

# Aggregate Volatility and International Dynamics. The Role of Credit Supply.

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## Abstract

Changes in country-specific aggregate volatility are positively correlated with the current account but negatively correlated with investment, output and credit flows. An International Real Business Cycle model with time-varying aggregate uncertainty, through a precautionary savings channel, can account for the positive correlation but implies counterfactual comovements for the other variables. Adding a credit supply channel with default and lenders exposed to aggregate risk allows the model to match all the facts. Higher volatility contracts credit supply and lowers investment and output. The current account turns to a surplus because savings increase, but also because investment collapses.

**Keywords:** Credit Supply; Current Account; Uncertainty; Trade Balance; Precautionary Savings.

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# 1 Introduction

There is increasing evidence that time-varying uncertainty is important for macroeconomic dynamics (see for example Bloom 2014 for a survey). A new literature studies the international dimensions of uncertainty. For example, Fogli and Perri (2015) and Hoffmann, Krause and Tillmann (2016) document that uncertainty and current account dynamics are positively correlated across countries. Both papers explain the correlation using an International Real Business Cycle model (IRBC) with a precautionary savings channel: when countries become more volatile than their partners, their households save and run a current account surplus.

In this paper we use OECD data from the period 1970q1–2014q4 to document four other international facts: when aggregate uncertainty increases in a country, then investment, credit flows and output fall, while the credit spread increases. An IRBC model with only the precautionary savings channel is unable to simultaneously get right all the previous correlations. In the model, investment and output increase in the more volatile country. The reason is an application of Jensen’s inequality: due to convex returns from investment, higher volatility leads to higher investment, capital, output and employment.<sup>1</sup>

We show that an IRBC model correctly predicts all the previous correlations if it is expanded with a credit supply mechanism in which countries have domestic credit markets with default and lenders exposed to aggregate risk. Moreover, with a credit supply channel, the model generates current account dynamics consistent with the data as higher uncertainty induces an investment collapse and a surge of savings. In the IRBC the counterfactual investment boom pushes the current account towards a deficit.

We study a two-country, incomplete markets, IRBC model with trend growth shocks extended with a costly state verification friction à la Bernanke, Gertler and Gilchrist (1999, BGG) between domestic entrepreneurs and domestic lenders. Households deposit with banks that lend to a continuum of entrepreneurs, who use the funds to buy capital that they then rent to the firms. However, a crucial difference from BGG is that in our financial contract lenders are exposed to both aggregate and idiosyncratic credit risk. That is, the lenders’ return is not risk-free. If lenders are not exposed to aggregate risk, then the BGG financial accelerator generates the same counterfactual predictions as the IRBC model.

The mechanism works as follows: higher aggregate uncertainty increases the probability of entrepreneurs’ default and, because banks are exposed to aggregate risk, this leads to a con-

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<sup>1</sup>Cho et al. (2015) and Lester et al. (2014) analyze how higher uncertainty leads to higher investment in the standard real business cycle model with variable productive inputs.

traction of credit supply even if banks' cost of funds remains constant.<sup>2</sup> Moreover, when banks' credit risk increases, the risk of losses on bank deposits also becomes higher and households, who would like to avoid the riskier deposits, require a higher risk premium to finance the banks. The combined effect is that higher aggregate uncertainty induces a large contraction of credit supply, and lending rates to entrepreneurs soar. Since entrepreneurs need credit to finance investment, the credit crunch leads to an investment collapse. Less investment lowers capital, employment and output. Moreover, the current account reacts strongly and moves towards a surplus since the precautionary savings channel is accompanied by an investment collapse.

Quantitative simulations of the model show that the credit channel is consistent with the data. That is, following volatility shocks, the credit crunch dominates the convex returns from investment that lead to the counterfactual predictions of the IRBC model. Moreover, the model with a credit channel is supported by the cross-country evidence on credit flows and spreads that we show in Section 3.<sup>3</sup> That is, more volatile countries see a reduction in credit towards the private non-financial sector and an increase in credit spreads.

The credit channel that we analyze in the benchmark economy is mitigated when we study global instead of domestic banks. The reason is that with diversified global banks higher volatility in one country does not alter the ability of the global bank to raise funds. Although, higher uncertainty still contracts credit supply because it increases the likelihood of default and debt contracts imply concave payoffs for the lender. In this regard, the model shows that the retreat of banking globalization after the 2008 financial crisis (Forbes, Reinhart and Wieladek 2017) may amplify the negative effects of higher uncertainty.

The rest of the paper is organized as follows. Section 2 discusses the related literature. Section 3 documents the facts. Section 4 presents the model. Section 5 explains how volatility affects credit supply. Section 6 compares the models with and without credit channel. Section 7 studies the case when banks are global instead of domestic. Section 8 compares with the time-varying volatility of interest rates studied by Fernandez-Villaverde et al. (2011). Section 9 concludes. The appendix documents the data sources. An online appendix contains the algebra and some extra results.

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<sup>2</sup>In a debt contract, banks' payoff from holding risky loans is a concave function of the borrowers' stochastic income. Thus, a mean-preserving spread (i.e. higher uncertainty) to the borrowers' income reduces lenders' expected return through Jensen's inequality effect.

<sup>3</sup>We also show that higher volatility on the borrower's income is a potential micro-foundation for the time-varying volatility of interest rates studied by Fernandez-Villaverde et al. (2011).

## 2 Related Literature

Our paper contributes to two growing literatures: 1) the literature studying the effects of changes in aggregate uncertainty in open economies; and 2) the literature studying the links between changes in uncertainty and credit markets.

Concerning the international literature on uncertainty, Fogli and Perri (2006) pioneered the importance of volatility changes and precautionary motives for current account dynamics. Fogli and Perri (2015) and Hoffmann, Krause and Tillmann (2016) further study the topic. Both papers document that countries which become more volatile have current account surpluses and both papers use models driven by precautionary savings motives.

Our paper complements those papers in both the empirical and the theoretical dimensions. On the empirical side, we confirm the link between volatility and current account dynamics and expand it to other key macro variables: investment, output and credit variables. We show that a precautionary savings channel alone can account for the correlation between volatility and current account dynamics, but it generates counterfactual predictions concerning the effects of volatility on investment and output. We show how to extend the IRBC model with a credit sector in order to be consistent with all the empirical correlations. This is important from the perspective of current account dynamics, which are savings minus investment. The combination of precautionary savings with a credit channel allows to get both savings and investment reaction to uncertainty consistent with the data.

Hoffmann, Krause and Tillmann (2016) find that investment in developing economies does not seem to respond significantly to higher aggregate volatility, while our findings indicate that investment matters much more in OECD countries.<sup>4</sup> Our model rationalizes these differences with the different relative weight of credit markets in the two groups of economies. That is, we show that financial intermediation is key in the transmission of uncertainty into investment. Since total credit-to-GDP ratio in most developing countries is low compared to developed countries, then our model can account for these different effects of uncertainty on investment in the two groups of countries.

The credit channel that we propose in this paper also fixes a problem in Gourio, Siemer and Vardelhan (2013). They show that a complete markets IRBC model can account for several exchange rate puzzles if countries differ in terms of their exposure to disaster shocks.<sup>5</sup> Their model implies the counterfactual result that more volatile countries should have lower interest

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<sup>4</sup>Our findings are consistent with evidence documented by other authors for different samples and countries. See for example, Bloom (2009), Cesa-Bianchi, Pasaran and Rebucci (2016) or Ramey and Ramey (1995).

<sup>5</sup>Disaster shocks are shocks that, if realized, alter both TFP and the stock of capital.

rates. This paper shows that incorporating credit markets with lenders exposed to risk avoids the counterfactual.

Also, concerning the international literature on uncertainty, Fernandez-Villaverde et al. (2011) show that changes in the volatility of international interest rates have significant negative effects on small open economies. We complement Fernandez-Villaverde et al. (2011) because our model makes the changes in interest rates endogenous. We show that shocks to interest rate volatility are observationally equivalent to the shocks to domestic TFP growth volatility. This result offers one potential micro-foundation for the time-varying volatility of interest rates.

Concerning the literature studying the links between changes in uncertainty and credit markets, this paper brings two novelties: first, the international dimension and, second, that the source of the uncertainty is an aggregate shock, rather than a change in cross-sectional dispersion.

To our knowledge, we are the first to document the cross-country patterns of uncertainty and credit variables. Several recent papers have looked at U.S. data. For example, Gilchrist, Sim and Zakrajsek (2014) document that in the U.S. fluctuations in idiosyncratic uncertainty across-firms (measured from high-frequency stock market data) affect credit spreads. Baum, Caglayan and Ozkan (2009) and Bordo, Duca and Koch (2016), using U.S. bank data, show that aggregate uncertainty is a driver of credit supply. Caldara et al. (2016) show that identified uncertainty shocks have a significant negative effect on real economic activity, and that the effect is larger when these shocks are being accompanied by tightening of financial conditions.

In terms of the model, the recent literature that analyzes credit frictions and volatility fluctuations has focused on closed economies and shocks to the cross-sectional dispersion of firms' productivity. This literature includes, among others, Arellano, Bai and Kehoe (2016), Christiano, Motto and Rostagno (2014), Chugh (2016), Gilchrist, Sim and Zakrajsek (2014), Pesaran and Xu (2016) and Straub and Ulbricht (2015). In this paper we show that aggregate uncertainty shocks with lenders exposed to those shocks generate similar transmission channels. Given the substantial evidence on aggregate uncertainty discussed above (see also Mumtaz and Theodoridis 2017) there is value in expanding the credit channel to aggregate shocks, which requires to depart from the BGG framework as we show in this paper.

### 3 Facts

In this section we document that, in OECD countries, larger macroeconomic volatility leads to a positive trade balance, lower investment and output growth, larger credit spreads and less credit.<sup>6</sup> We measure macroeconomic uncertainty as the volatility of realized stock market returns. This is the standard measure in the literature on the economics of uncertainty (see for example, Bloom 2009, Baker and Bloom 2013, Cesa-Bianchi, Pasaran and Rebucci 2016 or Gilchrist, Sim and Zakrajsek 2014, among others).<sup>7</sup>

We define volatility  $\Omega_{i,t}$  in quarter  $t$  for country  $i$ , as the quarterly standard deviation of daily stock market returns,

$$\Omega_{i,t} = 100 \sqrt{\frac{1}{d_t} \sum_{d=1}^{d_t} (u_{i,t}^d - \bar{u}_{i,t})^2}, \quad (1)$$

where  $u_{i,t}^d$  is the daily stock market return,  $d_t$  denotes the number of trading days in the quarter, and  $\bar{u}_{i,t}$  is the average daily return in quarter  $t$ ,

$$\bar{u}_{i,t} = \frac{1}{d_t} \sum_{d=1}^{d_t} u_{i,t}^d. \quad (2)$$

This measure of aggregate uncertainty has significant variation at the quarterly frequency and can be compared across OECD countries because these economies have developed stock markets.<sup>8</sup>

Figure 1 plots the associations between stock market returns volatility and each variable of interest. We focus on the trade balance-to-GDP ratio, investment and output growth, and the change in bank credit-to-GDP. For ease of appearance we plot binned scatterplots following Jorda, Schularick and Taylor (2016). Each dot groups quarterly observations of volatility and each variable of interest between 1970q1 and 2014q4. Figure 1 indicates that there is a positive association between aggregate uncertainty and the trade balance-to-output ratio, and a negative

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<sup>6</sup>Following the IRBC literature, we focus on the trade balance as a measure of a country's external position. However, all the results (both empirical and theoretical) that we obtain regarding the trade balance, also hold for the current account, which in our model is a well-defined object because markets are incomplete. In our panel of OECD countries, the average correlation between the two series is 0.84.

<sup>7</sup>VIX-type indices are not available for most countries in our sample. Figure B1 in the online appendix shows that for the U.S., the VIX index and realized equity returns volatility are strongly correlated, with a correlation coefficient of 0.93.

<sup>8</sup>Figure B2 in the online appendix shows that the volatility of stock market returns is very correlated with TFP growth volatility. Thus, we can interpret the volatility shocks as capturing changes in uncertainty about economic policy (fiscal, trade, or financial policies), or broadly about future growth prospects.

correlation of uncertainty with output growth, investment growth, and with the change in bank credit-to-output ratio.

Table 1 has the regression analysis of the previous facts, which we interpret as correlations since we lack an identification mechanism to think on causality.<sup>9</sup> Panel A reports the results from pooled OLS regressions of the previous four variables and also credit spreads on aggregate uncertainty.<sup>10</sup> Panel B controls for other macro variables that could potentially drive the association between volatility and economic outcomes, like inflation, exchange rates dynamics, government consumption, trade openness (measured as imports plus exports to GDP) and the level of stock market returns. In both Panels A and B we control for country and time fixed effects.

The results are robust across panels of Table 1. An increase in quarterly stock market returns volatility is associated with an increase in the trade balance-to-output ratio and credit spreads, with a decrease in investment and output growth, and with a decrease in the bank credit-to-output ratio. The increase in spreads and the contraction in credit suggest a credit mechanism.

As the online appendix shows, we obtain similar results if we use the country's relative volatility, or alternative measures of a country's external balance, credit supply and interest spreads.<sup>11</sup>

The online appendix redoes Table 1 using multi-year rolling windows of the standard deviation of quarterly GDP growth as measure of uncertainty. This is the measure of uncertainty analyzed by Fogli and Perri (2015), although it is not common in the literature. The results are broadly consistent with those discussed above. However, this measure has several drawbacks that lead us to prefer stock market volatility. For example, rolling windows have a strong time-varying trend component and do not fluctuate much at quarterly frequency. In addition, Figure B3 shows that rolling windows spike at different dates than the popular indices of uncertainty of Baker, Bloom and Davis (2016).

To sum up, the data suggest that countries with larger macroeconomic volatility run trade surpluses, have less investment and output, with credit being more expensive and less available. As we will show next, an IRBC model without a credit sector can generate the positive corre-

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<sup>9</sup>All variables are quarterly, non-filtered and stationary (quarterly growth rates, or ratios to GDP). The appendix describes the dataset. It is an unbalanced panel that uses the maximum data available.

<sup>10</sup>Credit spreads are defined as the difference between the domestic corporate lending rate and long-term German government bond yields.

<sup>11</sup>Like for example, trade balance or current account, total credit or bank credit to the private non-financial sector, and corporate lending spread or government bond spread.

lation between volatility and the trade balance, but it fails with the other correlations. Adding credit supply with lenders exposed to aggregate volatility can reconcile the model with the data.

## 4 Model

We study a two-country model with domestic credit markets subject to costly state verification frictions. The key ingredient is that lenders are exposed to aggregate risk. Each country is inhabited by households, entrepreneurs, banks, and firms producing goods and capital. The two countries trade consumption goods and risk-free bonds.

### 4.1 Households and Banks

In each country ( $i = 1, 2$ ) there is a continuum of homogeneous households who maximize expected utility over consumption ( $C_{i,t}$ ) and hours worked ( $H_{i,t}$ ). Households can invest in risky domestic deposits ( $D_{i,t}$ ), and in riskless international bonds ( $B_{i,t}$ ). The representative household of country  $i$  maximizes

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_{i,t}, H_{i,t}), \quad (3)$$

subject to a sequence of budget constraints,

$$C_{i,t} + B_{i,t} + D_{i,t} = W_{i,t} H_{i,t} + R_{t-1}^f B_{i,t-1} + R_{i,t}^D D_{i,t-1} - \frac{\phi_B}{2} Z_{i,t} \left( \frac{B_{i,t}}{Z_{i,t}} - \widehat{B} \right)^2 + \Pi_{i,t} + \Pi_{i,t}^c - Z_{i,t} T^E, \quad (4)$$

where  $W_{i,t}$  is the wage in country  $i$ ,  $\Pi_{i,t}$  and  $\Pi_{i,t}^c$  are the profits of the producers of goods and capital respectively and  $R_{t-1}^f$  is the gross return on last period holdings of the international bond. The parameter  $T^E$  is lump-sum transfers to domestic entrepreneurs.<sup>12</sup> To ensure a balanced growth path we follow Rabanal, Rubio-Ramirez and Tuesta (2011) and impose small adjustment costs ( $\phi_B$ ) on international bond holdings, which depend on the non-stationary technology process ( $Z_{i,t}$ ). For the same purpose, we scale up the lump-sum transfers to the domestic entrepreneurs by the trending variable  $Z_{i,t}$ .

In each country there is a continuum of perfectly competitive banks who collect deposits

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<sup>12</sup>These transfers are a standard mechanism to ensure that entrepreneurs' equity is never zero. All results hold if we use alternative mechanisms, like giving labor income to the entrepreneurs.



from domestic households and lend these funds to the entrepreneurs. Since banks make zero profits, the return on loans equals the return on deposits. Thus,  $R_{i,t}^D$ , the gross return on bank deposits of country  $i$ , is risky because banks may suffer credit losses and be unable to repay their borrowings (banks are 100% deposit financed in the model). Therefore, households of country  $i$  are exposed to the credit risk of their financial system.

The previous assumption is consistent with the recent experiences of Ireland, Iceland, Portugal and Spain during the 2008 financial crisis. These countries had deposit insurance systems in place, but when their local banks suffered major credit losses, the countries were unable to honor all the borrowings of their domestic financial systems (Santos 2014, Zeissler et al. 2015). Households in those countries either suffered losses on their deposits (Iceland), experienced higher taxes, or their government debt increased to fund the bailout of their domestic banks.<sup>13</sup> Thus, the recent Euro crisis supports the theory that households are exposed to the credit risk of their domestic banks. This is a crucial assumption for our results, as we will discuss later.

Denoting by  $U_H$  and  $U_C$  the marginal utility of leisure and consumption the households' optimality conditions are:

$$\frac{-U_H(C_{i,t}, H_{i,t})}{U_C(C_{i,t}, H_{i,t})} = W_{i,t}, \quad (5)$$

$$R_t^f \mathbb{E}_t [M_{i,t+1}] = 1 + \phi_B \left( \frac{B_{i,t}}{Z_{i,t}} - \widehat{B} \right), \quad (6)$$

and

$$\mathbb{E}_t [M_{i,t+1} R_{i,t+1}^D] = 1, \quad (7)$$

where

$$M_{i,t+1} \equiv \beta \frac{U_C(C_{i,t+1}, H_{i,t+1})}{U_C(C_{i,t}, H_{i,t})} \quad (8)$$

is the household's stochastic discount factor.

## 4.2 Entrepreneurs and Financial Contract

In each country there is a continuum of mass one of risk-neutral entrepreneurs. In period  $t$ , the equity of entrepreneur  $j$  in country  $i$  is  $N_{i,j,t}$ . Each entrepreneur borrows  $L_{i,j,t}$  from the domestic banks and buys domestic capital at price  $Q_{i,t}$ ,

$$Q_{i,t} K_{i,j,t} = N_{i,j,t} + L_{i,j,t}. \quad (9)$$

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<sup>13</sup>Moreover, the financial repression which followed the crisis has translated into limits on banking competition and low returns on deposits. Reinhart (2012) refers to this as a partial default on depositors.

After purchasing the capital, each entrepreneur experiences an idiosyncratic shock  $\omega_j$  such that  $K_{i,j,t}$  units of capital generate  $\omega_j K_{i,j,t}$  units of effective capital. Next period, the entrepreneur rents her effective capital to domestic firms at the rental rate,  $r_{i,t+1}$ , and then sells the undepreciated capital,  $\omega_j(1 - \delta)K_{i,j,t}$ , at price  $Q_{i,t+1}$ . Thus, an entrepreneur with idiosyncratic productivity  $\omega_j$  has a rate of return  $\omega_j R_{i,t+1}^K$ , where  $R_{i,t+1}^K$  is the rate of return on capital in country  $i$ ,

$$R_{i,t+1}^K = \frac{r_{i,t+1} + Q_{i,t+1}(1 - \delta)}{Q_{i,t}}. \quad (10)$$

The idiosyncratic productivity shocks  $\omega_j$  are not observable when borrowing happens and ex-post create profitable and unprofitable entrepreneurs. These shocks are i.i.d. across both entrepreneurs and time. In both countries, the shocks are drawn from a log-normal distribution with a cumulative density function  $F(\omega)$  with mean one and standard deviation  $\sigma_\omega$ .

In time  $t$ , the financial contract between a bank and an entrepreneur  $j$  specifies a loan amount,  $L_{i,j,t}$ , and a default threshold for next period  $\bar{\omega}_{i,j,t+1}$  such that if the entrepreneur has idiosyncratic productivity below  $\bar{\omega}_{i,j,t+1}$ , then the entrepreneur defaults and her assets are seized by the bank. Default costs are a share  $\mu$  of the entrepreneur's assets and paid by the bank. The state-contingent interest rate  $R_{i,j,t+1}^L$  is implicit in

$$R_{i,j,t+1}^L L_{i,j,t} = \bar{\omega}_{i,j,t+1} R_{i,t+1}^K Q_{i,t} K_{i,j,t}. \quad (11)$$

The lender's return on deposits is the revenue from those entrepreneurs who repay plus the value of the assets seized from the entrepreneurs who default,

$$R_{i,t}^D L_{i,j,t-1} = \int_{\bar{\omega}_{i,j,t}}^{\infty} R_{i,j,t}^L L_{i,j,t-1} dF(\omega) + \int_0^{\bar{\omega}_{i,j,t}} (1 - \mu) \omega R_{i,t}^K Q_{i,t-1} K_{i,j,t-1} dF(\omega). \quad (12)$$

Following Carlstrom, Fuerst and Paustian (2016), we assume that entrepreneurs are forward looking and maximize expected discounted terminal equity.<sup>14</sup> To avoid self-financing in the long-run, entrepreneurs die at the end of each period with an exogenous probability  $(1 - \chi)$  and consume their equity, which evolves as

$$N_{i,j,t+1} = \int_{\bar{\omega}_{i,j,t+1}}^{\infty} [\omega R_{i,t+1}^K Q_{i,t} K_{i,j,t} - R_{i,j,t+1}^L L_{i,j,t}] dF(\omega). \quad (13)$$

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<sup>14</sup>All the results hold when entrepreneurs are one period myopic like in BGG. We impose forward looking entrepreneurs because under this assumption the contract is optimal as shown by Carlstrom, Fuerst and Paustian (2016).

Carlstrom, Fuerst and Paustian (2016) show that the optimal contract maximizes entrepreneurs utility

$$V_{i,j,t} = (1 - \chi) \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\chi)^s N_{i,j,t+s}, \quad (14)$$

subject to the lenders' participation constraint, which is the household's Euler equation (7) with the return on deposits defined in (12).

Because of constant returns to scale and risk neutrality, the financial contract is linear in entrepreneur's equity.<sup>15</sup> This implies that all entrepreneurs have the same default threshold ( $\bar{\omega}_{i,j,t+1} = \bar{\omega}_{i,t+1}$ ), lending rate ( $R_{i,j,t+1}^L = R_{i,t+1}^L$ ) and leverage ratio

$$\kappa_{i,j,t} \equiv \frac{Q_{i,t} K_{i,j,t}}{N_{i,j,t}} = \kappa_{i,t}. \quad (15)$$

Thus, we can drop the  $j$  notation as only the country's aggregate variables matter, not the distribution inside the country.

It is convenient to follow Bernanke, Gertler and Gilchrist (1999) and define the function  $\Gamma(\bar{\omega}_{i,t+1})$  to denote the next period's expected gross share of outcome going to the bank,

$$\Gamma(\bar{\omega}_{i,t+1}) \equiv \int_0^{\bar{\omega}_{i,t+1}} \omega dF(\omega) + \bar{\omega}_{i,t+1} \int_{\bar{\omega}_{i,t+1}}^{\infty} dF(\omega), \quad (16)$$

and the function  $G(\bar{\omega}_{i,t+1})$  to denote expected monitoring costs,

$$G(\bar{\omega}_{i,t+1}) \equiv \int_0^{\bar{\omega}_{i,t+1}} \omega dF(\omega). \quad (17)$$

From combining household's Euler equation and (12) with the previous definitions we obtain lenders' participation constraint,

$$\mathbb{E}_t [M_{i,t+1} \kappa_{i,t} R_{i,t+1}^K [\Gamma(\bar{\omega}_{i,t+1}) - \mu G(\bar{\omega}_{i,t+1})]] = \kappa_{i,t} - 1, \quad (18)$$

which is the credit supply equation. Equation (18) includes households' stochastic discount factor ( $M_{i,t+1}$ ) as banks' ability to raise funds depends on households' willingness to provide them at the risky deposit rate. Thus, (18) captures lenders' exposure to aggregate risk.

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<sup>15</sup>The online appendix has the detailed derivation of all the results in this section.

### 4.3 Capital Producers

In each country there is a representative capital producer owned by the domestic households. It buys goods ( $I_{i,t}$ ) from the firms, and the undepreciated capital  $(1 - \delta)K_{i,t-1}$  from the entrepreneurs, to produce new capital according to

$$I_{i,t}^n = \left[ 1 - \frac{\phi_I}{2} \left( \frac{I_{i,t}}{I_{i,t-1}} - g \right)^2 \right] I_{i,t}, \quad (19)$$

where  $I_{i,t}^n$  is the net investment and  $I_{i,t}$  is gross investment. Capital is non-tradable across countries. The parameter  $\phi_I$  controls the capital adjustment cost that ensures that the price of capital varies endogenously, affecting entrepreneurs' equity. The parameter  $g$  is the growth rate along the balanced-growth path.

The law of motion of the capital stock is

$$K_{i,t} = (1 - \delta)K_{i,t-1} + I_{i,t}^n. \quad (20)$$

The capital producer sells the capital to the entrepreneurs at price  $Q_{i,t}$  making profits:

$$\Pi_{i,t}^c = Q_{i,t} I_{i,t}^n - I_{i,t}. \quad (21)$$

The capital producer chooses investment to maximize the present discounted value of its profits

$$\max_{I_{i,t}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U_C(C_{i,t}, H_{i,t}) \Pi_{i,t}^c, \quad (22)$$

subject to (19).

### 4.4 Consumption Goods Producers

Firms producing consumption goods ( $Y_{i,t}$ ) use labor ( $H_{i,t}$ ) and capital ( $K_{i,t-1}$ ) according to the production function

$$Y_{i,t} = A_{i,t} K_{i,t-1}^\alpha (Z_{i,t} H_{i,t})^{1-\alpha}, \quad (23)$$

where  $A_{i,t}$  is a transitory TFP shock, and  $Z_{i,t}$  is a labor-augmenting permanent shock component as in Aguiar and Gopinath (2007). We define these processes below.

Consumption goods producers hire labor and rent capital to maximize profits<sup>16</sup>

$$\Pi_{i,t} = Y_{i,t} - W_{i,t}H_{i,t} - r_{i,t}K_{i,t-1}. \quad (24)$$

## 4.5 Market Clearing

International bonds are in zero net supply across countries,

$$B_{1,t} + B_{2,t} = 0. \quad (25)$$

In each country, households' supply of deposits equals entrepreneurs' borrowings,

$$D_{i,t} = L_{i,t}. \quad (26)$$

Also, from the balance sheets of the entrepreneurs, the value of the capital stock of country  $i$  equals the debt and equity of the entrepreneurs:

$$Q_{i,t}K_{i,t} = L_{i,t} + N_{i,t}. \quad (27)$$

The trade balance can be defined as

$$\text{Trade Balance}_{i,t} = B_{i,t} - R_{f,t-1}B_{i,t-1}, \quad (28)$$

and the current account is the change in the net foreign asset position,

$$\text{Current Account}_{i,t} = B_{i,t} - B_{i,t-1}. \quad (29)$$

## 4.6 Technology

The transitory component follows a stationary AR(1) process

$$\log(A_{i,t}) = \rho_A \log(A_{i,t-1}) + \sigma_A \varepsilon_{A,i,t}, \quad (30)$$

where  $\varepsilon_{A,i,t}$  are Gaussian white noise shocks with mean zero and unit variance. The parameter  $\sigma_A$ , which is the same across countries, controls the size of the shock. The cross-country

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<sup>16</sup>Because of the constant returns to scale production function, these profits are zero in equilibrium.

correlation of the stationary TFP shocks is the parameter  $\vartheta$ .

We follow Ireland (2013) and Rabanal, Rubio-Ramirez and Tuesta (2011) in assuming that the labor-augmenting technology shocks,  $\log(Z_{i,t})$ , are cointegrated across countries to ensure a balanced growth path in the global economy. Denoting the growth rate of  $Z_{i,t}$  in country  $i$  as

$$g_{i,t} \equiv \frac{Z_{i,t}}{Z_{i,t-1}}, \quad (31)$$

the labor augmenting technology shocks follow

$$\log(g_{1,t}) = (1 - \rho_g) \log(g) + \rho_g \log(g_{1,t-1}) + \varphi [\log(Z_{1,t-1}) - \log(Z_{2,t-1})] + e^{\sigma_{g,1,t}} \varepsilon_{g,1,t}, \quad (32)$$

$$\log(g_{2,t}) = (1 - \rho_g) \log(g) + \rho_g \log(g_{2,t-1}) - \varphi [\log(Z_{1,t-1}) - \log(Z_{2,t-1})] + e^{\sigma_{g,2,t}} \varepsilon_{g,2,t}, \quad (33)$$

where  $\varepsilon_{g,i,t}$  are Gaussian innovations with mean zero and unit variance. The parameter  $g$  is the long-run growth rate of productivity, which is the same for both countries. The parameter  $\varphi$  governs the rate of convergence between the two countries. It takes a small negative value such that when the cross-country differential  $\frac{Z_{1,t-1}}{Z_{2,t-1}}$  is larger than its long-run value, then  $\varphi < 0$  guarantees that  $g_{1,t}$  will fall and  $g_{2,t}$  will rise, driving the differential back to its long-run value. That is, no country grows so much in relative terms that at some point it becomes the whole world. Then,  $g_{i,t}$  and  $\frac{Z_{i,t}}{Z_{2,t}}$  are stationary and the detrended model has a well-defined deterministic steady state.

$\sigma_{g,i,t}$  is a country-specific volatility shock on trend growth that follows a stationary AR(1) process,

$$\sigma_{g,i,t} = (1 - \rho_\sigma) \sigma_g + \rho_\sigma \sigma_{g,i,t-1} + \sigma_\sigma \varepsilon_{\sigma,i,t}, \quad (34)$$

where  $\varepsilon_{\sigma,i,t}$  are Gaussian innovations with mean zero and unit variance. The parameter  $\sigma_\sigma$ , the same across countries, controls the size of the volatility shocks. The volatility shocks are uncorrelated across countries. Moreover, TFP and the volatility shocks are uncorrelated within each country.

As we show below, the previous specification of the volatility shocks as shocks to trend growth and adding a credit channel to the model avoid a problem common in the literature on aggregate uncertainty. To amplify precautionary savings effects, this literature uses volatility shocks on transitory TFP with nearly unit roots (0.9999) for both the persistence of the stationary TFP level and its standard deviation (see for example Fogli and Perri 2015). However, those nearly unit roots contradict the estimates of transitory TFP processes of the RBC literature.

## 5 Volatility and Credit Supply

In this section, to build intuition for the key mechanism of the model, we show how credit supply reacts to changes in uncertainty in a partial equilibrium setting. The next section solves the full general equilibrium model and contains the quantitative results.

Figure 2 plots the credit supply equation (18) for two levels of aggregate uncertainty.<sup>17</sup> That is, the rates that lenders require to lend at a given leverage level. To compute Figure 2, first we use (11) to rewrite (18) as

$$\mathbb{E}_t \left[ M_{t+1} \kappa_t R_{t+1}^K \left[ \Gamma \left( \frac{R_{t+1}^L (\kappa_t - 1)}{R_{t+1}^K \kappa_t} \right) - \mu G \left( \frac{R_{t+1}^L (\kappa_t - 1)}{R_{t+1}^K \kappa_t} \right) \right] \right] = \kappa_t - 1. \quad (35)$$

Then, we set the stochastic discount factor  $M_{t+1}$  at its steady state value and assume, in partial equilibrium, that the return on capital  $R_t^K$  follows an AR(1) process with time-varying volatility:

$$R_t^K = (1 - \rho_g) R^K + \rho_g R_{t-1}^K + e^{\sigma_{g,t} \varepsilon_t}, \quad (36)$$

where  $\sigma_{g,t}$  follows (34). The steady state value of volatility,  $\sigma_g$ , governs the long-run level of aggregate risk. We compare two values of  $\sigma_g$ . Using a third-order approximation to (35) we solve for the leverage ratio  $\kappa_t$  in the stochastic steady-state for different lending rates  $R_{t+1}^L$ .<sup>18</sup>

Figure 2 shows that higher aggregate volatility (higher  $\sigma_g$ ) contracts credit supply. This effect is due to the structure of debt contracts. Higher volatility of a borrower's income increases the area of default and, since in debt contracts lenders' payoffs are concave in the value of borrower's income, it decreases lenders' expected revenue. Thus, for the same leverage ratio, when aggregate volatility is higher, lenders charge more expensive credit to compensate them for bearing higher default risk.

The effect of uncertainty on credit supply is non-linear in entrepreneurs' leverage ratio. Lending rates react more to increases in aggregate volatility when the entrepreneurs have higher leverage. The reason is that for a given negative shock, default is more likely when leverage is higher.

As we will discuss in the next section, the previous results are stronger in general equilibrium because households are risk-averse and their deposits are exposed to credit risk. Thus, when higher aggregate volatility makes bank deposits riskier, households require larger risk premiums

<sup>17</sup>Throughout this section, we drop country subscripts since we focus on partial equilibrium analysis.

<sup>18</sup>We set the steady state and parameter values as in the full general equilibrium model discussed in the next section. The results are robust to changes in parameters.

to supply bank deposits. The higher cost of raising deposits is another factor pushing lenders to raise their lending rates.

## 6 The Model with and without Credit Channel

In this section, we compare the model with the credit channel presented in Section 4 and another without it. First, we discuss how we parametrize the model, then the impulse responses and simulation results. We solve the stationary version of the model (that is, all trending variables deflated by their trends along the balanced growth path) using a third-order approximation. Fernandez-Villaverde et al. (2011) show that this is the minimum order of approximation for volatility shocks to appear independently in the policy functions, and that model dynamics are unaffected by adding higher order terms to the approximations.

### 6.1 Parametrization

We use GHH preferences common in the international literature to avoid wealth effects on labor supply,

$$U(C_{i,t}, H_{i,t}) = \frac{1}{1-\gamma} \left( C_{i,t} - \eta Z_{i,t} \frac{(H_{i,t})^{1+\frac{1}{\xi}}}{1+\frac{1}{\xi}} \right)^{1-\gamma},$$

where  $\xi$  is the elasticity of labor supply and  $\gamma$  controls the curvature of the utility function. We include  $Z_{i,t}$  in the labor disutility term to ensure that labor supply remains bounded along the balanced growth path (Aguiar and Gopinath 2007).

We set some parameters exogenously following standard values in the literature. Then we estimate the rest of the parameters with a simulated method of moments (SMM).

Table 2 contains the exogenous parameters. We choose the value of  $\eta$  so that the long-run mean of hours worked equals  $\frac{1}{3}$ . We set a period in the model to be one quarter and pick standard values in the literature for the subjective discount factor ( $\beta = 0.99$ ), risk aversion ( $\gamma = 3$ ), elasticity of labor supply ( $\xi = 0.5$ ), depreciation rate ( $\delta = 0.025$ ) and capital share in production ( $\alpha = 0.33$ ). For the trend of TFP growth we use the standard 2% annual rate ( $g = 1.005$ ). Following Backus and Kehoe (1992), the cross-country correlation of stationary TFP level shocks ( $\vartheta$ ) is set to 0.258. For the cost of changing the holdings of international bonds, we follow Fernandez-Villaverde et al. (2011) and select a very small number ( $\phi_B = 0.001$ ) to guarantee well-defined stationary dynamics. We assign a small value ( $\varphi = -0.002$ ) to the technology convergence parameter as its sole purpose is to ensure a well-defined balanced-



growth path. For the survival rate of entrepreneurs ( $\chi$ ) we set a value (0.965) in the middle of the values used in the financial frictions literature. For example, BGG set this parameter at 0.973, Christiano, Motto and Rostagno (2014) at 0.982, and Carlstrom, Fuerst and Paustian (2016) use 0.94.

We estimate the following parameters: 1)  $\sigma_A$ , the standard deviation of the stationary productivity shock; 2)  $\sigma_g$ , the steady-state value of the volatility shock; 3)  $\sigma_\sigma$ , the standard deviation of the volatility shock; 4)  $\rho_A$ , the persistence of the stationary TFP level shock; 5)  $\rho_g$ , the persistence of the growth shock; 6)  $\rho_\sigma$ , the persistence of the volatility shock; 7)  $\mu$ , the monitoring cost; 8)  $\sigma_\omega$ , the cross-sectional standard deviation of entrepreneur's idiosyncratic productivity; and, 9)  $\phi_I$ , the investment adjustment cost.

We target the following 12 moments from the data analyzed in Section 3: 1) standard deviation of output growth; 2 and 3) standard deviations of investment and consumption growth relative to that of output growth; 4) standard deviation of trade balance-to-output ratio; 5 and 6) mean and standard deviation of stock market returns volatility; 7 and 8) persistence of output growth and stock market returns volatility;<sup>19</sup> 9 and 10) the regression coefficients for bank credit-to-GDP and the credit spread in the regression of Table 1, Panel A; 11) long-run mean of entrepreneurs' leverage ratio like in Gourio (2013);<sup>20</sup> 12) long-run means of entrepreneurs' default like in BGG.

To estimate the endogenous parameters we minimize the squared percent deviation between the moments of the model simulations and the actual data.<sup>21</sup> To obtain a model counterpart of the volatility measure, we follow Basu and Bundick (2017) and define a model-implied stock returns volatility,  $\Omega_{i,t}^{\text{model}}$ , as a conditional standard deviation of the returns of entrepreneurs' equity,

$$\Omega_{i,t}^{\text{model}} = 100 \sqrt{\mathbb{E}_t[(R_{i,t+1}^K)^2] - [\mathbb{E}_t(R_{i,t+1}^K)]^2}. \quad (37)$$

<sup>19</sup>Persistence is measured with the AR(1) coefficient. Standard deviations and persistence coefficients are averages across the countries in our sample.

<sup>20</sup>With high-order perturbations, deterministic steady states of stationary endogeneous variables are in general different from their long-run means defined as stochastic steady-states (Juillard and Kamenik 2005).

<sup>21</sup>The algorithm is as follows: let  $m_i(\mathbf{X})$  be an empirical moment  $i$  computed from the data  $\mathbf{X}$ . Denote by  $m_i(\mathbf{X}^{\text{sim}}(\theta))$  the model-implied moment from simulating the model using the parameter vector  $\theta$ . Starting from the stochastic steady state we simulate the stationary model for 180 periods (length of our dataset) with all the shocks. Like Fogli and Perri (2015) we simulate the model 20 times saving the results of Country 1 to generate a world economy of 20 countries. Then, we compute the moments of interest in exactly the same way as in the actual data. We repeat this procedure 10 times such that the model-implied moment  $m_i(\mathbf{X}^{\text{sim}}(\theta))$  is the average over 10 simulations of the 20-country world economy. The estimated parameter vector  $\hat{\theta}$  minimizes the squared percent deviation in order to avoid scale dependence in the objective function:

$$\hat{\theta} = \arg \min_{\theta} \sum_i \left[ \frac{m_i(\mathbf{X}^{\text{sim}}(\theta)) - m_i(\mathbf{X})}{m_i(\mathbf{X})} \right]^2$$

Table 3 reports the results of the estimation. Table 4 shows the model-implied moments and empirical targets. The model is successful at matching the targets and the estimated parameters are within the range of the values used in the RBC and financial frictions literature. For example, the investment adjustment cost parameter is estimated at 1.59, which is close to the 1.4 used by Fogli and Perri (2015). The estimated values for  $\sigma_\omega$  and  $\mu$  are 0.3 and 0.23, close to the values used in BGG (0.28 and 0.12, respectively), and to the values (0.26 and 0.215) estimated by Christiano, Motto and Rostagno (2014). The persistence ( $\rho_A = 0.79$ ) and standard deviation ( $\sigma_A = 0.007$ ) of the stationary level TFP shock are also consistent with the values used in the RBC literature. Concerning the growth shocks, the estimates are in the range of those obtained by Aguiar and Gopinath (2007), Boz, Daude and Durdu (2011) and Cicco, Pancrazi and Uribe (2010).

## 6.2 Impulse Responses

Figures 3 and 4 compare impulse responses to an unanticipated one standard deviation aggregate volatility shock in Country 1. One line is the model with the credit channel presented in Section 4, and the other line is the same model but with no financial frictions and no entrepreneurs. That is, like the IRBC model of Fogli and Perri (2015) but with the volatility shocks in the trend growth to avoid transitory TFP shocks with nearly unit roots. Figure 3 focuses on the responses that are similar across the models. Figure 4 highlights the differences across the models and the mechanism that generates the differences.

Figure 4 shows that both the model with and the model without the credit channel predict that consumption and the risk-free rate decrease in the country that becomes more volatile (Country 1).<sup>22</sup> These results are due to a precautionary savings motive and to a flight-to-quality mechanism. Higher volatility induces prudent households to consume less and save. Higher demand for the international bonds implies a fall in the risk-free rate.

In both models higher volatility induces a surplus in the trade balance of the volatile country. However, the reaction of the trade balance is larger and more persistent in the model with the credit channel. This is because in both models the surge in domestic savings push towards a surplus. Moreover, with a credit channel, higher volatility induces lower investment, as Panel

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<sup>22</sup>The impulse responses display the trending variables as percent deviations from their balanced-growth path. Stationary variables are in percentage point differences from their stochastic steady state values. To compute the stochastic steady-state we simulate the detrended model for many periods with zero innovations of exogenous shocks until the economy converges to a point where all the stationary variables are constant. Following Fernandez-Villaverde et al. (2011), we use this stochastic steady state as the initial point for computing the impulse response functions.

b in Figure 4 shows. Thus, in the model with a credit channel, both the investment collapse and a surge of savings push the trade balance towards surplus. Without the credit channel, investment increases, pushing the trade balance towards a deficit.

Figure 4 plots output, investment, employment and capital. For these variables, the reaction to a volatility shock has opposite signs in the model with a credit channel relative to the model without it. When the labor input can be adjusted freely and investment is reversible, output and investment are convex functions of productivity and thus, by Jensen’s inequality, their expected values increase in the volatility of TFP. Thus, the standard IRBC without a credit channel predicts that higher uncertainty leads to higher investment and output, which contradicts the empirical evidence of Section 3.

Adding the credit channel fixes the comovement problem because it makes investment depend on credit (entrepreneurs need to borrow to finance their capital purchases). Panels e and f of Figure 4 plot the reaction of domestic credit market. Higher uncertainty increases default risk and triggers the contraction of credit supply discussed in Section 5. Moreover, households are now more exposed to the risk of losing their deposits. Thus, they reduce their credit supply, asking for a higher risk premium, which leads to higher funding costs for banks. This general equilibrium effect reinforces the contraction in credit supply. Credit to entrepreneurs falls, investment, output and the price of capital collapse, triggering a financial accelerator à la BGG in which lower entrepreneurs’ equity makes their cost of external funds even higher. Employment drops as lower capital stock in the next period implies lower returns to the labor supply. Thus, the model with the credit channel is consistent with the comovements reported in Section 3.

### 6.3 Simulations

Table 5 contains the results of simulating the models with and without the credit channel to redo Table 1A with model generated data. That is, we create an artificial world economy of 20 countries and regress the simulated series of interest on the model-implied volatility of the stock market returns.<sup>23</sup> The first row of Table 5 displays the regression coefficients reported in Panel A of Table 1 from OECD countries. The second row has the regression coefficients from the artificial data generated by simulating the model with the credit channel. The last row reports the results for the model without the credit channel.

Table 5 shows that both versions of the model predict a positive correlation between aggregate volatility and the trade balance-to-output ratio, as in the data. Although the model with

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<sup>23</sup>We repeat this procedure 10 times such that the reported model-implied regression coefficients are averages over 10 simulations of the 20-country world economy.

the credit mechanism is closer to the data because in that model the trade balance is driven by both an increase in savings and a collapse of investment when volatility rises.

The second and third columns of Table 5 highlight the problem of the model without a credit channel. It predicts a positive correlation between aggregate volatility and investment and output, while in the data these correlations are negative. Incorporating the credit channel allows us to generate the correlation found in the data.

Table B7 in the online appendix shows that incorporating the credit channel does not prevent the model from being consistent with other stylized facts. For example, Hoffmann, Krause and Tillmann (2016) provide evidence that the trade balance-to-GDP ratio is less countercyclical when the volatility of output growth is high. Table B7 shows that the same fact holds in the model with the credit channel.<sup>24</sup>

## 7 Global versus Domestic Banks

The analysis so far has assumed that domestic entrepreneurs are financed by domestic lenders. In this section we analyze the implications of allowing foreign financing of the domestic entrepreneurs. To keep the analysis tractable, we consider two different small open economy versions of the model of Section 4. First, we study only domestic lenders as in the credit supply equation (18). Second, we assume that domestic entrepreneurs are financed by a global bank which collects funds from international investors and builds a diversified portfolio of loans across-countries that allow the global bank to diversify the individual country shocks. Thus, with a global bank, the credit supply equation (18) is replaced by

$$\mathbb{E}_t [M \kappa_t R_{t+1}^K [\Gamma(\bar{\omega}_{t+1}) - \mu G(\bar{\omega}_{t+1})]] = \kappa_t - 1, \quad (38)$$

where the global bank's stochastic discount factor  $M$  is fixed at its steady state value.<sup>25</sup>

Figure 5 compares the reaction of both versions of the model (domestic banks versus global bank) to the same uncertainty shock analyzed in Section 6.2. Qualitatively both models display the same dynamics, although the global bank significantly mitigates the effects of volatility shocks. Since the global bank has a diversified portfolio, higher volatility in one country does not alter the ability of the global bank to raise funds. That is, credit supply contracts only

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<sup>24</sup>Figure B4 illustrates the mechanism behind Table B7. Following a positive TFP shock, the trade balance deteriorates, but less when uncertainty is high. Consumption reacts less because of precautionary savings. Investment is less responsive because credit reacts less to good TFP news when uncertainty is high.

<sup>25</sup>This is equivalent to a risk-neutrality assumption.

because of the mechanism of Section 5 without the amplification generated by households' aversion to the higher risk of their deposits.

Thus, global banks mitigate the contraction of credit supply and the fall in investment and output, associated with higher volatility. This result is relevant for policymakers. Banking globalization has been in retreat since the 2008 financial crisis (Forbes, Reinhart and Wieladek 2017), while, in many countries, aggregate volatility has increased since that crisis (Baker, Bloom and Davis 2016). Our model suggests that the more domestic the financial system becomes, the larger are the effects of volatility.

## 8 Interest Rate Volatility

In a seminal paper, Fernandez-Villaverde et al. (2011) show that volatility shocks to interest rates have an important effect in small open economies. In this section we compare the model with TFP volatility and the credit channel of Section 4 with interest rate volatility shocks à la Fernandez-Villaverde et al. (2011). To do so, we study a small open economy version of Section 4 but we now assume that the risk-free rate on international bonds is subject to volatility shocks. That is, we make the households net borrowers in the international bonds market and the international rate follows an AR(1) process with time-varying volatility as in Fernandez-Villaverde et al. (2011),<sup>26</sup>

$$R_t^f = (1 - \rho_R) R^f + \rho_R R_{t-1}^f + e^{\sigma_{R,t}} \varepsilon_{R,t}, \quad (39)$$

$$\sigma_{R,t} = (1 - \rho_{\sigma_R}) \sigma_R + \rho_{\sigma_R} \sigma_{R,t-1} + \sigma_{\sigma_R} \varepsilon_{\sigma_R,t}. \quad (40)$$

Households borrow from international lenders in order to finance their own consumption and to give loans to domestic entrepreneurs. When interest rate volatility increases, households translate this into their lending conditions to the entrepreneurs. Thus, the analysis in this section allows to compare volatility that comes from the borrower side as entrepreneurs' income fluctuates with TFP volatility, and volatility emanating from the lenders' side, with the fluctuations in the international rate.

Figure 6 compares the impulse responses to volatility shocks to the international rate and to TFP. In both models the size of the shock is one standard deviation. Figure 6 shows that the two shocks are observationally equivalent. That is, higher volatility in borrowers income

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<sup>26</sup>We use the quarterly equivalents of the parameters estimated by Fernandez-Villaverde et al. (2011),  $\rho_R = 0.91$ ,  $\rho_{\sigma_R} = 0.83$ ,  $\sigma_R = -5.71$ ,  $\sigma_{\sigma_R} = 0.8$ .

generates the same dynamics as higher volatility in lenders' cost of funds. Thus, volatility on the borrower's income is a potential micro-foundation for the time-varying volatility of interest rates studied by Fernandez-Villaverde et al. (2011).

Table 6 presents an additional exercise inspired by Fernandez-Villaverde et al. (2011). It measures the contribution to aggregate fluctuations of each of the shocks. Fernandez-Villaverde et al. (2011) discuss that in this class of models the precautionary savings motive is so strong that following TFP level shocks consumption is less volatile than output. The second column of Table 6 confirms this result. In the data, for most emerging economies, consumption is more volatile than output. Table 6 shows that the key to making consumption more volatile than output is to depart from TFP level shocks. For example, column 5 shows that when the economy borrows from abroad to finance their entrepreneurs, fluctuations in interest rates make consumption much more volatile than output.

## 9 Conclusions

There is growing consensus that changes in aggregate volatility play a major role for macroeconomic dynamics. This paper contributes to the growing literature studying the international dimensions of volatility changes. We show that open-economy models built around the precautionary savings channel can explain the positive correlation between volatility and current account dynamics, but generate counterfactual comovements concerning investment and output in OECD economies.

We show that when the precautionary savings channel is complemented with a credit supply channel, the model can simultaneously be consistent with all the comovements. Higher uncertainty increases default risk and credit supply contracts, while spreads rise and investment collapses leading, to a current account surplus. For this credit channel to match the data, the financial contract cannot have a predetermined lenders' return, as is common in the BGG literature. Lenders need to be exposed to aggregate credit risk.

Our results suggest that the link between credit supply and uncertainty is important in understanding recent cross-country dynamics. The model with a credit channel is supported by the cross-country evidence on credit flows and spreads. Future research may further study how this matters for optimal policy. For example, some authors argue that recent regulations have encouraged banking deglobalization after the 2008 financial crisis. Our paper shows that this may make economies more vulnerable to increases in uncertainty.

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## Appendix: Data Sources

Our sample includes Australia (AUS), Austria (AUT), Belgium (BEL), Canada (CAN), Denmark (DNK), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Italy (ITA), Mexico (MEX), Japan (JPN), South Korea (KOR), Netherlands (NED), Norway (NOR), Spain (ESP), Sweden (SWE), Switzerland (CHE), United Kingdom (GBR) and the United States (USA). These are the data sources for the series used in the paper:

a) GDP, investment, consumption, government expenditure and the trade balance-to-GDP ratio are from OECD Quarterly National Accounts and cover 1970Q1-2014Q4.

b) Current account-to-GDP ratio is from OECD's Economic Outlook database. The length of the series varies across the countries: AUS (1970q1-2014q4), AUT (1970q1-2014q4), BEL (1975q1-2014q4), CAN (1970q1-2014q4), CHE (1972q1-2014q4), DEU (1971q1-2014q4), DNK (1975q1-2014q4), ESP (1975q1-2014q4), FIN (1974q4-2014q4), FRA (1973q1-2014q4), GBR (1970q1-2014q4), GRC (1995q1-2014q4), ITA (1970q1-2014q4), JPN (1970q1-2014q4), KOR (1975q1-2014q4), MEX (1993q1-2014q4), NED (1970q1-2014q4), NOR (1975q1-2014q4), SWE (1975q1-2014q4), and USA (1970q1-2014q4).

c) The volatility and level of stock market returns are computed using MSCI Index daily data from Datastream. The series are available for 1970q1-2014q4 for all countries in our sample, except for FIN (1982q1-2014q4), GRC (1988q1-2014q4), KOR (1988q1-2014q4), MEX (1988q1-2014q4).

d) Credit variables come from the Bank of International Settlements. Bank credit is credit extended by domestic banks to the private non-financial sector. Total credit comprises financing from all sources, including domestic banks, other domestic financial corporations, non-financial corporations and non-residents. The length of the series varies across countries: AUS (1970q1-2014q4), AUT (1970q1-2014q4), BEL (1970q4-2014q4), CAN (1970q1-2014q4), CHE (1970q4-2014q4), DEU (1970q1-2014q4), DNK (1970q1-2014q4), ESP (1970q1-2014q4), FIN (1974q4-2014q4), FRA (1970q1-2014q4), GBR (1970q1-2014q4), GRC (1970q4-2014q4), ITA (1974q4-2014q4), JPN (1970q1-2014q4), KOR (1970q1-2014q4), MEX (1980q4-2014q4), NED (1970q1-2014q4), NOR (1970q1-2014q4), SWE (1970q1-2014q4), and USA (1970q1-2014q4). Total credit-to-GDP ratio data for each country is available for the same period as the bank credit series, except for FIN (1970q4-2014q4) and ITA (1970q1-2014q4).

e) Corporate lending rates are from Global Financial Data. For all countries we use corporate bond yield data, except for FIN, NLD and GRC in which, due to lack of data, we use the interest rate on bank loans to non-financial corporations. The length of the series varies

across countries: AUS (1983q2-2011q4), AUT (1970q1-2014q4), BEL (1970q1-2012q3), CAN (1970q1-2014q4), CHE (1982q1-2014q4), DEU (1970q1-2014q4), DNK (1987q1-2012q4), ESP (1977q1-2013q3), FIN (2003q1-2013q4), FRA (1970q1-2014q4), GBR (1970q1-2014q4), GRC (2003q1-2013q3), ITA (1970q1-2014q4), JPN (1970q1-2014q4), KOR (1972q1-2014q4), MEX (1993q2-2014q4), NED (2003q1-2013q3), NOR (1970q1-2003q4), SWE (1974q1-2011q4), and USA (1970q1-2014q4).

f) Government bond yields are from the IMF's International Financial Statistics, line 61. The series are available for the period 1970q1-2014q4 for all countries in our sample, except for ESP (1978Q2-2014Q4), FIN (1988Q1-2014Q4), GRC (1992Q4-2014Q4), KOR (1973Q3-2014Q4), MEX (1999Q2-2014Q4).

g) CPI inflation (1970Q1-2014Q4) and exchange rates (1970Q1-2014Q4) are from the IMF's International Financial Statistics.

# Tables and Figures

**Table 1. Aggregate Uncertainty and Macroeconomic Dynamics**

Panel A					
	$\frac{TB}{Y}$	$\Delta \log Y$	$\Delta \log I$	$\Delta \frac{\text{Bank credit}}{Y}$	Credit spread
Volatility of stock returns	1.27** (0.012)	-0.19* (0.052)	-0.52** (0.043)	-0.27** (0.03)	1.93** (0.049)
Controls	No	No	No	No	No
Country & time FE	Yes	Yes	Yes	Yes	Yes
Number Observations	3336	3336	3336	3311	2681
$R^2$	0.61	0.29	0.14	0.17	0.55
Panel B. Adding control variables					
	$\frac{TB}{Y}$	$\Delta \log Y$	$\Delta \log I$	$\Delta \frac{\text{Bank credit}}{Y}$	Credit spread
Volatility of stock returns	1.24** (0.018)	-0.16* (0.063)	-0.45* (0.064)	-0.25* (0.071)	1.2*** (0.008)
Controls	Yes	Yes	Yes	Yes	Yes
Country & time FE	Yes	Yes	Yes	Yes	Yes
Number Observations	3307	3307	3307	3282	2681
$R^2$	0.61	0.33	0.15	0.19	0.69

Notes: P-values are in parentheses (\*p-value<0.10, \*\*p-value<0.05, \*\*\*p-value<0.01). Robust standard errors are clustered at the country level. All variables, unless otherwise noted, are expressed in percentages. Volatility of stock returns is defined as the quarterly standard deviation of daily stock market returns, computed using the MSCI index.  $\frac{TB}{Y}$  denotes trade balance-to-GDP ratio.  $\Delta \log Y$  and  $\Delta \log I$  denote quarterly growth rates of real GDP and investment, respectively.  $\Delta \frac{\text{Bank credit}}{Y}$  is quarterly change (in percentage points) in the ratio of bank credit-to-GDP. Credit spread is the difference between the domestic lending rate to corporations and the interest rate of long-term German government bond (in annualized percentage points). Panel A reports the results from pooled OLS regressions of each variable of interest on the volatility of stock market returns. Panel B adds quarterly control variables: CPI inflation, change in exchange rate (national currency per USD), trade openness ( $\frac{\text{Exports}+\text{Imports}}{\text{GDP}}$ ), growth of real government spending, and stock market returns. The sample period is 1970:q1-2014:q4 (subject to data availability, see Appendix).

**Table 2. Exogenous Parameters**

Discount factor	$\beta$	0.99
Risk aversion	$\gamma$	3
Elasticity of labor supply	$\xi$	0.5
Labor weight in utility function	$\eta$	14
Depreciation rate	$\delta$	0.025
Capital share in production	$\alpha$	0.33
Bond adjustment cost	$\phi_B$	0.001
Trend growth rate	$g$	1.005
Convergence parameter	$\varphi$	-0.002
Correlation of transitory TFP shocks	$\vartheta$	0.258
Survival rate of entrepreneurs	$\chi$	0.965
Transfers to entrepreneurs	$T^E$	0.0001

**Table 3. Estimated Parameters**

Investment adjustment cost	$\phi_I$	1.59 (0.68)
Std. dev. of entrepreneurs productivity	$\sigma_\omega$	0.3 (0.07)
Bankruptcy cost	$\mu$	0.23 (0.01)
Persistence of stationary technology shock	$\rho_A$	0.8 (0.2)
Persistence of trend shock	$\rho_g$	0.84 (0.22)
Persistence of volatility shock	$\rho_\sigma$	0.77 (0.25)
Std. dev. of stationary technology shock	$\sigma_A$	0.007 (0.002)
Std. dev. of volatility shock	$\sigma_\sigma$	0.51 (0.22)
Steady state value of volatility shock	$\sigma_g$	-5.74 (1.58)

Note: Standard errors are in parentheses and computed as in Lee and Wolpin (2010). Section 6.1 describes the estimation exercise.

**Table 4. Model vs. Empirical Targets**

	Model	Target
$\sigma(\Delta \log Y)$	1.15	1.12
$\frac{\sigma(\Delta \log I)}{\sigma(\Delta \log Y)}$	2.61	2.87
$\frac{\sigma(\Delta \log C)}{\sigma(\Delta \log Y)}$	0.82	0.96
$\sigma\left(\frac{TB}{Y}\right)$	2.74	2.81
Mean leverage ratio	1.86	1.8
Mean default rate (%)	2.95	3
Mean of stock returns volatility	1.31	1.14
Std. dev. of stock returns volatility	0.31	0.57
Persistence of output growth	0.19	0.17
Persistence of stock returns volatility	0.77	0.66
$\widehat{\beta}_{\Delta \frac{\text{Bank credit}}{Y}}$	-0.27	-0.27
$\widehat{\beta}_{\text{Credit spread}}$	1.92	1.93

Notes:  $\Delta \log Y$ ,  $\Delta \log I$  and  $\Delta \log C$  denote quarterly growth rates (in percentages) of output, investment and consumption.  $\frac{TB}{Y}$  is the trade balance-to-output (in percent).  $\sigma(x)$  denotes standard deviation of variable  $x$ .  $\widehat{\beta}_{\Delta \frac{\text{Bank credit}}{Y}}$  and  $\widehat{\beta}_{\text{Credit spread}}$  denote regression coefficients for the bank credit-to-output ratio and credit spread regressions in the equivalent of Table 1, Panel A with the model generated data. Section 6.1 discusses the details.



**Table 5. Regression Coefficients**

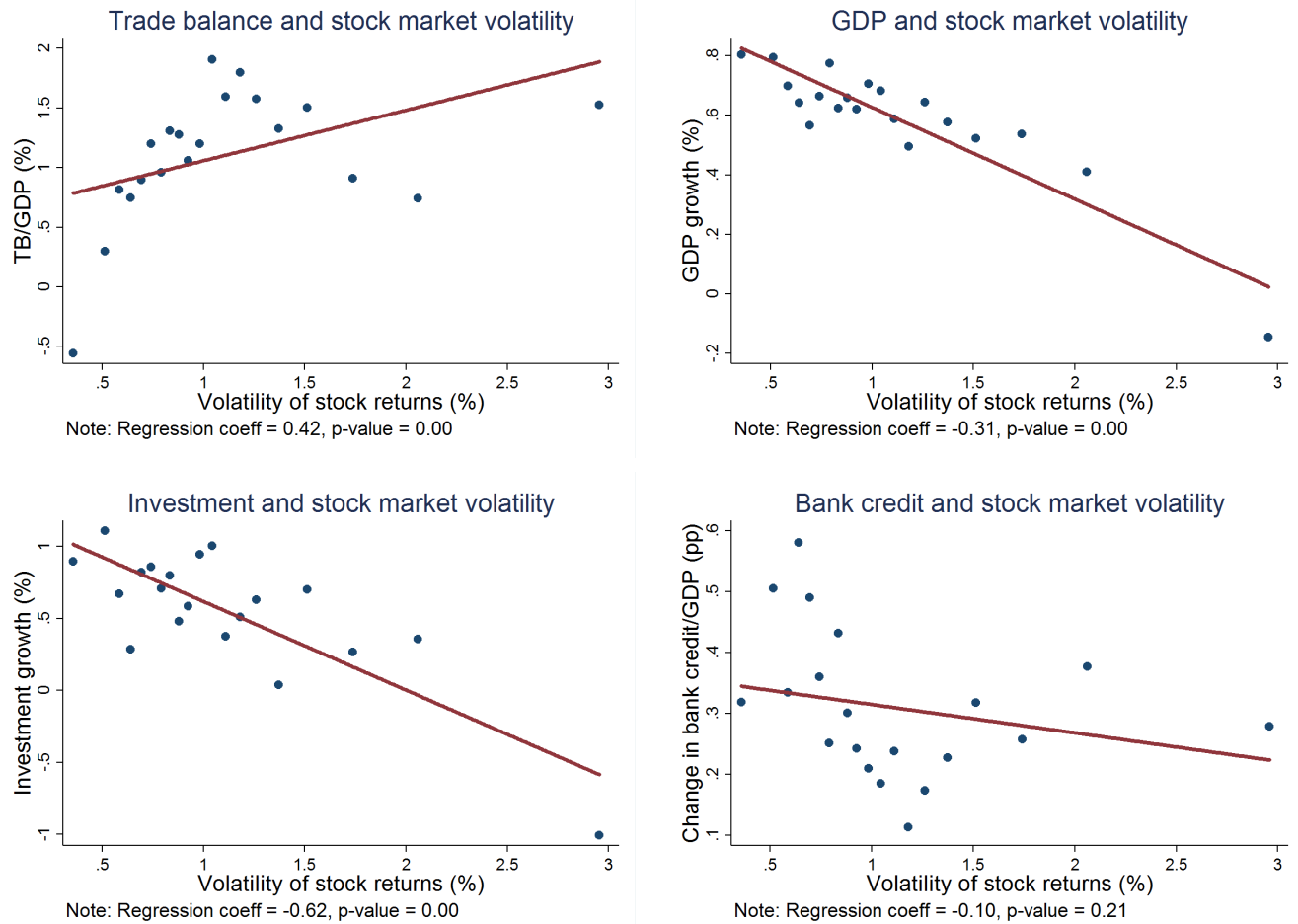
	$\frac{TB}{Y}$	$\Delta \log Y$	$\Delta \log I$
Data (Table 1, Panel A)	1.27	-0.19	-0.52
With credit channel	1.35	-0.21	-0.76
Without credit channel	0.15	0.10	0.19

Notes: The first row copies the regression coefficients from Table 1, Panel A. The second row has the regression coefficients estimated with data generated from the model with the credit channel. The third row is like the second row but the data come from the model without credit channel. Both models are simulated with all the shocks. Section 6.3 discusses the details.

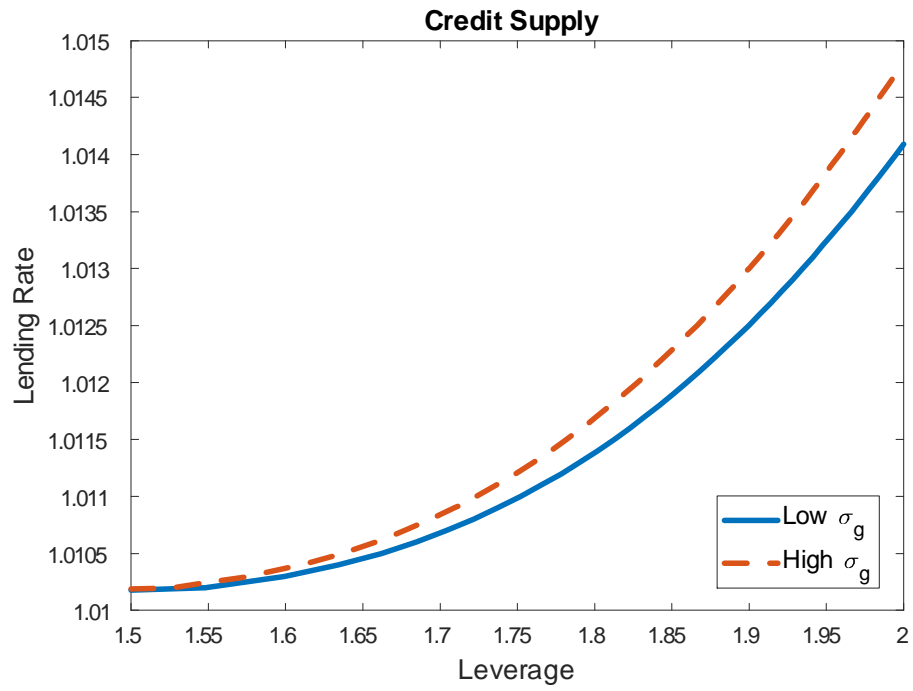
**Table 6. Conditional Standard Deviations**

	(1)	(2)	(3)	(4)	(5)
	All shocks	TFP level	Interest rate level	TFP volat.	Interest rate volat.
$\sigma(\Delta \log Y)$	1.43	1.10	0.19	0.02	0.01
$\sigma(\Delta \log I)$	14.1	4.21	3.88	0.43	0.26
$\sigma(\Delta \log C)$	2.54	0.96	0.58	0.10	0.10

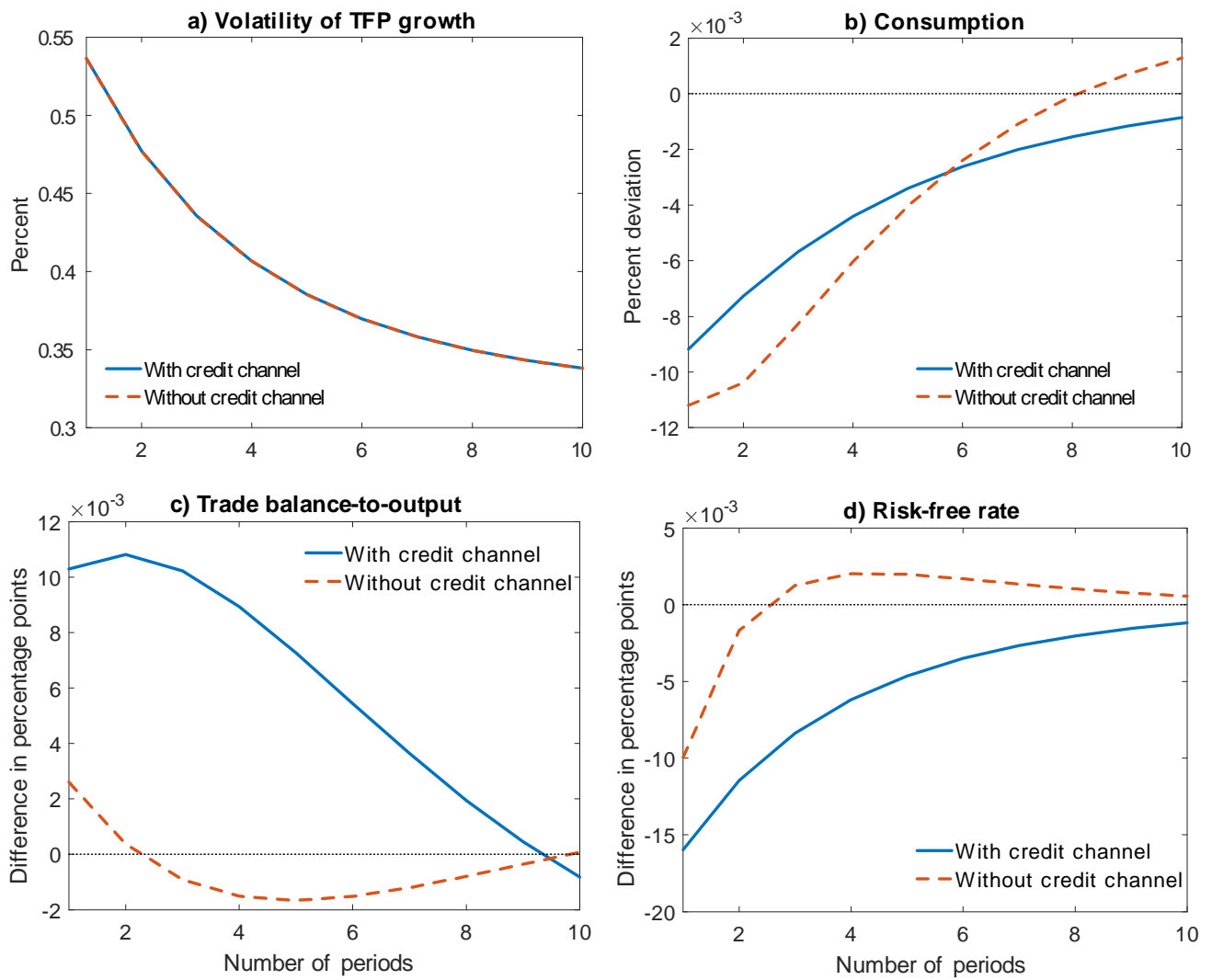
Notes: This table reports conditional standard deviations of growth rates (in percentages) of output, investment and consumption, when we feed into the small open economy model of Section 8 different combinations of the shocks. That is, we compare (1) all shocks; (2) only TFP level shocks; (3) only interest rate level shock; (4) only TFP volatility shock, and (5) only interest rate volatility shock.



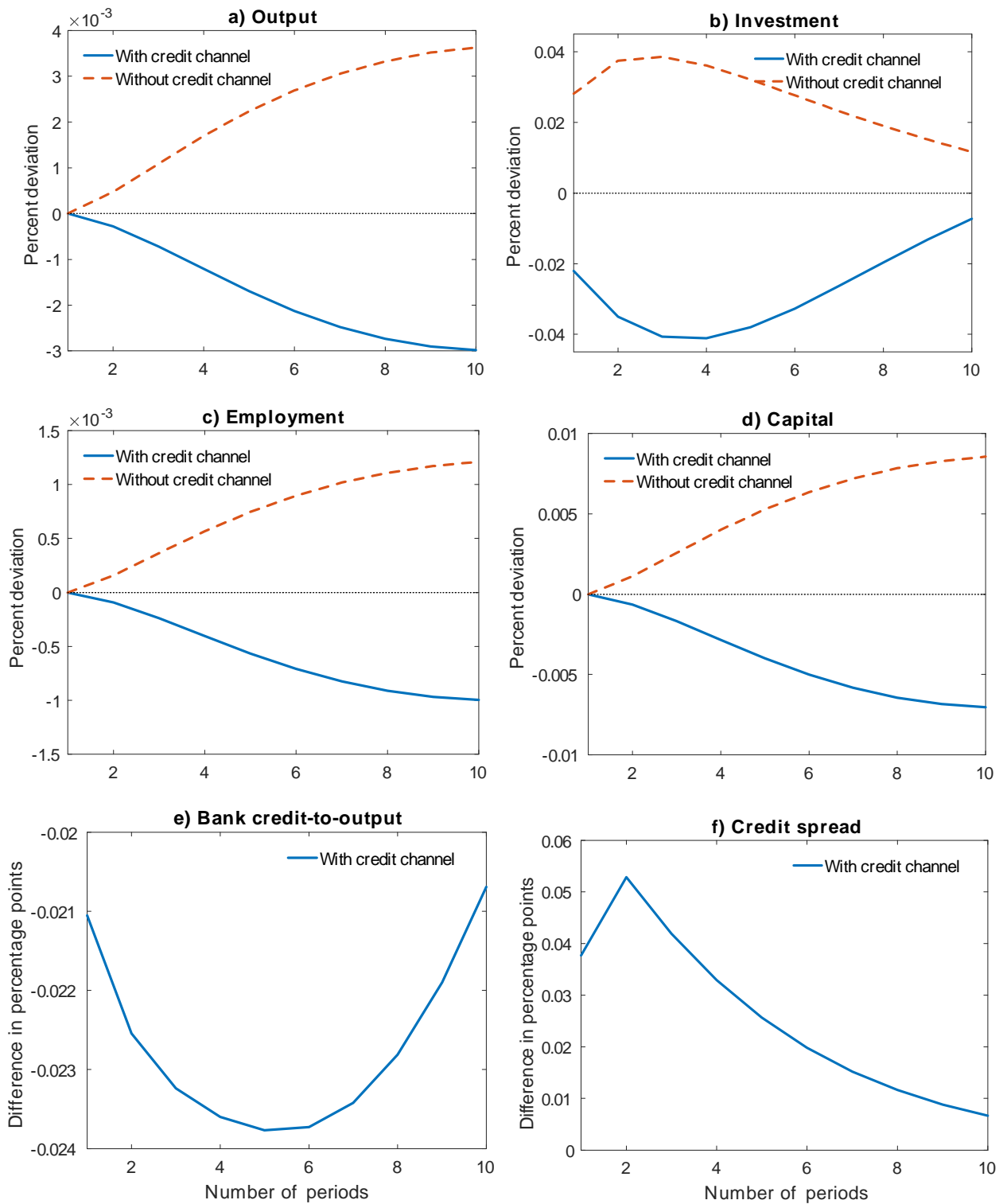
**Figure 1. Volatility of Stock Market Returns vs. Trade Balance, Output, Investment and Credit.** Each panel plots a binned scatterplot of the  $y$  variable of interest against the volatility of stock market returns. The  $y$  variables of interest are trade balance-to-GDP, real quarterly growth rates of GDP and investment, and quarterly change in bank credit-to-GDP ratio. Volatility of stock returns is the quarterly standard deviation of daily stock market returns, computed using MSCI index. Each scatterplot has 20 equally sized bins, each with around 166 observations. The fitted line is obtained from the OLS regression using the full sample, 1970q1-2014q4.



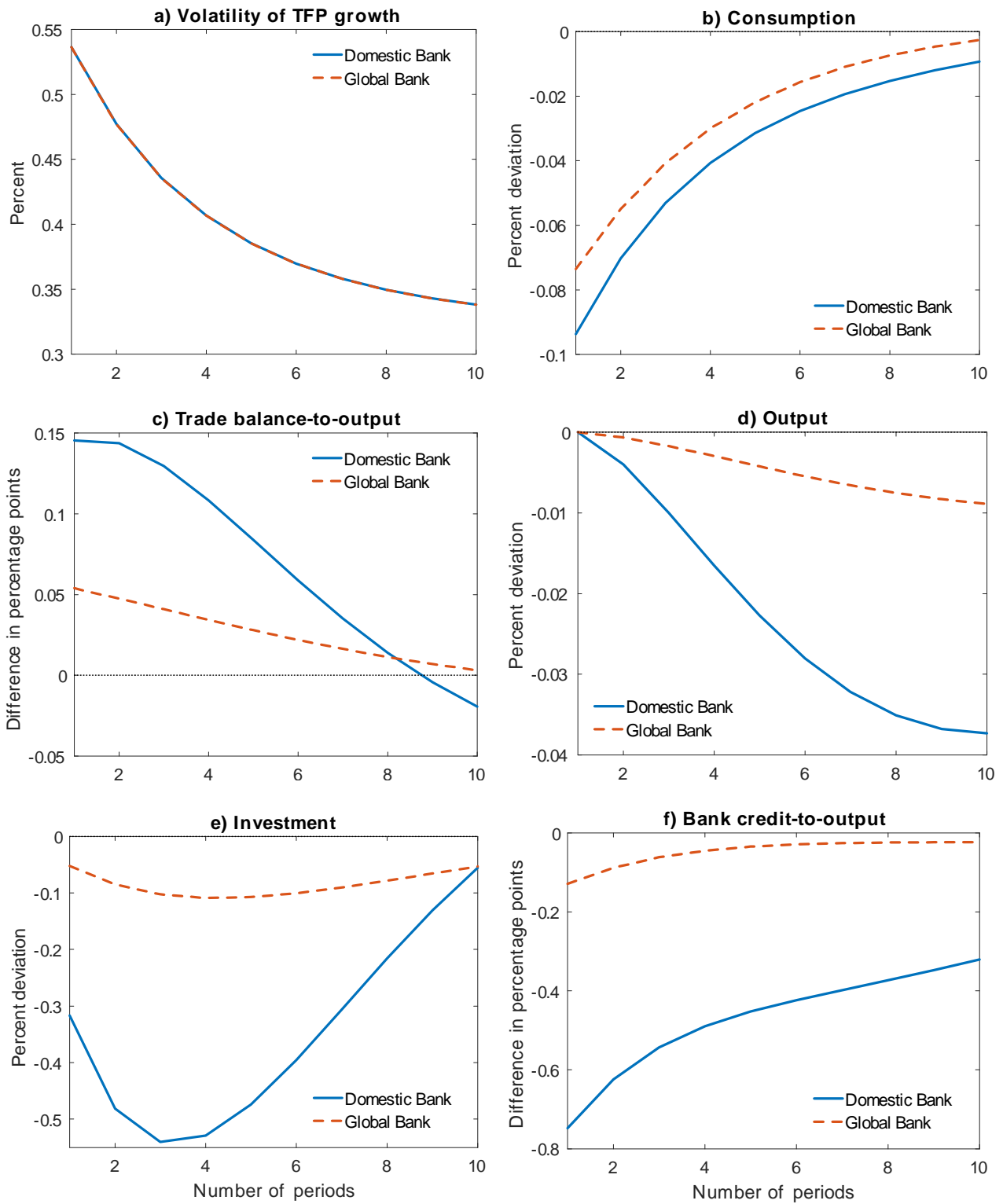
**Figure 2. Volatility and Credit Supply.** This figure plots the leverage ratios and gross lending rates that satisfy the lenders' participation constraint (12) for a high and a low value of the steady state volatility parameter.



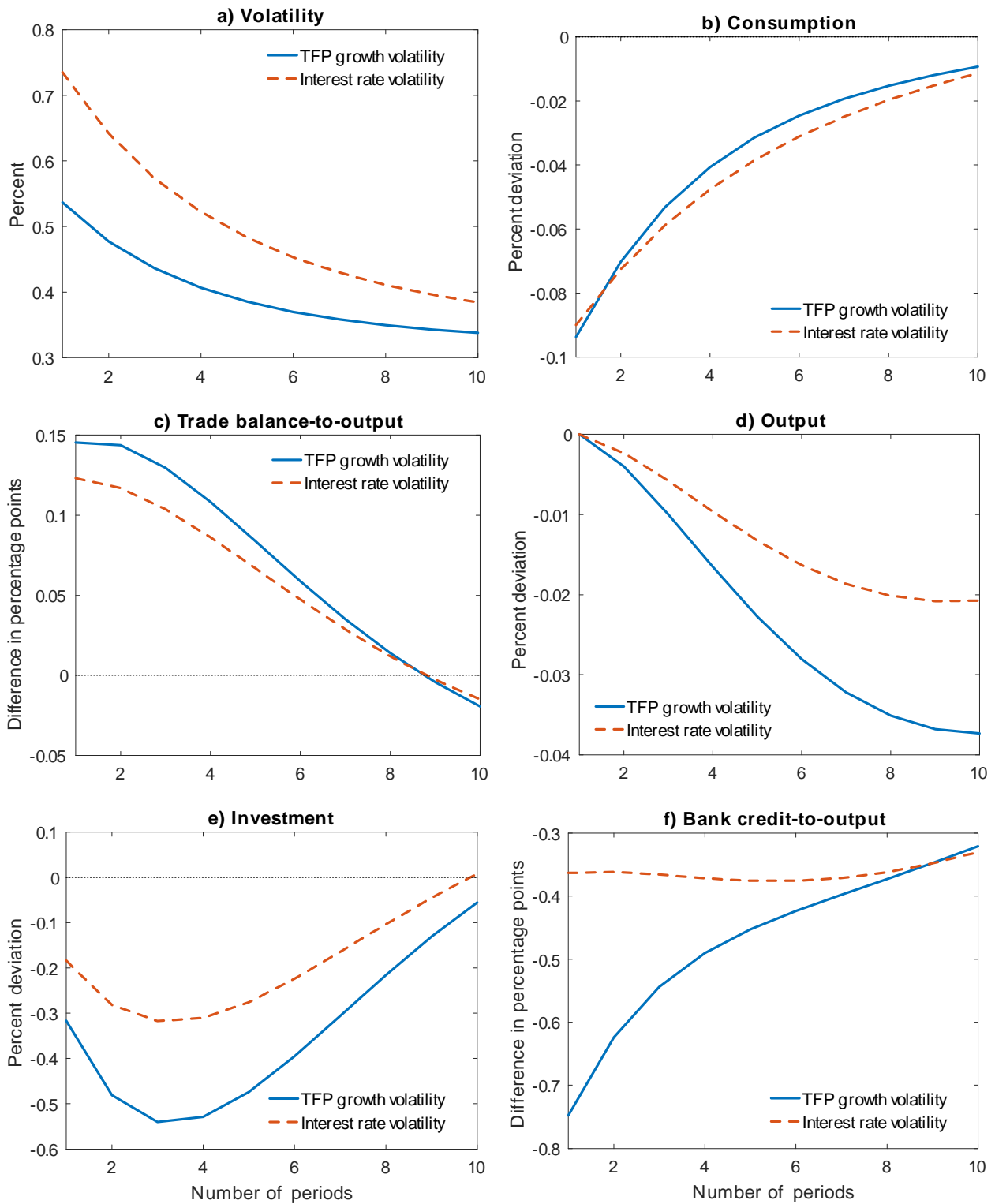
**Figure 3. Models With and Without Credit Channel: Common Patterns.** This figure compares the responses to a one standard deviation volatility shock in Country 1 in the models with and without a credit channel.



**Figure 4. Models With and Without Credit Channel: Differences.** This figure compares the responses to a one standard deviation volatility shock in Country 1 in the models with and without a credit channel.



**Figure 5. Response to a Volatility Shock: Domestic Bank vs. Global Bank.** This figure compares the responses to a one standard deviation volatility shock in the model with a domestic bank and in the model with a global bank. See Section 7 for details.



**Figure 6. TFP Growth Volatility vs. Interest Rate Volatility.** This figure compares the responses to shocks to TFP growth volatility and to interest rate volatility in a small open economy version of the model with the credit channel. Both shocks are one standard deviation shocks. The solid line is the same as in Figure 5. See Section 8 for details.



# Online Appendix A: NOT-FOR-PUBLICATION

## A Equilibrium Conditions

First we present the equilibrium conditions for the non-stationary system. Then we discuss how we transform it into a stationary one. We use subscript  $i$  to index the country ( $i = 1, 2$ ) and subscript  $j$  to refer to an individual entrepreneur.

### A.1 Households

The first order conditions for the household's problem are:

$$\eta Z_{i,t} (H_{i,t})^{\frac{1}{\xi}} = W_{i,t}, \quad (\text{A1})$$

$$R_t^f \mathbb{E}_t [M_{i,t+1}] = \left[ 1 + \phi_B \left( \frac{B_{i,t}}{Z_{i,t}} - \widehat{B} \right) \right], \quad (\text{A2})$$

$$\mathbb{E}_t [M_{i,t+1} R_{i,t+1}^D] = 1, \quad (\text{A3})$$

where  $M_{i,t+1}$  denotes household's stochastic discount factor:

$$M_{i,t+1} \equiv \beta \frac{\lambda_{i,t+1}}{\lambda_{i,t}} = \beta \frac{\left( C_{i,t+1} - \eta Z_{i,t+1} \frac{(H_{i,t+1})^{1+\frac{1}{\xi}}}{1+\frac{1}{\xi}} \right)^{-\gamma}}{\left( C_{i,t} - \eta Z_{i,t} \frac{(H_{i,t})^{1+\frac{1}{\xi}}}{1+\frac{1}{\xi}} \right)^{-\gamma}}. \quad (\text{A4})$$

### A.2 Capital Producers

Capital producers solve:

$$\max_{I_{i,t}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U_C(C_{i,t}, H_{i,t}) \left[ Q_{i,t} \left( 1 - \frac{\phi_I}{2} \left( \frac{I_{i,t}}{I_{i,t-1}} - g \right)^2 \right) I_{i,t} - I_{i,t} \right]. \quad (\text{A5})$$

The first order condition for this problem is:

$$1 + Q_{i,t} \left( \begin{array}{c} \phi_I \left( \frac{I_{i,t}}{I_{i,t-1}} - g \right) \left( \frac{I_{i,t}}{I_{i,t-1}} \right) \\ - \left( 1 - \frac{\phi_I}{2} \left( \frac{I_{i,t}}{I_{i,t-1}} - g \right)^2 \right) \end{array} \right) = \mathbb{E}_t \left[ M_{i,t+1} Q_{i,t+1} \phi_I \left( \frac{I_{i,t+1}}{I_{i,t}} - g \right) \left( \frac{I_{i,t+1}}{I_{i,t}} \right)^2 \right]. \quad (\text{A6})$$

### A.3 Firms Producing Goods

Profit maximization implies the following equilibrium conditions:

$$r_{i,t} = \alpha \frac{Y_{i,t}}{K_{i,t-1}}, \quad (\text{A7})$$

$$W_{i,t} = (1 - \alpha) \frac{Y_{i,t}}{H_{i,t}}. \quad (\text{A8})$$

### A.4 Entrepreneurs and the Financial Contract

The financial contract is a pair of leverage ratio  $\kappa_{i,j,t}$  and state-contingent default threshold  $\bar{\omega}_{i,j,t+1}$  that maximizes entrepreneur's value function,

$$V_{i,j,t} = (1 - \chi) N_{i,j,t} + \beta \chi \max_{\{\bar{\omega}_{i,j,t+1}, \kappa_{i,j,t}\}} \mathbb{E}_t (V_{i,j,t+1}) \quad (\text{A9})$$

subject to lenders' participation constraint:

$$\mathbb{E}_t [M_{i,t+1} \kappa_{i,j,t} R_{i,t+1}^K [\Gamma(\bar{\omega}_{i,j,t+1}) - \mu G(\bar{\omega}_{i,j,t+1})]] = \kappa_{i,j,t} - 1, \quad (\text{A10})$$

where  $M_{i,t+1}$  is household's stochastic discount factor. Equation (A9) is the entrepreneur's Bellman equation and is obtained by recursive formulation of (14). We will show that the leverage ratio  $\kappa_{i,j,t}$  and the default threshold  $\bar{\omega}_{i,j,t+1}$  are the same for all the entrepreneurs of country  $i$ .

Using the functions (16), (17), and the definition of leverage (15), entrepreneur  $j$ 's equity can be written as:

$$N_{i,j,t+1} = [1 - \Gamma(\bar{\omega}_{i,j,t+1})] R_{i,t+1}^K Q_{i,t} K_{i,j,t} = [1 - \Gamma(\bar{\omega}_{i,t+1}^j)] R_{i,t+1}^K \kappa_{i,j,t} N_{i,j,t}. \quad (\text{A11})$$

Because of constant returns to scale and risk neutrality, we guess and verify that the value function is linear in individual equity:

$$V_{i,j,t} = V_{i,t} N_{i,j,t}, \quad (\text{A12})$$

where  $V_{i,t}$  is time-varying and common across entrepreneurs. Substituting this guess into the

Bellman equation (A9) and using (A11), we obtain:

$$V_{i,t} = (1 - \chi) + \beta\chi \max_{\{\bar{\omega}_{i,j,t+1}, \kappa_{i,j,t}\}} \mathbb{E}_t [V_{i,t+1} [1 - \Gamma(\bar{\omega}_{i,j,t+1})] R_{i,t+1}^K \kappa_{i,j,t}]. \quad (\text{A13})$$

The Lagrangian for this problem is:

$$\mathcal{L}_{i,j,t} = \left\{ \begin{array}{l} \beta\chi \mathbb{E}_t [V_{i,t+1} [1 - \Gamma(\bar{\omega}_{i,j,t+1})] R_{i,t+1}^K \kappa_{i,j,t}] + \\ + \Lambda_{i,j,t} [\mathbb{E}_t [M_{i,t+1} \kappa_{i,j,t} R_{i,t+1}^K [\Gamma(\bar{\omega}_{i,j,t+1}) - \mu G(\bar{\omega}_{i,j,t+1})]] - (\kappa_{i,j,t} - 1)] \end{array} \right\}.$$

The first order conditions with respect to  $\bar{\omega}_{i,j,t+1}$ ,  $\kappa_{i,j,t}$  and Lagrange multiplier  $\Lambda_{i,j,t}$  are:

$$-\beta\chi V_{i,t+1} \Gamma'(\bar{\omega}_{i,j,t+1}) + \Lambda_{i,j,t} M_{i,t+1} [\Gamma'(\bar{\omega}_{i,j,t+1}) - \mu G'(\bar{\omega}_{i,j,t+1})] = 0, \quad (\text{A14})$$

$$\beta\chi \mathbb{E}_t [V_{i,t+1} [1 - \Gamma(\bar{\omega}_{i,j,t+1})] R_{i,t+1}^K] + \Lambda_{i,j,t} [\mathbb{E}_t \{M_{i,t+1} R_{i,t+1}^K [\Gamma(\bar{\omega}_{i,j,t+1}) - \mu G(\bar{\omega}_{i,j,t+1})]\} - 1] = 0, \quad (\text{A15})$$

and

$$\mathbb{E}_t \{M_{i,t+1} \kappa_{i,j,t} R_{i,t+1}^K [\Gamma(\bar{\omega}_{i,j,t+1}) - \mu G(\bar{\omega}_{i,j,t+1})]\} = \kappa_{i,j,t} - 1. \quad (\text{A16})$$

Combining (A14) and (A15), we obtain that the default threshold does not depend on individual equity and is the same for all entrepreneurs, that is,

$$\bar{\omega}_{i,j,t+1} = \bar{\omega}_{i,t+1}.$$

Equation (A16) implies that the leverage ratio is common across entrepreneurs,

$$\kappa_{i,j,t} = \kappa_{i,t}.$$

Combining (A15) and (A16) with (A13) we obtain:

$$V_{i,t} = (1 - \chi) + \Lambda_{i,t}. \quad (\text{A17})$$

This equation shows that  $V_{i,t}$  is common across entrepreneurs, thus we do not need the  $j$  subscript.

Substituting (A17) into (A14) and dropping the  $j$  index we obtain the equilibrium conditions:

$$\Lambda_{i,t} M_{i,t+1} [\Gamma'(\bar{\omega}_{i,t+1}) - \mu G'(\bar{\omega}_{i,t+1})] = \beta\chi \Gamma'(\bar{\omega}_{i,t+1}) [(1 - \chi) + \Lambda_{i,t+1}], \quad (\text{A18})$$

$$\left\{ \begin{array}{l} \beta\chi\mathbb{E}_t [(1 - \chi + \Lambda_{i,t}) [1 - \Gamma(\bar{\omega}_{i,t+1})] R_{i,t+1}^K] + \\ + \Lambda_{i,t} [\mathbb{E}_t [M_{i,t+1} R_{i,t+1}^K [\Gamma(\bar{\omega}_{i,t+1}) - \mu G(\bar{\omega}_{i,t+1})]] - 1] \end{array} \right\} = 0, \quad (\text{A19})$$

$$\mathbb{E}_t [M_{i,t+1} \kappa_{i,t} R_{i,t+1}^K [\Gamma(\bar{\omega}_{i,t+1}) - \mu G(\bar{\omega}_{i,t+1})]] = \kappa_{i,t} - 1. \quad (\text{A20})$$

Finally, by aggregating (A11) over individual entrepreneurs and adding the transfers from the households entrepreneurs' we obtain entrepreneurs aggregate equity:

$$N_{i,t} = \chi [1 - \Gamma(\bar{\omega}_{i,t})] R_{i,t}^K Q_{i,t-1} K_{i,t-1} + Z_{i,t} T^E. \quad (\text{A21})$$

The aggregate consumption of the entrepreneurs who pass-away is:

$$C_{i,t}^E = (1 - \chi) [1 - \Gamma(\bar{\omega}_{i,t})] R_{i,t}^K Q_{i,t-1} K_{i,t-1}. \quad (\text{A22})$$

## A.5 Making the System Stationary

The previous model has stationary and trending variables. The trending variables in the model are:  $C_{i,t}, Y_{i,t}, I_{i,t}, I_{i,t}^n, K_{i,t}, N_{i,t}, C_{i,t}^E, L_{i,t}, D_{i,t}, B_{i,t}, W_{i,t}$ . For a given variable  $x_{i,t}$  with trend of  $Z_{i,t}$ , we define the stationary variable  $\hat{x}_{i,t} \equiv \frac{x_{i,t}}{Z_{i,t}}$ .

# Online Appendix B: NOT-FOR-PUBLICATION

## B Additional Tables and Figures

**Table B1. Robustness to Alternative Measures of External Position, Credit Flows and Interest Rate Spreads**

	Panel A		
	$\frac{CA}{Y}$	$\Delta \frac{\text{Total credit}}{Y}$	Gov. spread
Volatility of stock returns	1.20** (0.025)	-0.42** (0.001)	0.92* (0.061)
Controls	No	No	No
Country & time FE	Yes	Yes	Yes
Number Observations	3182	3331	3216
$R^2$	0.55	0.19	0.64
Panel B. Adding control variables			
	$\frac{CA}{Y}$	$\Delta \frac{\text{Total credit}}{Y}$	Gov. spread
Volatility of stock returns	1.21** (0.033)	-0.43*** (0.001)	0.79* (0.091)
Controls	Yes	Yes	Yes
Country & time FE	Yes	Yes	Yes
Number Observations	3181	3302	3202
$R^2$	0.58	0.21	0.67

Note: P-values are in parentheses (\*p-value<0.10, \*\*p-value<0.05, \*\*\*p-value<0.01). Robust standard errors are clustered at the country level. The measure of volatility and the control variables are the same as in Table 1.  $\frac{CA}{Y}$  denotes current account balance as percent of GDP.  $\Delta \frac{\text{Total credit}}{Y}$  is quarterly change (percentage points) in total credit-to-GDP ratio. Government spread is defined as the difference between the yields of the long-term domestic government bond and the German government bond (in annualized percentage points). The sample period is 1970:q1-2014:q4 (subject to data availability). The appendix describes the sample and data sources.

**Table B2. Robustness to Using Relative Volatility**

	Panel A				
	$\frac{TB}{Y}$	$\Delta \log Y$	$\Delta \log I$	$\Delta \frac{\text{Bank credit}}{Y}$	Credit spread
Relative volat. of stock returns	1.2** (0.012)	-0.18* (0.053)	-0.49** (0.043)	-0.26** (0.029)	1.82** (0.049)
Controls	No	No	No	No	No
Country & time FE	Yes	Yes	Yes	Yes	Yes
Number Observations	3336	3336	3336	3311	2681
$R^2$	0.61	0.29	0.14	0.17	0.55
	Panel B. Adding control variables				
	$\frac{TB}{Y}$	$\Delta \log Y$	$\Delta \log I$	$\Delta \frac{\text{Bank credit}}{Y}$	Credit spread
Relative volat. of stock returns	1.17** (0.019)	-0.15* (0.083)	-0.43* (0.065)	-0.24* (0.071)	1.11*** (0.008)
Controls	Yes	Yes	Yes	Yes	Yes
Country & time FE	Yes	Yes	Yes	Yes	Yes
Number Observations	3307	3307	3307	3282	2681
$R^2$	0.61	0.33	0.15	0.19	0.69

Note: P-values are in parentheses (\*p-value<0.10, \*\*p-value<0.05, \*\*\*p-value<0.01). Robust standard errors are clustered at the country level. The measure of volatility is relative stock market returns volatility, that is, the country's domestic volatility minus average volatility in the rest of the countries in the sample. The outcome variables and controls are the same as in Table 1. The appendix describes the sample and data sources.

**Table B3. Volatility Measured with GDP Growth 5-year Rolling Windows**

	Panel A				
	$\frac{TB}{Y}$	$\Delta \log Y$	$\Delta \log I$	$\Delta \frac{\text{Bank credit}}{Y}$	Credit spread
Volat. of GDP growth (5yrs.)	1.31** (0.017)	-0.12* (0.072)	-0.30* (0.065)	-0.23* (0.066)	2.74** (0.036)
Controls	No	No	No	No	No
Country & time FE	Yes	Yes	Yes	Yes	Yes
Number Observations	3200	3200	3200	3149	2511
$R^2$	0.62	0.26	0.13	0.18	0.59
	Panel B. Adding control variables				
	$\frac{TB}{Y}$	$\Delta \log Y$	$\Delta \log I$	$\Delta \frac{\text{Bank credit}}{Y}$	Credit spread
Volat. of GDP growth (5yrs.)	1.35** (0.027)	-0.13* (0.087)	-0.41 (0.101)	-0.18 (0.23)	1.62** (0.015)
Controls	Yes	Yes	Yes	Yes	Yes
Country & time FE	Yes	Yes	Yes	Yes	Yes
Number Observations	2947	2947	2947	2937	2449
$R^2$	0.64	0.33	0.16	0.19	0.71

Note: P-values are in parentheses (\*p-value<0.10, \*\*p-value<0.05, \*\*\*p-value<0.01). Robust standard errors are clustered at the country level. The measure of volatility is the standard deviation of quarterly real GDP growth rates (in percentage) over 5-year rolling windows. The outcome variables and controls are the same as in Table 1. The appendix describes the sample and data sources.

**Table B4. Volatility Measured with GDP Growth 10-year Rolling Windows**

	Panel A				
	$\frac{TB}{Y}$	$\Delta \log Y$	$\Delta \log I$	$\Delta \frac{\text{Bank credit}}{Y}$	Credit spread
Volat. of GDP growth (10yrs.)	1.84** (0.024)	-0.19*** (0.005)	-0.27** (0.045)	-0.35** (0.03)	3.5* (0.085)
Controls	No	No	No	No	No
Country & time FE	Yes	Yes	Yes	Yes	Yes
Number Observations	2800	2800	2800	2776	2221
$R^2$	0.62	0.26	0.12	0.19	0.6
Panel B. Adding control variables					
	$\frac{TB}{Y}$	$\Delta \log Y$	$\Delta \log I$	$\Delta \frac{\text{Bank credit}}{Y}$	Credit spread
Volat. of GDP growth (10yrs.)	1.92* (0.092)	-0.08 (0.44)	-0.04 (0.89)	-0.21 (0.26)	2.33 (0.141)
Controls	Yes	Yes	Yes	Yes	Yes
Country & time FE	Yes	Yes	Yes	Yes	Yes
Number Observations	2587	2587	2719	2587	2169
$R^2$	0.65	0.33	0.17	0.21	0.73

Note: P-values are in parentheses (\*p-value<0.10, \*\*p-value<0.05, \*\*\*p-value<0.01). Robust standard errors are clustered at the country level. The measure of volatility is the standard deviation of quarterly real GDP growth rates (in percentage) over 10-year rolling windows. The outcome variables and controls are the same as in Table 1. The appendix describes the sample and data sources.



**Table B5. All Variables Measured over 5-year Rolling Windows**

Panel A					
	$\frac{TB}{Y}$	$\Delta \log Y$	$\Delta \log I$	$\Delta \frac{\text{Bank credit}}{Y}$	Credit spread
Volat. of GDP growth (5yrs.)	1.27** (0.027)	-0.14** (0.036)	-0.31** (0.021)	-0.19* (0.084)	2.61** (0.046)
Controls	No	No	No	No	No
Country & time FE	Yes	Yes	Yes	Yes	Yes
Number Observations	3200	3200	3200	3176	2524
$R^2$	0.7	0.66	0.42	0.28	0.78
Panel B. Adding control variables					
	$\frac{TB}{Y}$	$\Delta \log Y$	$\Delta \log I$	$\Delta \frac{\text{Bank credit}}{Y}$	Credit spread
Volat. of GDP growth (5yrs.)	1.64 (0.16)	-0.07* (0.094)	-0.19 (0.14)	-0.06 (0.677)	0.80 (0.11)
Controls	Yes	Yes	Yes	Yes	Yes
Country & time FE	Yes	Yes	Yes	Yes	Yes
Number Observations	2987	2987	2987	2987	2472
$R^2$	0.83	0.74	0.58	0.31	0.89

Note: P-values are in parentheses (\*p-value<0.10, \*\*p-value<0.05, \*\*\*p-value<0.01). Robust standard errors are clustered at the country level. This table shows the results from pooled OLS regressions using the same methodology as Fogli and Perri (2015). The measure of volatility is the standard deviation of quarterly real GDP growth rates (in percentage) over 5-year rolling windows, as in Table B3, but now the dependent variables of Panels A and B, and the control variables of Panel B, are averages over 5-year rolling windows. The sample period is 1970:q1-2014:q4 (subject to data availability). The appendix describes the sample and data sources.

**Table B6. All Variables Measured over 10-year Rolling Windows**

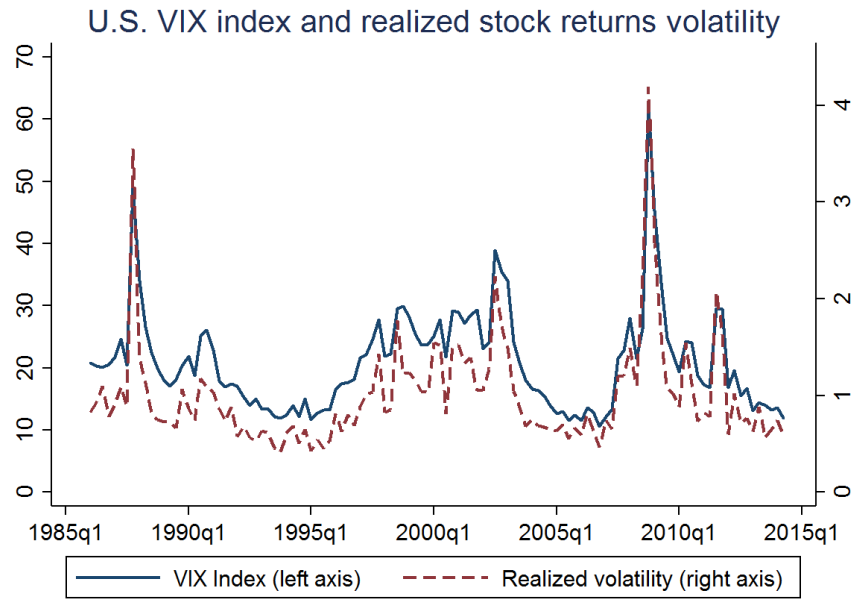
	Panel A				
	$\frac{TB}{Y}$	$\Delta \log Y$	$\Delta \log I$	$\Delta \frac{\text{Bank credit}}{Y}$	Credit spread
Volat. of GDP growth (10yrs.)	1.46** (0.017)	-0.20*** (0.002)	-0.37*** (0.000)	-0.27** (0.037)	2.97 (0.104)
Controls	No	No	No	No	No
Country & time FE	Yes	Yes	Yes	Yes	Yes
Number Observations	2800	2800	2800	2796	2328
$R^2$	0.77	0.75	0.48	0.35	0.78
	Panel B. Adding control variables				
	$\frac{TB}{Y}$	$\Delta \log Y$	$\Delta \log I$	$\Delta \frac{\text{Bank credit}}{Y}$	Credit spread
Volat. of GDP growth (10yrs.)	0.28 (0.519)	-0.07 (0.23)	-0.11 (0.308)	-0.23 (0.229)	0.94 (0.168)
Controls	Yes	Yes	Yes	Yes	Yes
Country & time FE	Yes	Yes	Yes	Yes	Yes
Number Observations	2667	2667	2667	2667	2296
$R^2$	0.83	0.79	0.57	0.36	0.94

Note: P-values are in parentheses (\*p-value<0.10, \*\*p-value<0.05, \*\*\*p-value<0.01). Robust standard errors are clustered at the country level. This table shows the results from pooled OLS regressions using the same methodology as Fogli and Perri (2015). The measure of volatility is the standard deviation of quarterly real GDP growth rate (in percentages) over 10-year rolling windows, as in Table B4, but now the dependent variables of Panels A and B, and the control variables of Panel B, are averages over 10-year rolling windows. The sample period is 1970:q1-2014:q4 (subject to data availability). The appendix describes the sample and data sources.

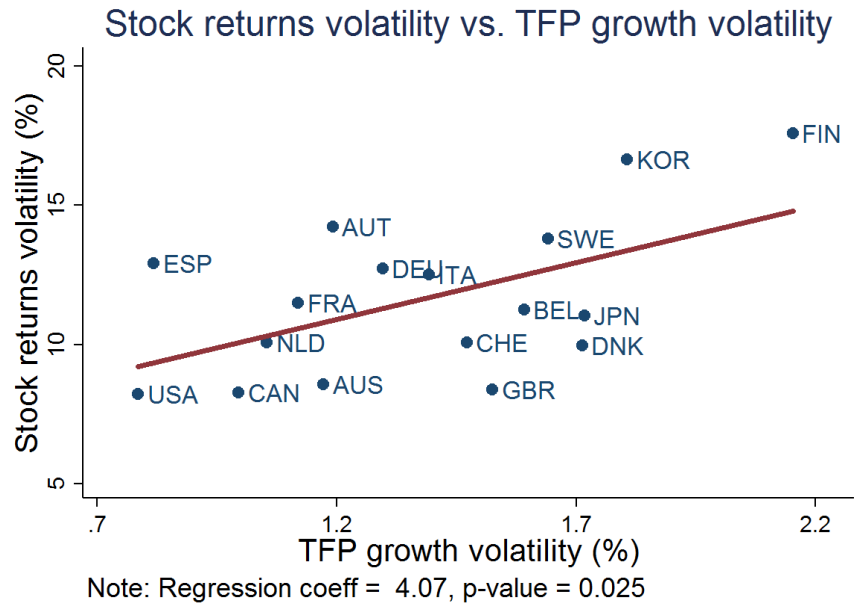
**Table B7. Volatility and the countercyclicality of the trade balance**

	Low volatility	High volatility
$\text{corr}(\frac{TB}{Y}, \Delta \log Y)$	-0.183	-0.165

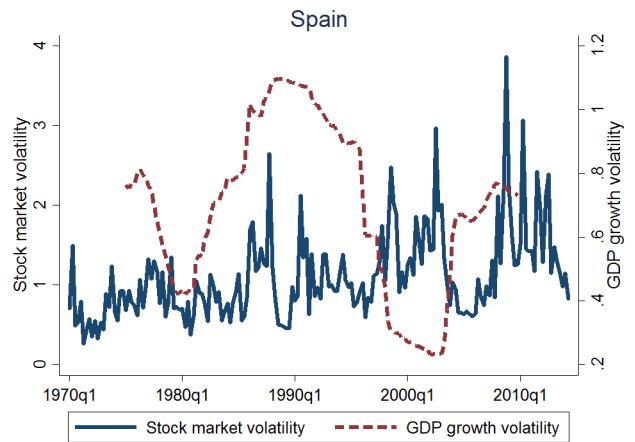
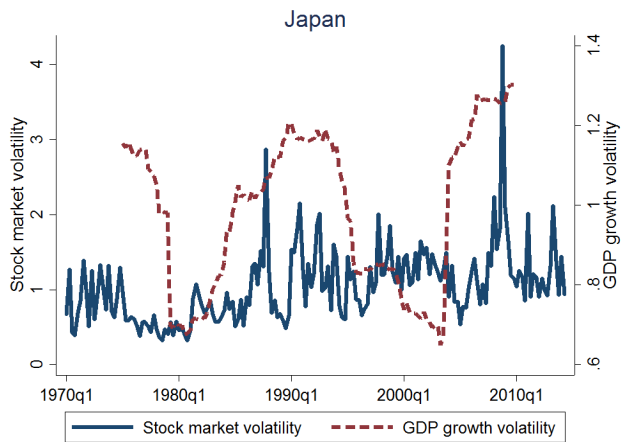
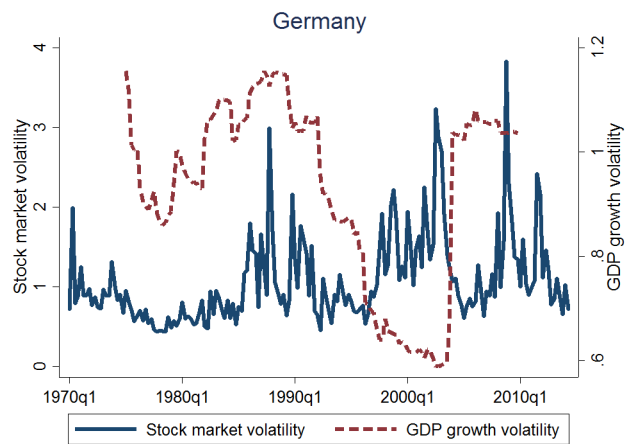
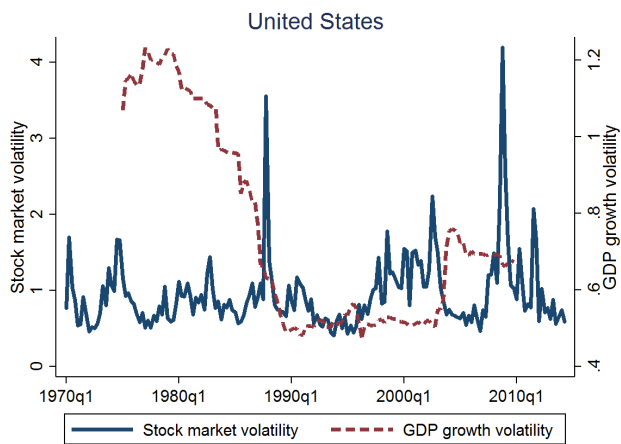
Note: This table reports the correlation between the trade balance-to-output ratio and output growth under when the volatility of TFP growth is high ( $\sigma_g = -3.74$ ) and it is low ( $\sigma_g = -5.74$ ). The correlation coefficients are obtained by simulating the model with credit channel for 4000 periods with all the shocks.



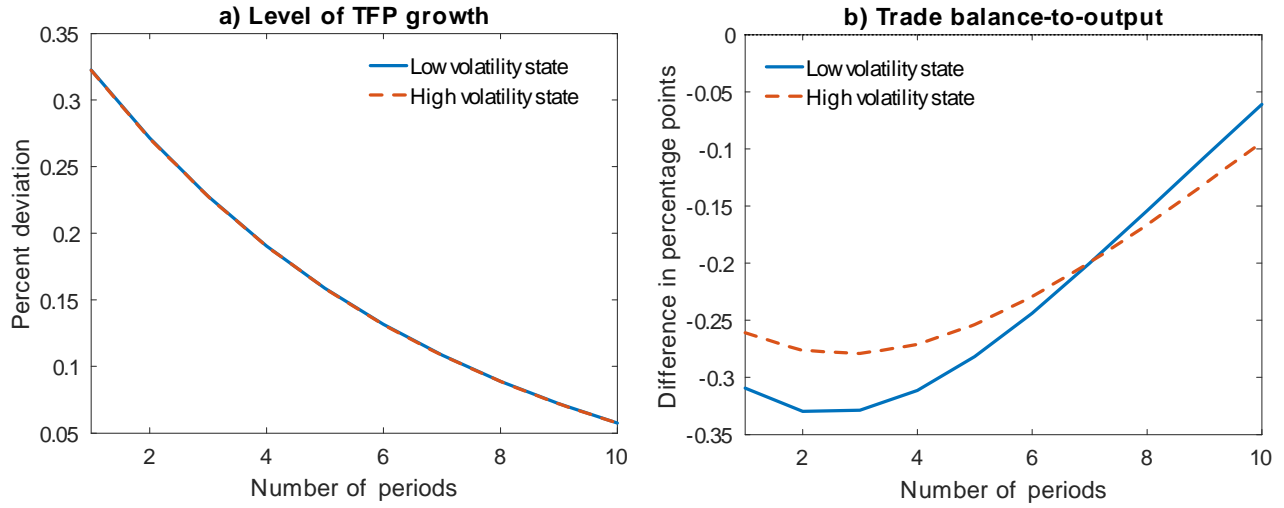
**Figure B1. Comparing VIX and the Volatility of Stock Market Returns.** This figure plots time series of the quarterly VIX Index and of the realized stock returns volatility in the U.S. for the period 1986q1-2014q4.



**Figure B2. Stock Market Returns Volatility vs. TFP Growth Volatility.** The data for TFP growth is from OECD’s Multi-Factor Productivity database which covers 1985-2011. TFP growth volatility is the standard deviation of annual TFP growth rates. Stock returns volatility is the standard deviation of annual stock returns. The fitted line is the OLS line.



**Figure B3. Comparing Measures of Volatility.** This figure plots the volatility of daily stock market returns and the volatility of real GDP growth over a 10-year rolling windows.



**Figure B4. State-dependent Responses to a TFP Growth Shock: High vs. Low Volatility.** Panel a) reports a shock to the level of TFP growth. Panel b) reports the responses of the trade balance-to-output ratio in the model with credit channel when volatility is high and when it is low. The dashed line has a high parameter of volatility of TFP growth ( $\sigma_g = -3.74$ ) while in the solid line the volatility is lower ( $\sigma_g = -5.74$ ).