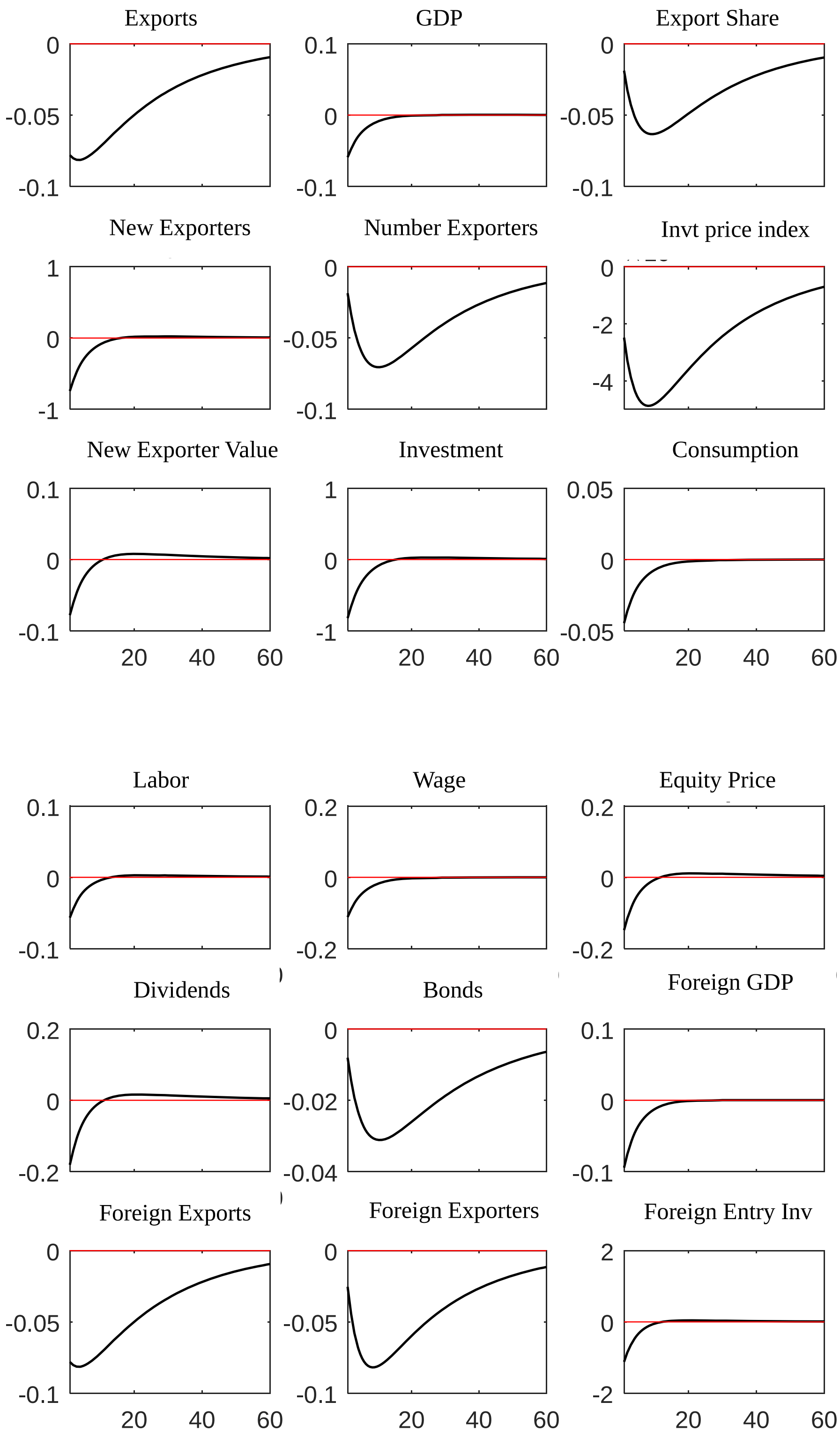


Fig. 9. Impulse Responses for model with no bonds

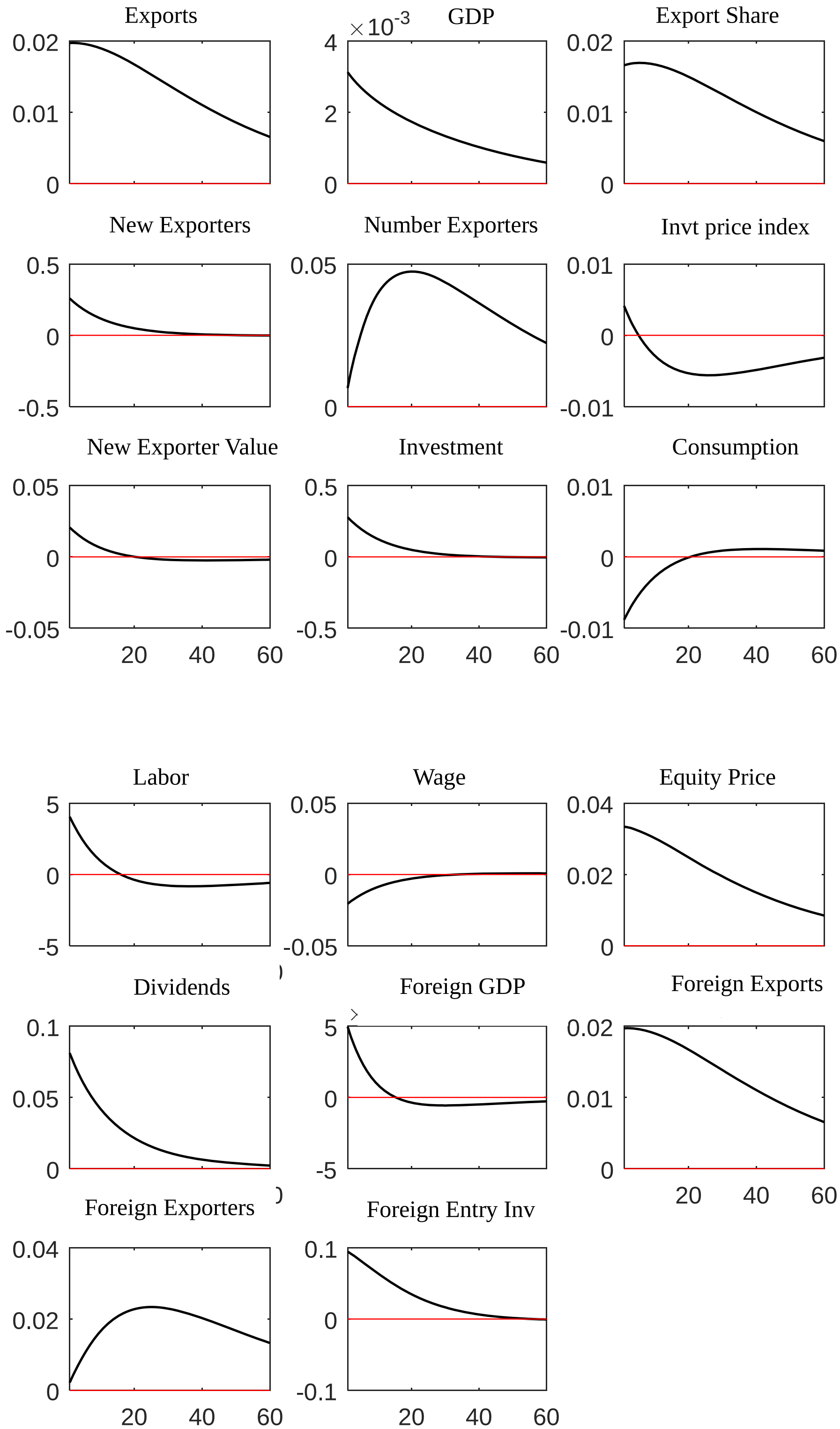
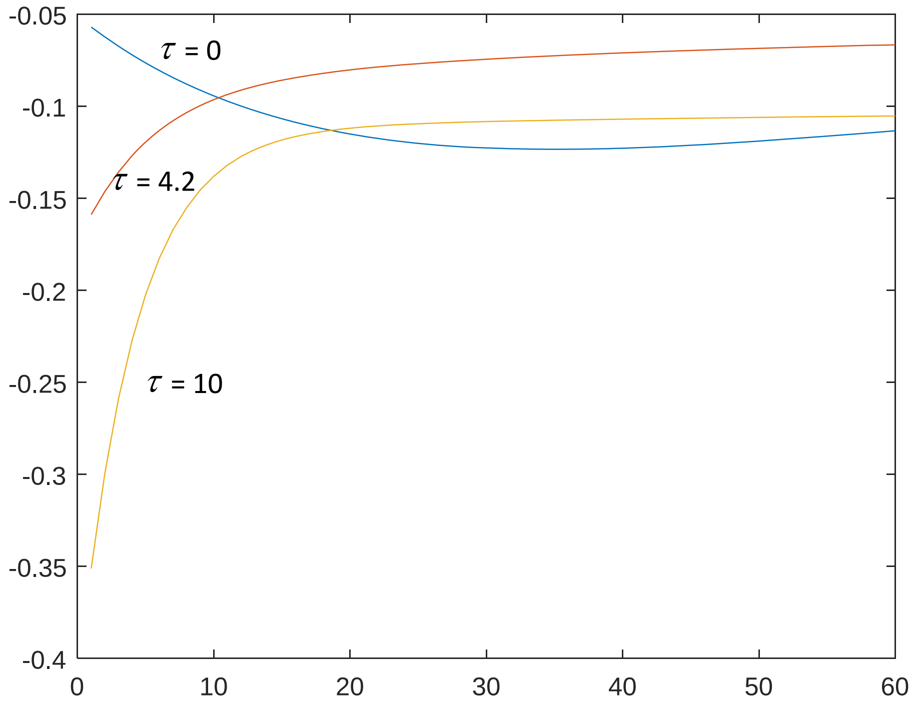


Fig. 10. Export impulse response for various parameterizations of congestion externality



6. Appendix Table: Equilibrium Conditions

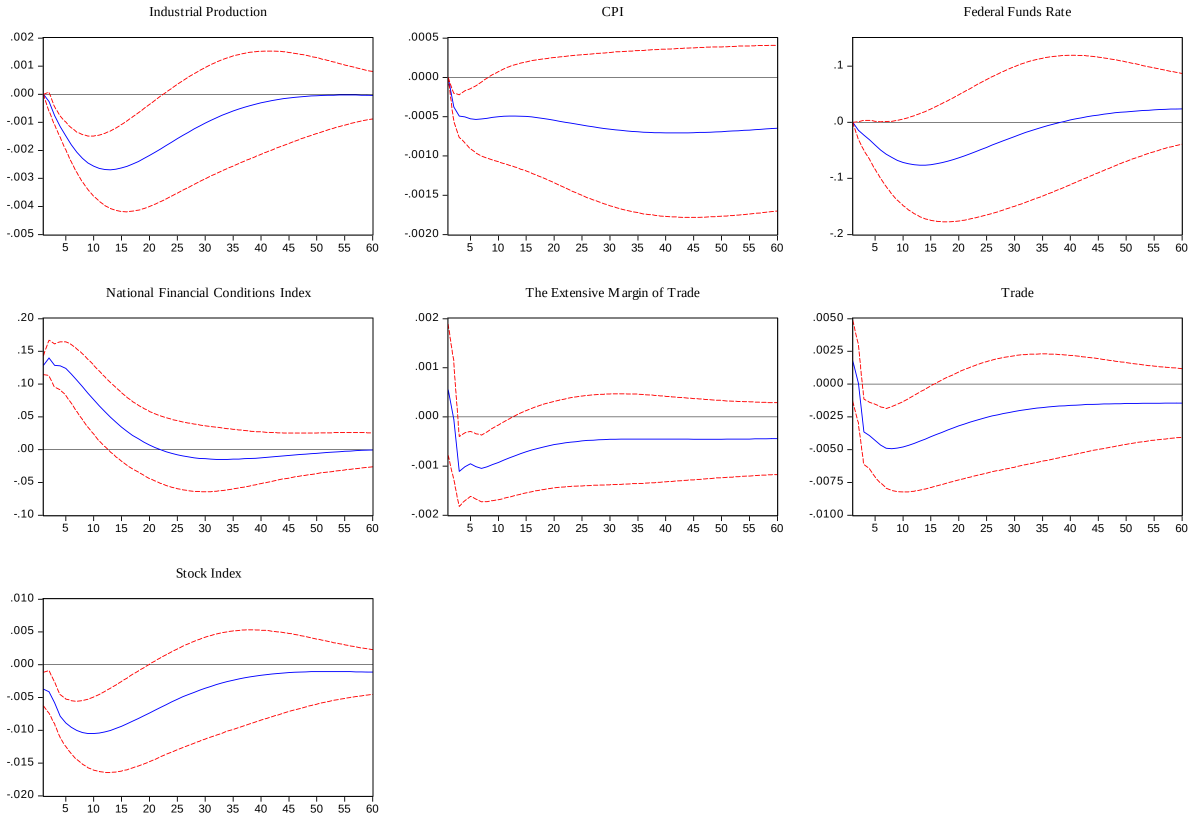
	Benchmark Economy: New Entrants Entry Simultaneously With Production
Firm Dynamics	(1) $n_{xt} = (1-\lambda)(n_{xt-1} + ne_{xt})$ (2) $n_{nxt}^{begin} = 1-(n_{xt-1} + ne_{xt})$ (3) $n_{nxt}^{end} = (1-\lambda) n_{nxt}^{begin}$
Demand and CPI	(4) $P_t = \left[P_{Ht}^{1-\sigma} + P_{Ft}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$ (5) $P_{Ht} \equiv \left[\int_0^{n_{xt-1}+ne_{xt}} p_{\mathrm{d}xit}^{1-\sigma} di + \int_{1-(n_{xt-1}+ne_{xt})}^{1} p_{nxit}^{1-\sigma} di\right]^{\frac{1}{1-\sigma}}$ (6) $P_{Ft} \equiv \left[\int_0^{n_{xt-1}^{*}+ne_{xt}^{*}} p_{fxit}^{1-\sigma} di\right]^{\frac{1}{1-\sigma}} = \left(n_{xt-1}^{*} + ne_{xt}^{*}\right)^{\frac{1}{1-\sigma}} p_{fxit}$ (7) $C_{Ht} = \left(\frac{P_{Ht}}{P_t}\right)^{-\sigma} C_t$ (8) $C_{Ft} = \left(\frac{P_{Ft}}{P_t}\right)^{-\sigma} C_t$ (9) $c_{nxit} = \left(\frac{p_{nxit}}{P_{Ht}}\right)^{-\sigma} C_{Ht}$ (10) $c_{dxit} = \left(\frac{p_{dxit}}{P_{Ht}}\right)^{-\sigma} C_{Ht}$ (11) $c_{fxit} = \left(\frac{p_{fxit}}{P_{Ft}}\right)^{-\sigma} C_{Ft} = \left(n_{xt-1}^{*} + ne_{xt}^{*}\right)^{\frac{\sigma}{1-\sigma}} C_{Ft}$
Entry Investment	(12) $I_t = ne_{xt} K_t^E$ (13) $P_{It} = \left[\theta P_{Ht}^{1-\phi} + (1-\theta) P_{Ft}^{1-\phi}\right]^{\frac{1}{1-\phi}}$

	(14) $I_{Ht}=\theta\left(\frac{P_{Ht}}{P_{It}}\right)^{-\phi} I_t$ (15) $I_{Ft}=(1-\theta)\left(\frac{P_{Ft}}{P_{It}}\right)^{-\phi} I_t$ (16) $i_{nxit}=\left(\frac{p_{nxit}}{P_{Ht}}\right)^{-\phi} I_{Ht}$ (17) $i_{dxit}=\left(\frac{p_{dxit}}{P_{Ht}}\right)^{-\phi} I_{Ht}$ (18) $i_{fxit}=\left(\frac{p_{fxit}}{P_{Ft}}\right)^{-\phi} I_{Ft}=\left(n_{xt-1}^{*}+ne_{xt}^{*}\right)^{\frac{\phi}{1-\phi}} I_{Ft}$
Worker	(19) $U_{C_{wt}} w_t + U_{Lt} = 0$ (20) $\beta(1-\lambda)E_t\left[U_{C_{wt+1}} R_t\right]=U_{C_{wt}}$
Investor	(21) $C_{It}+\left(n_{xt-1}+ne_{xt}\right)q_{xt}s_{xt}+n_{nxt}^{begin}q_{nxt}s_{nxt}\le n_{xt-1}s_{xt-1}\left(q_{xt}+d_{xt}\right)+n_{nxt-1}^{end}\left(q_{nxt}+d_{nxt}\right)$ (22) $\beta_I(1-\lambda)E_t\left[U_{C_{It+1}}\left(q_{xt+1}+d_{xt+1}\right)\right]=U_{C_{It}} q_{xt}$ (23) $\beta_I(1-\lambda)E_t\left[U_{C_{It+1}}\left(q_{nxt+1}+d_{nxt+1}\right)\right]=U_{C_{It}} q_{nxt}$
Financial Constraint	(24) $\xi_t E_t(m_{t+1}V_{xit+1}(b_{xit}))\ge w_t l_{xit}$ (25) $\xi_t E_t(m_{t+1}V_{nxit+1}(b_{nxit}))\ge w_t l_{nxit}$
Incumbents	(26) $y_{nxit}=c_{nxit}+i_{nxit}$ (27) $y_{xit}=y_{dxit}+y_{hxit}^{*}$ (28) $y_{dxit}=c_{dxit}+i_{dxit}$ (29) $y_{hxit}^{*}=\frac{c_{hxit}^{*}+i_{hxit}^{*}}{1-\eta}$

	(30) $y_{xit} = A_t l_{xit}$, (31) $y_{nxit} = A_t l_{nxit}$, (32) $d_{xit} = \pi_{dxit} + \pi^*_{hxit} - \left(b_{xit-1} - \frac{b_{xit}}{R_t} \right)$ (33) $d_{nxit} = \pi_{nxit} - \left(b_{nxit-1} - \frac{b_{nxit}}{R_t} \right)$ (34) $\pi_{dxit} = \frac{p_{dxit}}{P_t} y_{hxit} - w_t \frac{y_{dxit}}{A_t}$ (35) $\pi^*_{hxit} = \frac{p^*_{hxit}}{P_t} y^*_{hxit} (1-\eta) - w_t l^*_{hxit}$ (36) $\pi_{nxit} = \frac{p_{nxit}}{P_t} y_{nxit} - w_t l_{nxit}$ (37) $V_{xit}(b_{xit-1}) = \max_{p_{dxut}, p^*_{hxit}, b_{xit}} \{ d_{xit} + E_t (m_{t+1} V_{xit+1}(b_{xit})) \}$ (38) $V_{nxit}(b_{nxit-1}) = \max_{p_{nxit}, b_{nxit}} \{ d_{nxit} + E_t (m_{t+1} V_{nxit+1}(b_{nxit})) \}$. (39) $\frac{p_{dxit}}{P_t} = \frac{\sigma}{\sigma-1} \frac{w_t}{A_t} (1+\mu_{xit})$ (40) $\frac{p^*_{hxit}}{P_t} = \frac{\sigma}{\sigma-1} \frac{w_t}{(1-\eta) A_t} (1+\mu_{xit})$ (41) $\frac{p_{nxit}}{P_t} = \frac{\sigma}{\sigma-1} \frac{w_t}{A_t} (1+\mu_{nxit})$ (42) $\mu_{xit} = \frac{\frac{1}{R_t} - E_t m_{t+1}}{\xi_t E_t m_{t+1}}$ (43) $\mu_{nxit} = \mu_{xit}$
New Entrants	(44) $d^{new}_{xit} = \pi_{nxit} + \pi^{*new}_{hxit} - b_{nxit-1} + \frac{b^{new}_{xit}}{R_t} - \frac{P_{It}}{P_t} K^E_t$ $\pi^{*new}_{hxit} = \frac{p^{*new}_{hxit}}{P_t} y^{*new}_{hxit} (1-\eta) - w_t l^{*new}_{hxit}$ (45) $\frac{P_{It}}{P_t} K^E_t = E_t (m_{t+1} \left(\pi^{*new}_{hxit+1} + \frac{P_{It+1}}{P_{t+1}} K^E_{t+1} \right)) + \left(\frac{1}{R_t} - E_t m_{t+1} \right) \left(b^{new}_{xit} - b_{nxit} \right)$

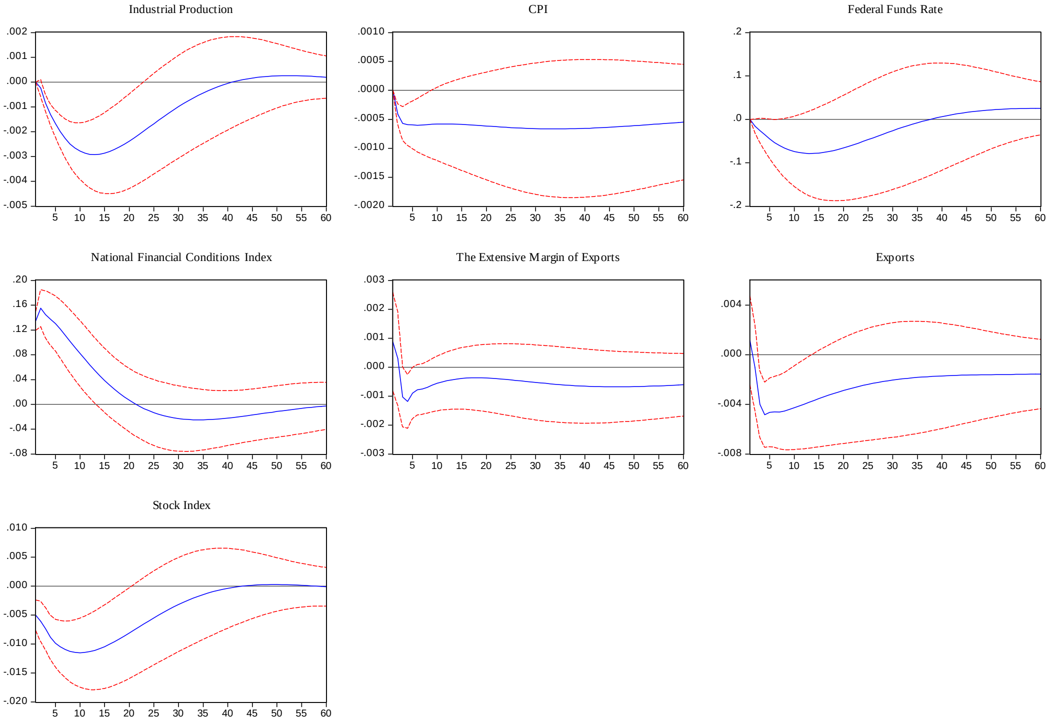
	(46) $V_{it}^{new}\left(b_{nxit-1}\right)=d_{xit}^{new}+E_t\left(m_{t+1}V_{xit+1}\left(b_{xit}^{new}\right)\right)$ (47) $K_t^E=\bar{K}^E\left(\frac{ne_{xt}}{ne_{xt-1}}\right)^{\tau}$
Market Clearing	(48) $L_t=\left(1-\left(n_{xt-1}+ne_{xt}\right)\right)l_{nxt}+\left(n_{xt-1}+ne_{xt}\right)l_{xt}$ (49) $C_t=C_{It}+C_{wt}$
Balanced Trade	(50) $\left(n_{xt-1}+ne_{xt}\right)p_{hxit}^{*}y_{hxit}^{*}=\left(n_{xt-1}^{*}+ne_{xt}^{*}\right)p_{fxit}y_{fxit}$
Normalization	(51) $P_t=1$

Appendix Fig. 1 Impulse Responses to National Financial Conditions Index: Trade



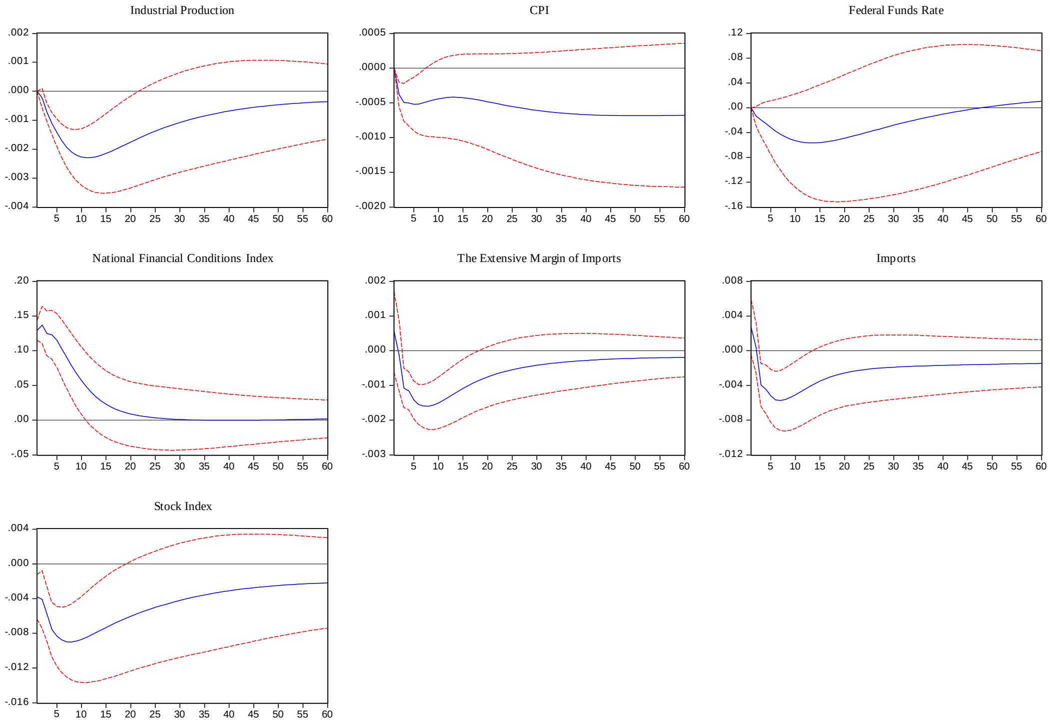
Note: Data are at monthly frequency, based on 6-digit HS disaggregate U.S. export and import flows, running from 2002:1 to 2016:11.

Appendix Fig. 2 Impulse Responses to National Financial Conditions Index: Exports



Note: Data are at monthly frequency, based on 6-digit HS disaggregate U.S. export flows, running from 2002:1 to 2016:11.

Appendix Fig. 3 Impulse Responses to National Financial Conditions Index: Imports



Note: Data are at monthly frequency, based on 6-digit HS disaggregate U.S. import flows, running from 2002:1 to 2016:11