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Jürgen von Hagen, Haiping Zhang

Financial Openness and Macroeconomic Volatility

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Jürgen von Hagen† Haiping Zhang‡

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Abstract

We analyze the implications of financial openness to macroeconomic volatility in a small open economy. Major macroeconomic aggregates show non-monotonic volatility patterns with respect to the degree of financial openness in the model without domestic financial frictions. The introduction of domestic financial frictions makes the volatility patterns flatter.

Our model explains the lack of empirical evidence on the linkage between financial openness and macro volatility. If the empirical data of countries with different degree of financial openness are pooled, we cannot estimate a significant linear relationship between financial openness and macro volatility, because the underlying relationship is non-monotonic.

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†University of Bonn, Indiana University and CEPR. E-mail: vonhagen@uni-bonn.de
‡Corresponding author. University of Bonn. E-mail: hzhang@uni-bonn.de.

1 Introduction

According to neoclassical models, the economic benefits of international capital flows are significant. On the one hand, they provide developing economies with the means to exploit promising investment opportunities; on the other hand, international investors are able to earn higher returns and to reduce risk via international portfolio diversification (Stulz, 2005). In the past two decades, many countries have deregulated financial markets and reduced explicit barriers to foreign investors. As a result, global capital flows have achieved record highs relative to global income.

Countries differ in the efficiency of their legal systems and market institutions. These differences may affect the return on foreign funds and thus the ex ante lending behavior of foreign investors. Ceteris paribus, countries with better protection of foreign investors attract more foreign funds. In this sense, institutional differences in the protections of foreign investors can affect the actual degree of financial openness.

Backus, Kehoe, and Kydland (1992) show that financial opening should lower consumption volatility while raising investment volatility, if most shocks are country-specific and transitory. However, the empirical literature cannot provide statistically significant evidence on the relationship between financial openness and macroeconomic volatility (Razin and Rose, 1994). Using a panel dataset for OECD countries, Buch, Doepke, and Pierdzioch (2005) find that the implications of financial openness for business cycle volatility depend on the nature of the shocks and the link between macroeconomic policy, financial openness, and business cycle volatility varies over time. Developing economies are more vulnerable to external shocks due to some structure features, e.g., limited diversification of foreign trade,[1] sudden reversal of capital flows, the small country size. These factors hamper the unbiased empirical estimation of the relationship between financial openness and macroeconomic volatility. Kose, Prasad, and Terrons (2003) provide a comprehensive examination of changes in macroeconomic volatility in a large group of industrial and developing economies over the period of $1960 - 1999$. They find that the relative volatility of consumption has a non-linear relationship with financial openness.

We develop a real dynamic general equilibrium model of a small open economy and show that financial openness has non-monotonic implications for macroeconomic volatility. Domestic financial frictions may explain the lack of strong empirical evidences on the significant linear relationship between financial openness and macroeconomic volatility.

The intuition behind our results is as follows. We consider a small open economy with two types of domestic agents: entrepreneurs and households. They have production projects using a domestic productive asset (land). Entrepreneurs and households should not be understood literally: the former refers to the more productive agents, while the

[1] Kose (2002) shows in a dynamic small-open-economy model that terms of trade shocks can explain a sizeable fraction of volatility.

latter refers to the less productive agents.

A continuum of foreign investors provide funds at a constant interest rate lower than the domestic interest rate. Both households and entrepreneurs prefer to borrow abroad. Due to the debt enforcement problem, domestic agents use their productive assets as collateral for foreign borrowing. As foreign investors are unfamiliar with the domestic asset market and legal system, foreign borrowing is overcollateralized in the sense that only a fraction of the expected value of the collateral assets is pledgable. We measure financial openness by the degree of collateralization.

By assumption, households are risk averse and the project of entrepreneurs is subject to idiosyncratic risk. Mutual funds emerge as financial intermediaries. They collect deposits from households and lend to entrepreneurs. Thus, in addition to foreign borrowing, entrepreneurs also borrow from households via domestic mutual funds. If they could credibly pledge their entire project outcomes to mutual funds, productive assets would be all allocated into their project. Due to the moral hazard problem à la Holmstrom and Tirole (1997), entrepreneurs can credibly pledge only a fraction of their project output for domestic loans, i.e., they are subject to domestic financial frictions. As a result, some of the productive assets are inefficiently allocated into the household project.

As foreign investors are risk neutral and households are risk averse, the land-backed foreign loan contract provides households with a safe post-repayment asset value, while foreign investors bear all capital gains or losses on collateral assets. As foreign investors and entrepreneurs are both risk neutral, they share capital gains or losses proportionally.

Consider a positive transitory shock to the foreign interest rate (FIR, henceforth). In the model without domestic financial frictions, entrepreneurs first borrow abroad to the limit against their land stock and then pledge the rest of their project value to mutual funds. Land is all allocated into their projects. After the project completion, they first repay foreign investors and then transfer all project outcomes to mutual funds. The rise in the degree of financial openness has two effects: first, the domestic economy is more exposed to FIR shocks; second, foreign investors bear a larger share of the capital gains or losses related to collateral assets. The first factor makes macro variables, e.g., output, consumption, labor, domestic loans, and foreign trade, respond more strongly to FIR shocks, while the second effect is opposite. The non-monotonic wealth effects induce households to adjust their labor supply and macro variables have the hump-shaped volatility patterns with respect to the degree of financial openness. Similar patterns can be obtained for the terms-of-trade (ToT, henceforth) shock and the productivity shocks.

In the model with domestic financial frictions, entrepreneurs have to finance part of their project investment using own funds. The standard loan contract between mutual funds and entrepreneurs specifies a fixed repayment. On the one hand, entrepreneurial net worth absorbs capital gains or losses on their land stock and household wealth is less affected by exogenous FIR shock; on the other hand, changes in entrepreneurial net

worth due to capital gains or losses amplify endogenous asset reallocation. We can show that the hump-shaped volatility patterns of macro variables are flatter than in the model without domestic financial frictions.

In sum, the financial contract with proportional risk-sharing between entrepreneurs and foreign investors leads to the hump-shaped volatility patterns with respect to the degree of financial openness. In the presence of domestic financial frictions, endogenous asset reallocation results in flatter volatility patterns. Our findings also hold with respect to the productivity shock and the terms-of-trade shock.

In this sense, domestic financial frictions and the foreign borrowing contract with proportional risk-sharing may explain the empirical evidence that there is no significant linear relationship between financial openness and macroeconomic volatility. The logic is as follows. If we pool the empirical data of countries with different degrees of financial openness, we might not be able to find a clear relationship between financial openness and macroeconomic volatility using a simple OLS regression, because the underlying relationship is $\bigcup$-shaped or $\bigcap$-shaped.

The rest of this paper is organized as follows. Section 2 describes the model. Section 3 analyzes the model dynamics with respect to exogenous shocks. Section 4 summarizes the main findings.

2 The Model

Consider a small, open, real economy. There is a domestic durable asset (land) with a fixed total supply, K. There are three perishable goods: an intermediate good, a domestic final good, and a foreign final good. There are two types of domestic agents with infinite numbers: households and entrepreneurs, each of unit mass. There is a continuum of foreign investors.

Households are risk averse and infinitely lived. They have a safe backyard project to produce intermediate goods using land as the only input; they are endowed with a unit of labor that can be supplied to the production of domestic final goods. Entrepreneurs are risk neutral and each has a constant probability of death. In each period, entrepreneurs of mass $(1-\pi)$ exit from the economy and new entrepreneurs of the same mass are born, keeping the population size of entrepreneurs constant. The newcomers and the surviving entrepreneurs supply their labor endowment to the production of domestic final goods.[2] They have two projects for the production of intermediate goods using both land and domestic final goods as inputs. Both projects are subject to idiosyncratic risk: projects have positive output in the case of success and there is no output in the case of failure. Each entrepreneur can choose only one project and his project choice is

[2]Each entrepreneur must put a positive amount of own funds in the project in order to acquire loans. Carlstrom and Fuerst (1997) and Bernanke, Gertler, and Gilchrist (1999) adopt the same approach.

unobservable to others. It takes one period for households and entrepreneurs to complete their projects. Land does not depreciate, while the input of domestic final goods fully depreciates during the project process. Intermediate goods are country-specific and only used in the production of domestic final goods. Thus, there is no foreign trade on intermediate goods. Domestic and foreign final goods are imperfect substitutes for the consumption of domestic agents. There is no trade barrier for final goods. For simplicity, we denote s_t as the relative price of foreign final goods in terms of domestic final goods. Thus, the terms of trade is $\frac{1}{s_t}$ for the small economy. Foreign investors are risk neutral and lend foreign final goods at the gross interest rate of r_t^*.

The economy is small enough that the terms of trade and the foreign interest rate are determined exogenously abroad and modeled as $AR(1)$ in logarithms,

$$\log \frac{1}{s_t} = (1-\rho^s) \log \frac{1}{\bar{s}} + \rho^s \log \frac{1}{s_{t-1}} + \epsilon_t^s, \tag{1}$$

$$\log r_t^* = (1-\rho^*) \log \bar{r}^* + \rho^* \log r_{t-1}^* + \epsilon_t^*, \tag{2}$$

where $\frac{1}{\bar{s}}$ and $\bar{r}^*$ denote the non-stochastic steady state values of the terms of trade and the foreign interest rate; ρ^s and ρ^* denote their respective autocorrelation coefficients. Let E_t denote the expectation operator based on information available in period t. The ToT shock has mean zero, $E_t \epsilon_{t+1}^s = 0$, and the variance of σ_s^2. ToT shocks can be interpreted as changes in the foreign demand for domestic final goods, i.e., preference shocks. The FIR shock has mean zero, $E_t \epsilon_{t+1}^* = 0$, and the variance of σ_*^2. Besides the ToT shock and the FIR shock, there is an exogenous shock to the production of domestic final goods: the TFP shock. Aggregate shocks enter at the beginning of each period.

The project that entrepreneurs choose in equilibrium is expected to be more productive than the households' projects. A continuum of mutual funds accept deposits from households and provide loans to entrepreneurs. A deposit contract is a claim on the financial position of the mutual funds. The gross domestic interest rate r_t is defined as the expected rate of return on mutual funds. We focus on one-period financial contracts.

We choose the consumption composite of domestic agents as the numeraire. See subsection 2.2 for the definition of consumption composite. Land is traded on the spot market. Let v_t and q_t denote the prices of intermediate goods and land, respectively. Let p_t denote the price of domestic final goods and the price of foreign final goods is $p_t s_t$. Let w_t and w_t^e denote the the wage rates of households and entrepreneurs, respectively.

2.1 Asset-Backed Foreign Borrowing

Our calibration guarantees that the foreign interest rate is always smaller than the domestic interest rate around the steady state, $r_t^* < r_t$. Thus, domestic agents prefer to borrow abroad. A unit of the foreign final good borrowed abroad has the domestic value of $p_t s_t$ in period t and the required repayment is expected to be $r_t^* E_t p_{t+1} s_{t+1}$ in terms of

domestic composite consumption. For convenience of notation, let

$$r_t^f = \frac{r_t^* E_t(p_{t+1}s_{t+1})}{p_t s_t}, \tag{3}$$

denote the effective foreign interest rate in terms of domestic composite consumption.

Mutual funds have the exclusive technology to perfectly verify the project outcomes of domestic agents and to liquidate the land stock of failed entrepreneurs at no discount. As foreign investors do not have such verification technology, domestic agents cannot credibly pledge them their project output. However, they can borrow abroad against their land stock. Normally, foreign investors are less familiar with the domestic land market and would incur larger costs in liquidating collateral assets in the event of debtors' default than domestic mutual funds. Furthermore, the domestic legal system is biased against foreign investors. Either way, foreign borrowing has to be overcollateralized in the following sense. In period t, each unit of land is expected to have the value of $E_t q_{t+1}$ in period $t+1$ and domestic agents can pledge only $\theta E_t q_{t+1}$ to foreign investors for $\frac{E_t \theta q_{t+1}}{r_t^* E_t(p_{t+1}s_{t+1})}$ units of foreign final goods, where $\theta \in (0,1]$ denotes the degree of collateralization. $(1-\theta)$ can be regarded as a premium that foreign investors would have to pay to the domestic land buyers when they liquidate collateralized land.[3] For simplicity, we assume that θ is constant. θ can be affected by many factors, e.g., the efficiency of the domestic legal system, the structure and development of domestic market institutions, the tightness of financial regulations, and etc. Thus, θ reflects the effective degree of foreign investor protection and financial openness. Mutual funds do not have the land stock to pledge to foreign investors as collateral. Thus, foreign investors do not make deposits directly at mutual funds.

Given $r_t^f < r_t$, households prefer to borrow cheap foreign funds and deposit them at the mutual funds to take advantage of the interest rate differential. They borrow $z_t^{h,*}$ units of foreign final goods abroad against their land stock k_t in period t. Their collateral constraints are binding in equilibrium,

$$r_t^* z_t^{h,*} E_t p_{t+1} s_{t+1} = \theta E_t q_{t+1} k_t. \tag{4}$$

As households are risk averse and foreign investors are risk neutral, the optimal financial contract is a contract providing households with perfect insurance against unexpected changes in the land price. Foreign investors get $\frac{q_{t+1}k_t - (1-\theta)E_t q_{t+1} k_t}{p_{t+1}s_{t+1}}$ units of foreign final goods as repayment and the land has a net value of $(1-\theta)E_t q_{t+1} k_t$ to households in period $t+1$. The ex post rate of return to foreign investors is

$$r_{t+1}^{h,*} = r_t^* \left[\frac{E_t(p_{t+1}s_{t+1})}{p_{t+1}s_{t+1}}\right]\left[1 + \frac{q_{t+1} - E_t q_{t+1}}{\theta E_t q_{t+1}}\right]. \tag{5}$$

[3] This premium may vary along the business cycle and so does θ. See Iacoviello and Minetti (forthcoming) for a detailed discussion.

As shown in subsection 2.3, entrepreneurs differ in their end-of-period wealth and are indexed by $i \in [0,1]$. Given $r_t^f < r_t$, entrepreneur i pledge his land stock $k_{i,t}^e$ to foreign investors for $z_{i,t}^{e,*}$ units of foreign final goods before he turns to mutual funds for domestic loans. His collateral constraints are binding,

$$r_t^* z_{i,t}^{e,*} E_t(p_{t+1}s_{t+1}) = \theta E_t q_{t+1} k_{i,t}^e. \tag{6}$$

As the entrepreneur and foreign investors are risk neutral, the optimal financial contract is a contract sharing unexpected changes in the land price proportionally between them. In period $t+1$, foreign investors get $\frac{\theta q_{t+1} k_{i,t}^e}{p_{t+1}s_{t+1}}$ units of foreign final goods as repayment and the land has a net value of $(1-\theta)q_{t+1}k_{i,t}^e$ to the entrepreneur. The ex post rate of return to foreign investors is

$$r_{t+1}^{e,*} = r_t^* \left[\frac{q_{t+1} E_t(p_{t+1}s_{t+1})}{p_{t+1}s_{t+1} E_t q_{t+1}} \right]. \tag{7}$$

$r_{t+1}^{h,*}$ and $r_{t+1}^{e,*}$ differ from their expected value r_t^* due to unexpected changes in the prices of land and foreign final goods.

2.2 Households

Households have identical preferences over consumption and leisure,

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{c_t^{1-\sigma} - 1}{1-\sigma} + \chi \frac{(1-l_t)^{1+\psi} - 1}{1+\psi} \right],$$

where $\beta \in (0,1)$ and l_t denote their time discount factor and endogenous labor supply, respectively. The composite consumption of households is defined as $c_t \equiv (c_{D,t})^{\gamma}(c_{F,t})^{1-\gamma}$, where $c_{D,t}$ and $c_{F,t}$ denote their consumption of domestic and foreign final goods, respectively. See Clarida, Gali, and Gertler (2002). Households minimize their consumption expenditures on two goods, which implies $c_{D,t} = \frac{\gamma c_t}{p_t}$ and $c_{F,t} = \frac{(1-\gamma)c_t}{p_t s_t}$. The price of domestic final goods (foreign final goods) is positively (negatively) related to the terms of trade. Recall that s_t denotes the inverse of the terms of trade.

$$p_t = \gamma^{\gamma} \left(\frac{1-\gamma}{s_t} \right)^{1-\gamma}, \tag{8}$$

$$p_t s_t = (\gamma s_t)^{\gamma} (1-\gamma)^{1-\gamma}. \tag{9}$$

Given that k_{t-1} units of land were invested in the household's project in period $t-1$, $G(k_{t-1})$ units of intermediate goods are produced at the beginning of period t and household sales revenues amount to $v_t G(k_{t-1})$. The household's project is decreasing-return-to-scale, $G'(k) > 0$ and $G''(k) < 0$. Given that households deposited d_{t-1} at the mutual funds in period $t-1$, the deposits have a return of $\tilde{r}_t d_{t-1}$ to households in period t, where $\tilde{r}_t$ is the ex post rate of return on mutual funds in period t. Due to aggregate

risk, $\tilde{r}_t$ could differ from its expected value r_{t-1}, an issue discussed in subsection 2.4. By definition, $r_t = E_t\tilde{r}_{t+1}$. Given that households borrowed $z_{t-1}^{h,*}$ units of foreign final goods from foreign investors against their land stock k_{t-1}, the land stock has a safe net value of $(1-\theta)E_{t-1}q_tk_{t-1}$ to households. The household wage income is w_tl_t.

At the end of period t, households invest k_t units of land in their projects, deposit d_t, borrow $z_t^{h,*}$ units of foreign final goods, and consume c_t. According to equation (4), for each unit of land invested in their projects, households can borrow $\frac{\theta E_tq_{t+1}}{r_t^*E_t(p_{t+1}s_{t+1})}$ units of foreign final goods in period t and their net payment is only $q_t - \frac{\theta E_tq_{t+1}}{r_t^f}$. The household period-budget constraints are

$$\left(q_t - \frac{\theta E_tq_{t+1}}{r_t^f}\right)k_t + c_t + d_t = (1-\theta)E_{t-1}q_tk_{t-1} + v_tG(k_{t-1}) + \tilde{r}_td_{t-1} + w_tl_t. \tag{10}$$

The optimization over $\{c_t, l_t, d_t, k_t\}$ gives the following equilibrium conditions,

$$w_t = \chi(1-l_t)^{\psi}c_t^{\sigma}, \tag{11}$$

$$1 = \beta r_tE_t\left(\frac{c_{t+1}}{c_t}\right)^{-\sigma}, \tag{12}$$

$$q_t - \frac{\theta E_tq_{t+1}}{r_t^f} = \frac{E_t[(1-\theta)q_{t+1} + v_{t+1}G'(k_t)]}{r_t}. \tag{13}$$

2.3 Entrepreneurs

Each entrepreneur can choose one of the two projects: "Good" or "Bad" at the end of each period and his project choice is irreversible. Both projects have the same Leontief technology, i.e., a units of domestic final goods are required for each unit of land invested at the end of the period.[4] At the beginning of the next period, the project produces R units of intermediate goods per unit of the land invested, if the project succeeds; there is no output if the project fails. The two projects provide the entrepreneur with safe, nonpecuniary private benefits during the project process.[5] For convenience of aggregation, we assume that private benefits are proportional to the amount of land invested. Project "Good" ("Bad") has a probability of success p^G (p^B) and provides entrepreneurs with private benefits b^G (b^B) per unit of land invested, where $0 < p^B < p^G < 1$ and $b^B > b^G > 0$. In other words, project "Good" is safer than projects "Bad", but entrepreneurs get larger unit private benefits from project "Bad".

[4]In models with collateral constraints à la Kiyotaki and Moore (1997), the leverage ratio of borrowers, defined as the ratio of total investment over own funds, is equal to the inverse of the gross interest rate, which is too high and cannot be justified by the empirical data. We introduce the input of domestic final goods to reduce the leverage ratio of entrepreneurs to the reasonable level, e.g., 2.

[5]Our set-up resembles the principal-agent setting in Holmstrom and Tirole (1997, 1998). According to Hart (1995), private benefits may refer to any nonpecuniary benefits from running a project, e.g., large offices or luxury business cars. Private benefits are good for the project owners but may reduce the success probability of projects. The trade-off between the success probability and private benefits is a short-cut to capture divergent objectives between project owners and outside financiers.

As shown below, entrepreneurs differ in their end-of-period wealth and are indexed by $i \in [0,1]$. The expected utility function of entrepreneur i is,

$$E_0 \sum_{t=0}^{\tilde{T}} \beta^t \left[c_{i,t}^e + \mathcal{B} k_{i,t-1}^e \right],$$

where $\tilde{T}$ is the stochastic time of death and $\mathcal{B} \in \{b^G, b^B\}$ denotes private benefits per unit of the land invested in project "Good" or project "Bad". $c_{i,t}^e$ denotes his composite consumption in period t and $k_{i,t-1}^e$ denotes his land stock invested in period $t-1$.

Our calibration guarantees that only project "Good" has a positive expected net present value around the steady state,

$$E_t \left[\frac{p^G R v_{t+1} + (1-\theta) q_{t+1}}{r_t} + \frac{\theta q_{t+1}}{r_t^f} \right] > q_t + a p_t > E_t \left[\frac{p^B R v_{t+1} + (1-\theta) q_{t+1}}{r_t} + \frac{\theta q_{t+1}}{r_t^f} \right].$$

Therefore, project "Bad" should not be financed. Project "Good" also has a larger expected marginal rate of return than the households' project even in the case of $k_t = 0$,

$$\frac{E_t \left[\frac{p^G R v_{t+1} + (1-\theta_t) q_{t+1}}{r_t} + \frac{\theta_t q_{t+1}}{r_t^f} \right]}{q_t + a} > \frac{E_t \left[\frac{v_{t+1} G'(0) + (1-\theta_t) q_{t+1}}{r_t} + \frac{\theta_t q_{t+1}}{r_t^f} \right]}{q_t}.$$

Therefore, if the project choice of entrepreneurs were perfectly observable, they could borrow against all outcomes of project "Good" and land would be all allocated to them.

At the end of period t, the entrepreneur invests $k_{i,t}^e$ units of land and $a k_{i,t}^e$ units of domestic final goods into either project "Good" or project "Bad", using his own funds, $n_{i,t}$, foreign loans, $p_t s_t z_{i,t}^{e,*}$, and domestic loans, $z_{i,t}$, i.e., $(q_t + a p_t) k_{i,t}^e = n_{i,t} + p_t s_t z_{i,t}^{e,*} + z_{i,t}^m$. Thus, $n_{i,t}$ is the entrepreneur's net worth in the project. The land-backed loan contract between the entrepreneur and foreign investors has been specified in subsection 2.1. As mutual funds cannot observe the project choice of the entrepreneur, the domestic loan contract resembles the standard loan contract (Gale and Hellwig, 1985) and specifies a promise to repay $R_t^m k_{i,t}^e$ units of domestic composite consumption in period $t+1$ if the project succeeds. As the mutual funds can perfectly verify the project outcome, the entrepreneurs always repays the promised amount if he is able to do so. If the project fails, the entrepreneur hands over his land stock to mutual funds. After repaying the amount owed by the entrepreneur to foreign investors, the mutual funds keep the rest $(1-\theta) q_{t+1} k_{i,t}^e$. In order to motivate the entrepreneur to choose project "Good", mutual funds must provide him with enough incentives,

$$\left\{ p^G E_t [R v_{t+1} + (1-\theta) q_{t+1} - R_t^m] + b^G \right\} k_{i,t}^e \geq \left\{ p^B E_t [R v_{t+1} + (1-\theta) q_{t+1} - R_t^m] + b^B \right\} k_{i,t}^e.$$

The left (right) hand side denotes the expected utility of the entrepreneur if he chooses project "Good" ("Bad"). As the expected rate of return on project "Good" exceeds the

domestic interest rate, the entrepreneur prefers to borrow to the limit. The incentive constraints are binding around the steady state and can be simplified to,

$$R_t^m = E_t[Rv_{t+1} + (1-\theta)q_{t+1}] - \tilde{b}, \quad \text{where} \quad \tilde{b} \equiv \frac{b^B - b^G}{p^G - p^B} > 0. \tag{14}$$

Each unit of the land invested in project "Good" in period t has an expected value of $E_t(p^G R v_{t+1} + q_{t+1})$ in period $t+1$, in which $E_t \theta q_{t+1}$ is pledged to foreign investors first. Any promise to repay more than $R_t^m k_t^e$ to mutual funds in the case of success would violate the incentive constraints. The entrepreneur can only pledge $p^G R_t^m + (1-p^G)E_t(1-\theta)q_{t+1}$ per unit of the land invested to the mutual funds in period t. $E_t(p^G R v_{t+1} + q_{t+1})$ and $E_t[p^G(Rv_{t+1} - \tilde{b}) + q_{t+1}]$ are the expected full unit value and the expected external unit value of the land invested in project "Good", respectively. The difference between the two values, $p^G \tilde{b}$, is used to motivate the entrepreneur to choose project "Good" despite the lower private benefits it promises, $b^G < b^B$.

The mutual funds are expected to break even in period t, $r_t z_{i,t} = [p^G R_t^m + (1 - p^G)E_t(1-\theta)q_{t+1}]k_{i,t}^e$, which implies a credit constraint for the entrepreneur,

$$z_{i,t} = \Gamma_t n_{i,t}, \quad \text{where} \quad \Gamma_t \equiv \frac{\frac{p^G(RE_t v_{t+1} - \tilde{b}) + (1-\theta)E_t q_{t+1}}{r_t}}{(q_t + ap_t) - \frac{\theta E_t q_{t+1}}{r_t^f} - \frac{p^G(RE_t v_{t+1} - \tilde{b}) + (1-\theta)E_t q_{t+1}}{r_t}}.$$

Γ_t is the domestic credit multiplier. As we are interested in the case where entrepreneurs finance their projects using both own funds and external funds, our calibration guarantees that the denominator in the definition of Γ_t is positive around the steady state; otherwise, entrepreneurs would finance their projects using external funds only. As Γ_t is independent of $n_{i,t}$, domestic loans are proportional to the entrepreneur's net worth.

Suppose that entrepreneurs financed their project investment using foreign and domestic loans in period $t-1$. At the beginning of period t, entrepreneurs of mass $p^G(1-\pi)$ have successful projects and receive the signal of death; they repay their liabilities, sell off their assets, consume all proceeds, and exit from the economy. Entrepreneurs of mass $(1-p^G)(1-\pi)$ have failed projects and receive the signal of death; they hand over their land stock to mutual funds and exit from the economy without consumption.

The newcomers and the surviving entrepreneurs are endowed with a unit of labor and they supply their labor endowment inelastically $l_t^e = 1$ to the production of domestic final goods. Their wage income is w_t^e. At the end of period t, the entrepreneur maximizes his expected utility function, subject to his foreign borrowing constraints, as specified in equation (6), his period-budget constraints, and domestic credit constraints,

$$(q_t + ap_t)k_{i,t}^e - z_{i,t} - p_t s_t z_{i,t}^{e,*} = n_{i,t} \quad \text{where} \quad n_{i,t} \equiv \mathcal{N}_{i,t} - c_{i,t}^e,$$
$$z_{i,t} = \Gamma_t n_{i,t}$$

where $\mathcal{N}_{i,t}$ denotes his end-of-period wealth. The newcomers and entrepreneurs who have failed projects and survive to the next period are of mass $(1-\pi)+(1-p^G)\pi$ and their end-of-period wealth is $\mathcal{N}_{i,t} = w_t^e$; the surviving entrepreneurs with successful projects are

of mass $p^G\pi$ and their end-of-period wealth is $\mathcal{N}_{i,t} = w_t^e + [Rv_t + (1-\theta)q_t - R_{t-1}^m]k_{i,t-1}^e$. As the marginal rate of return on project "Good" exceeds the foreign and domestic interest rates, entrepreneurs invest all end-of-period wealth into their project, borrow to the limit, and postpone consumption to the period of death. It also justifies the fact that the newcomers and the surviving entrepreneurs supply all of their labor endowment.

Due to linear technologies and preferences, the external funds and the project investment of entrepreneur i are proportional to his net worth. As a result, only the first moment of the distribution of entrepreneurial net worth matters for the aggregate land stock in the entrepreneur sector. Let lower-case letters without the index i denote per capita variables of entrepreneurs. Per capita consumption c_t^e, net worth n_t, domestic loans z_t, foreign borrowing, $z_t^{e,*}$, and land holding k_t^e of entrepreneurs are

$$c_t^e = (1-\pi)p^G[Rv_t + (1-\theta)q_t - R_{t-1}^m]k_{t-1}^e, \tag{15}$$

$$n_t = \pi p^G[Rv_t + (1-\theta)q_t - R_{t-1}^m]k_{t-1}^e + w_t^e, \tag{16}$$

$$z_t = \frac{[p^G(RE_tv_{t+1} - \tilde{b}) + (1-\theta)E_tq_{t+1}]k_t^e}{r_t}, \tag{17}$$

$$z_t^{e,*} = \frac{\theta E_tq_{t+1}k_t^e}{r_t^f}, \tag{18}$$

$$k_t^e = \frac{n_t + p_ts_tz_t^{e,*} + z_t}{q_t + ap_t}. \tag{19}$$

2.4 Mutual Funds

Let K_{t-1}^e and Z_{t-1} denote the aggregate land stock and domestic borrowing of entrepreneurs at the end of period $t-1$, respectively. The aggregate expected break-even condition of the mutual funds in period $t-1$ is $r_{t-1}Z_{t-1} = [p^GR_{t-1}^m + (1-p^G)(1-\theta)E_{t-1}q_t]K_{t-1}^e$. At the beginning of period t, the total repayment of entrepreneurs with successful projects is $p^GR_{t-1}^mK_{t-1}^e$; entrepreneurs with failed projects hand over their land stock $(1-p^G)K_{t-1}^e$ to the mutual funds. After repaying $(1-p^G)\theta q_tK_{t-1}^e$ to foreign investors, the mutual funds keep the rest, $(1-p^G)(1-\theta)q_tK_{t-1}^e$.

The loan contract described in subsection 2.3 implicitly provides entrepreneurs with a net unit return, with a positive expected value, $p^G\tilde{b} > 0$, in period $t-1$. For a successful entrepreneur, the post-repayment return on a unit of land in period t is

$$Rv_t + (1-\theta)q_t - R_{t-1}^m = \tilde{b} + R(v_t - E_{t-1}v_t) + (1-\theta)(q_t - E_{t-1}q_t).$$

As shown in section 3, three types of exogenous shocks result in unexpected changes in the prices of land and intermediate goods in period t: $q_t \neq E_{t-1}q_t$ and $v_t \neq E_{t-1}v_t$. The expected net return to entrepreneurs, $p^G\tilde{b}K_{t-1}^e$, absorbs most aggregate risk and the ex

post rate of return on mutual funds is

$$\tilde{r}_t = \frac{[p^G R^m_{t-1} + (1-p^G)(1-\theta)q_t]K^e_{t-1}}{Z_{t-1}} = r_{t-1}\left\{1 + \frac{(1-p^G)(1-\theta)(q_t - E_{t-1}q_t)}{E_{t-1}[p^G(Rv_t - \tilde{b}) + (1-\theta)q_t]}\right\}, \tag{20}$$

which differs from its expected value $r_{t-1} \equiv E_{t-1}\tilde{r}_t$ due to unexpected changes in the price of land. According to our calibration, $1 - p^G = 0.01$, the ex post rate of return on mutual funds and deposits does not differ much from its expected value. Furthermore, as foreign investors also bear a fraction of capital gains or losses on the land stock of failed entrepreneurs, the discrepancy between the ex post rate of return on deposits and its expected value decreases in θ.

2.5 Domestic Final Goods Production and Foreign Trade

Intermediate goods and labor are employed to produce domestic final goods,

$$Y_t = A_t M_t^{\alpha} L_t^{(1-\alpha-\alpha')} (L^e_t)^{\alpha'}, \tag{21}$$

$$\log A_t = (1-\rho^a)\log \bar{A} + \rho^a \log A_{t-1} + \epsilon^a_t, \tag{22}$$

where M_t, L_t, and L^e_t denote aggregate inputs of intermediate goods, the households' labor, and the entrepreneurs' labor:[6] The total factor productivity, A_t, is an $AR(1)$ in logarithms with the autocorrelation coefficient $\rho^a \in (0,1)$ and the non-stochastic steady state value of $\bar{A} = 1$. The TFP shock has mean zero, $E_t\epsilon^a_{t+1} = 0$, and the variance of σ^2_a. Factor prices are equal to their respective marginal products,

$$v_t M_t = \alpha p_t Y_t, \tag{23}$$

$$w_t L_t = (1-\alpha-\alpha')p_t Y_t, \tag{24}$$

$$w^e_t L^e_t = \alpha' p_t Y_t. \tag{25}$$

The aggregate foreign borrowing $Z^*_t = z^{h,*}_t + z^{e,*}_t$ is backed by the aggregate land stock,

$$r^*_t Z^*_t E_t(p_{t+1}s_{t+1}) = \theta E_t q_{t+1} K, \tag{26}$$

Let X_t and I_t denote the exports in terms of domestic final goods and the imports in terms of foreign final goods in period t, respectively. The interest payment of foreign borrowing is covered by trade suplus,

$$NX_t + Z^*_t = r^{h,*}_t z^{h,*}_{t-1} + r^{e,*}_t z^{e,*}_{t-1}, \tag{27}$$

$$NX_t = \frac{X_t}{s_t} - I_t, \tag{28}$$

where NX_t denotes net exports in terms of foreign final goods. In order to rules out explosive bubbles in the land price, we assume $\lim_{s\to\infty} E_t(r^{-s}_{t+s}q_{t+s}) = 0$.

[6] As households and entrepreneurs are each of unit mass, the values of aggregate variables coincide with their per capita values.

2.6 Market Equilibrium

Markets of intermediate goods, domestic final goods, foreign final goods, and land clear,

$$M_t = G(k_{t-1}) + p^G R k^e_{t-1}, \tag{29}$$

$$Y_t = \frac{\gamma(c_t + c^e_t)}{p_t} + a k^e_t + X_t, \tag{30}$$

$$I_t = \frac{(1-\gamma)(c_t + c^e_t)}{p_t s_t}, \tag{31}$$

$$K = k_t + k^e_t. \tag{32}$$

Definition 1. *A market equilibrium is a set of allocations of households,* $\{k_t, l_t, c_t\}$*, and entrepreneurs,* $\{k^e_t, n_t, z_t, z^{e,*}_t, c^e_t\}$*, along with aggregate variables* $\{M_t, Y_t, I_t, X_t, NX_t, Z^*_t\}$ *and prices* $\{v_t, p_t, q_t, R^m_t, w_t, w^e_t, r_t, \tilde{r}_t, r^f_t\}$ *as well as the exogenous processes* $\{A_t, s_t, r^*_t\}$ *satisfying equations* (1)-(3), (8), (11)- (32)*.*

Let model MH refer to the model with unobservable project choices of entrepreneurs. Foreign investors may not lend ex ante to domestic agents in countries with very bad protection of foreign investors. In this case, the market equilibrium is almost same as defined above with $\theta = 0$. The only exception is that households have to bear unexpected changes in the land price and the first item on the right hand side of their flow-budget constraints is $q_k k_{t-1}$ instead of $E_{t-1} q_t k_{t-1}$ in equation (10),

$$q_t k_t + c_t + d_t = q_t k_{t-1} + v_t G'(k_{t-1}) + \tilde{r}_t d_{t-1} + w_t l_t. \tag{33}$$

2.7 Calibration

Taking the case of no foreign borrowing ($\theta = 0$) as the reference point, we calibrate the structure parameters here. We normalize the aggregate land stock, $K = 1$. The households' project takes the following functional form,

$$G(k_t) = \frac{\epsilon}{1+\lambda}\left[1 - (1-k_t)^{1+\lambda}\right], \tag{34}$$

and the marginal product, $G'(k_t) = \epsilon\,(1-k_t)^{\lambda}$, is decreasing in the households' land holding, where $\lambda = 8$. We set $\beta = 0.975$ and $\bar{r}^* = 1.01$ so that the annual domestic and foreign interest rates are 10% and 4% in the non-stochastic steady state, respectively. By convention, we set $\sigma = 2$ and $\psi = -5$. We set $\chi = 0.15$ so as to keep $l = \frac{1}{3}$ in the case of $\theta = 0$, i.e., households work eight hours a day in the production of domestic final goods. We set $\alpha = 0.36$ and $\alpha' = 0.000001$ so that the household wage income accounts for nearly 64% of aggregate output of domestic final goods and the entrepreneur wage income is negligible. By convention, we set the autocorrelation coefficient of TFP at $\rho^a = 0.9$. For simplicity, we set $\gamma = 0.5$ and $\bar{s} = 1$ so that the prices of domestic and foreign final goods are same: $p = ps = 0.5$; thus, domestic agents consume the equal

amounts of domestic and foreign final goods in the steady state. Following Devereux, Lane, and Xu (forthcoming), we set the autocorrelation coefficients of the terms of trade and the foreign interest rate at $\rho^s = 0.77$ and $\rho^* = 0.46$, respectively.

The surviving probability of entrepreneurs is set at $\pi = \frac{2}{3}$, implying that one-third of entrepreneurs have to exit from the economy each period. We normalize the land price at unity: $q = 1$. In addition, the land stock of entrepreneurs is three times as much as that of households, $\frac{k^e}{K} = 0.75$.[7] The leverage ratio of entrepreneurs is set at 2, implying that they finance half of the their project investments using own funds, as in Bernanke, Gertler, and Gilchrist (1999). In order to satisfy the conditions mentioned above, we set $\{R = 3085, \tilde{b} = 1.74, \epsilon = 411, a = 2.6\}$.

2.8 The Benchmark Case with Observable Project Choices

In order to show the role of domestic financial frictions in affecting macroeconomic volatility, we describe here the model without domestic financial frictions, i.e., mutual funds can perfectly observe the project choices of entrepreneurs. In this case, land is all invested into project "Good" of entrepreneurs, $k_t^e = K$. Given $r_t^f < r_t$, a rise in θ only affects the composition of the external funds of entrepreneurs. Given the binding foreign credit constraints and the expected break-even condition of the mutual funds, the project investment of entrepreneurs are fully financed using external funds,

$$q_t + ap_t = \frac{p_t s_t z_t^{e,*} + z_t}{k^e} = \frac{\theta E_t q_{t+1}}{r_t^f} + \frac{E_t[p^G R v_{t+1} + (1-\theta) q_{t+1}]}{r_t}. \tag{35}$$

Entrepreneurial net worth is not required and they consume their wage income w_t^e.

Suppose that households deposit d_{t-1} at the mutual funds in period $t-1$. After the project completion in period t, entrepreneurs repay their liabilities to foreign investors, $\theta q_t K$, and transfer the rest of the project outcomes to the mutual funds, $[p^G R v_t + (1-\theta) q_t]K$. The ex post rate of return on mutual funds is

$$\tilde{r}_t = \frac{[p^G R v_t + (1-\theta) q_t]K}{d_{t-1}} = r_{t-1}\left[1 + \frac{p^G R(v_t - E_{t-1}v_t) + (1-\theta)(q_t - E_{t-1}q_t)}{p^G R E_{t-1} v_t + (1-\theta) E_{t-1} q_t}\right], \tag{36}$$

which differs from its expected value r_{t-1} due to unexpected changes in the prices of intermediate goods and land.

As shown in subsection 2.4, the entrepreneurs' expected stake in the project outcomes, $p^G \tilde{b} k_t^e > 0$, helps absorb most of aggregate risk in the model with domestic financial frictions. While, in the model without domestic financial frictions, no incentive is required to induce entrepreneurs to engage in project "Good". Mutual funds only diversify the idiosyncratic project risk of entrepreneurs but not aggregate risk. Given that mutual funds do not accumulate reserves in our model, depositors have to bear more aggregate risk than in the model with domestic financial frictions.

[7] Our results are independent of the exact values of q and $\frac{k^e}{K}$.

Aggregate input for and output of the production of intermediate goods are proportional to the aggregate land stock, aK and $M = p^G RK$. Essentially, the model without domestic financial frictions is equivalent to a standard RBC model with a representative agent who has two production technologies: the linear technology to produce intermediate goods using land K and domestic final goods aK, and the Cobb-Douglas technology to produce domestic final goods. Aggregate output of domestic final goods, $Y_t = A_t M^{\alpha} L_t^{(1-\alpha-\alpha')}(L^e)^{\alpha'}$, depends on labor supply and total factor productivity.

Let model RBC denote the model without domestic financial frictions. The market equilibrium of model RBC is defined as the set of three exogenous state variables $\{A_t, s_t, r_t^*\}$ and sixteen control variables $\{r_t, c_t, z_t, l_t, w_t, Z_t^*, v_t, p_t, q_t, Y_t, I_t, X_t, NX_t\}$ satisfying equations (1)-(2), (8), (11)-(12), (22), (26), (28), (35), and (37)-(43).

$$r_t z_t = E_t[p^G R v_{t+1} + (1-\theta) q_{t+1}]K, \tag{37}$$

$$Y_t = A_t (p^G RK)^{\alpha} l_t^{1-\alpha-\alpha'}, \tag{38}$$

$$p^G RK v_t = \alpha p_t Y_t, \tag{39}$$

$$l_t w_t = (1-\alpha-\alpha') p_t Y_t, \tag{40}$$

$$p_t X_t = p_t(Y_t - aK) - \gamma(c_t + \alpha' p_t Y_t), \tag{41}$$

$$p_t s_t I_t = (1-\gamma)(c_t + \alpha' p_t Y_t), \tag{42}$$

$$p_t s_t (NX_t + Z_t^*) = \theta q_t K. \tag{43}$$

3 Dynamic Analysis

This section analyzes how financial openness can affect macroeconomic volatility in the small open economy with respect to FIR, TFP, and ToT shocks. We log-linearize the equilibrium conditions at the non-stochastic steady state and approximate endogenous variables to the first order as the linear functions of the state variables in logarithms, which we solve using the MATLAB codes provided by Schmitt-Grohé and Uribe (2004). We analyze the model dynamics to exogenous shocks in period 0 under various degrees of collateralization, given that models are in their respective non-stochastic steady states before period 0.

3.1 Impulse Responses to FIR Shocks

In the case of $\theta = 0$, there is no foreign borrowing and changes in the foreign interest rate do not affect the domestic economy. Figure 1 shows the impulse responses of model RBC (dashed line) and model MH (solid line) to a FIR shock in the case of $\theta = 0.5$. DFG, HH, and EN refer to domestic final goods, households, and entrepreneurs, respectively.

Consider first model RBC in the case of $\theta = 0.5$. A 1% positive FIR shock raises the cost of foreign funds. Entrepreneurs have to reduce their foreign borrowing and their

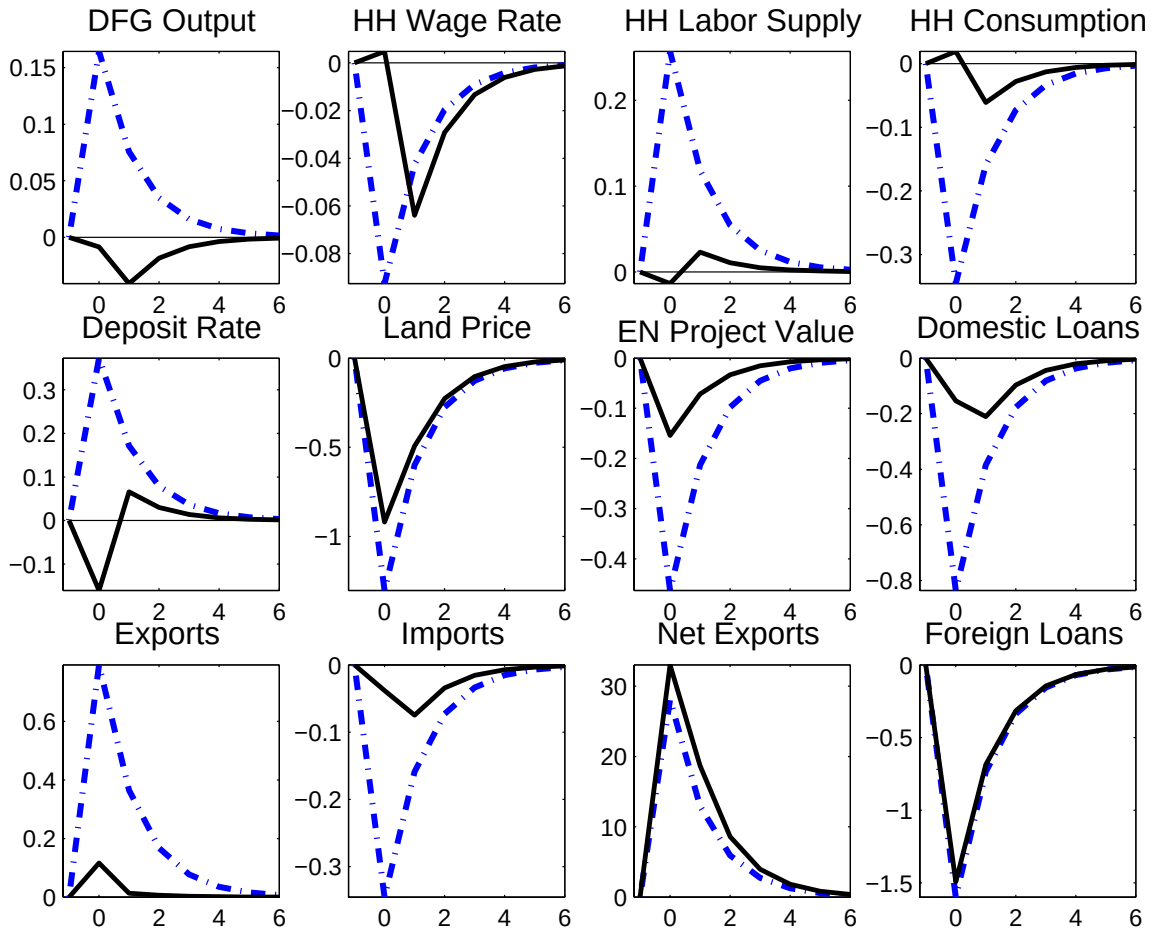

Figure 1: Impulse Responses to a FIR Shock: Model MH vs Model RBC

project investment. The land price declines. As the foreign interest rate is autocorrelated, the period-1 land price is still below the steady state value and entrepreneurs have to further reduce their period-0 land-backed foreign borrowing, $Z_0^* = E_0 \frac{\theta q_1 K}{p_1 s_1 r_0^*}$. According to the foreign borrowing contract, foreign investors bear 50% of capital losses. After repaying foreign loans, entrepreneurs transfer the rest of their project outcomes to mutual funds. Capital losses make the period-0 return on mutual funds below its expected value. In order to offset the negative wealth effect, households increase their labor supply and reduce consumption and deposits. Aggregate output of domestic final goods rises and the decline in household deposits raises the domestic interest rate.

Consider model MH in the case of $\theta = 0.5$. A 1% positive FIR shock depresses the domestic demand for land and the land price declines in period 0. Although foreign investors share half of capital losses with entrepreneurs, entrepreneurial net worth still falls and so does their land stock. The decrease in the entrepreneurs' demand for domestic loans lowers the domestic interest rate, in contrast to the rise in the domestic interest rate in model RBC. According to equation (10), the first and the third components

of household wealth are (almost) unaffected by the FIR shock. Households increase their consumption and reduce their deposits and labor supply in period 0. As a result, aggregate output of domestic final goods declines instead of rises as in the case of model RBC. Due to asset reallocation from entrepreneurs to households in period 0, aggregate output of intermediate goods falls in period 1 and aggregate output of domestic final goods is further below its steady state value in period 1.

In sum, according to financial contracts, the FIR shock affects the household wealth differently in models with and without domestic financial frictions. The endogenous supply of household labor driven by the wealth effect is the only factor determining aggregate output of final goods in the model without domestic financial frictions, while the endogenous asset reallocation is the dominant driving force behind aggregate output of final goods in the model with domestic financial frictions. As a result, aggregate output responds differently in the two models.

Figure 2 shows the unconditional standard deviations of major endogenous variables in model MH (solid line) and in model RBC (dashed line) normalized by that of FIR shocks.[8] The horizontal axis denotes $\theta \in [0, 1]$.

Consider the effects of financial openness on macroeconomic volatility in model RBC. As θ rises from 0 to 1, entrepreneurs use more foreign loans to substitute for domestic loans in their project investment. Changes in the foreign interest rate have larger effects on the land demand of entrepreneurs and the land price responds more strongly to FIR shocks. As long as $\theta < 0.6$, domestic deposits still account for a significant share of the household wealth. The rise in θ results in larger capital gains or losses in the event of the FIR shock and the ex post return on household deposits are affected more. Households then adjust their labor supply more strongly to offset the wealth effect. While, as θ rises from 0.6 to 1, domestic deposits account for a smaller fraction of household wealth, because entrepreneurs substitute foreign loans for domestic loans. Furthermore, foreign investors bear a larger share of capital gains or losses and the ex post return on households deposits vary less. Therefore, the volatility of the household labor supply with respect to FIR shocks has a hump-shaped fashion. As the household labor is the only dominant factor determining output here, major macroeconomic aggregates have the similar hump-shaped volatility patterns.

Consider the effects of financial openness on macroeconomic volatility in model MH. As θ rises from 0 to 1, entrepreneurs and households finance their project investment using more foreign funds. The net value of the land stock of entrepreneurs, $p^G(1-\theta)q_t k^e_{t-1}$ is affected by FIR shocks in a non-monotonic way as θ rises from 0 to 1 and so is entrepreneurial net worth, $p^G[Rv_t + (1-\theta)q_t - R^m_{t-1}]k^e_{t-1}$. As θ rises from 0 to 0.6, changes in FIR have larger effects on the project investment of entrepreneurs in the sense that

[8] Schmitt-Grohe (2005) shows that the unconditional standard deviations of endogenous variables are proportional to that of the exogenous shock up to the first order.

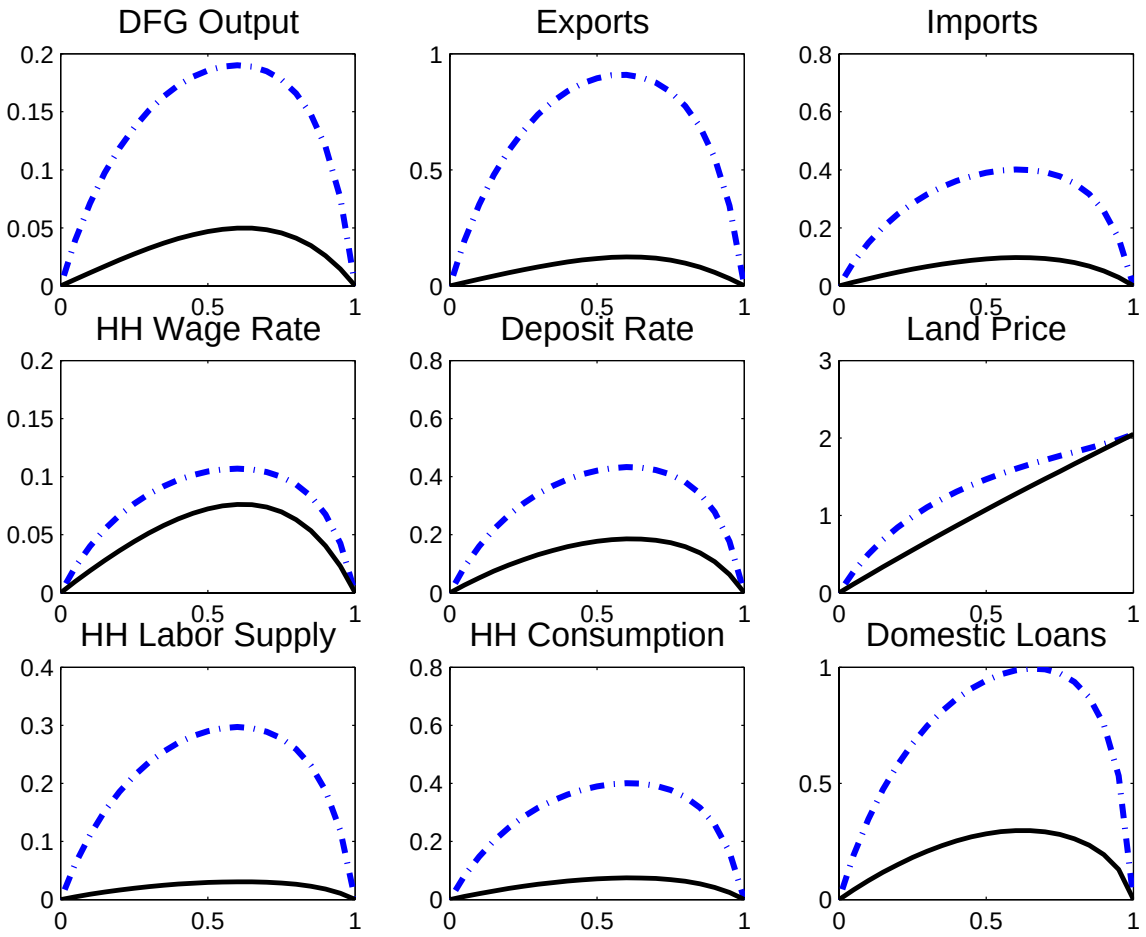

Figure 2: Foreign Openness and Macroeconomic Volatility: FIR shocks

the land stock of entrepreneurs responds more strongly to a FIR shock. However, as θ rises from 0.6 to 1, foreign investors bear a larger share of capital gains (losses) and thus changes in the land price related to FIR shocks have smaller effects on entrepreneurial net worth and their land holding. Other variables have the similar hump-shaped volatility patterns. In contrast to model RBC, household deposits have a rather safe return due to the buffer effect of entrepreneurial net worth in model MH. Endogenous asset reallocation is the dominant factor determining output and the hump-shaped volatility patterns are flatter than in model RBC.

3.2 Impulse Responses to TFP Shocks

Figure 3 shows the impulse responses of model RBC in the cases of $\theta = 0$ (dashed line) and $\theta = 0.5$ (solid line) to a TFP shock.

Consider first model RBC in the case of international financial autarky $\theta = 0$. As there is no endogenous state variables in model RBC, the dynamic structure is essentially $AR(1)$. The distinction between households and entrepreneurs does not matter for

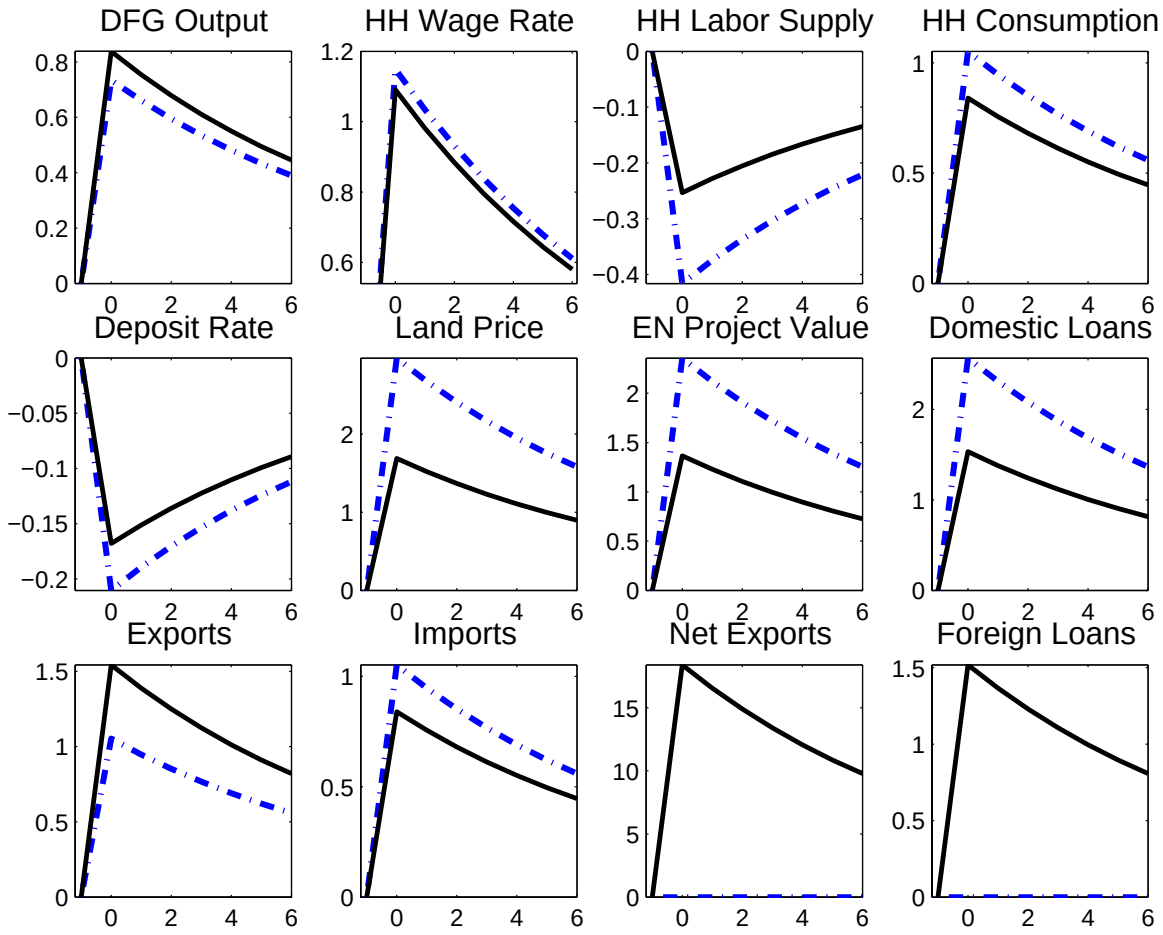

Figure 3: Impulse Responses to a TFP shock: Model RBC

aggregate allocation. A 1% positive TFP shock raises the marginal products of intermediate goods and labor in period 0. The price of intermediate goods rises to clear the market, given that aggregate output of intermediate goods is fixed at $M = p^G RK$. In the meantime, the household wage rate rises, too. In addition, given the autocorrelation in TFP, the marginal product of intermediate goods stays above its steady state value in period 1 and so does the price of intermediate goods. It improves the expected unit value of the land invested in the entrepreneurs' projects in period 0, $E_0(p^G R v_1 + q_1)$, and entrepreneurs are able to demand more loans and expand their project investment. Given the fixed aggregate land stock, the price of land rises to clear the market. Thus, the positive responses of the prices of land and intermediate goods to the TFP shock improves the ex post rate of return on mutual funds in period 0. See equation (36).

The household wealth consists of their deposit return and wage income. The positive TFP shock improves household wealth in period 0. As households prefer to smooth consumption over time and optimize between consumption and labor, they reduce labor supply in period 0 and make more deposits. The decline in household labor supply

partially offset the rise in TFP and thus the rise in aggregate output of domestic final goods is smaller than the rise in TFP. Note that in the model without domestic financial frictions, the supply effect dominates in the credit market in the sense that the rise in the households' deposits reduces the domestic interest rate.

Entrepreneurs only consume their wage income, which is tiny and proportional to aggregate output of domestic final goods. Thus, household consumption, $c_0 = p_0(Y_0 - aK) - w_0^e$, rises in period 0. As the responses of imports replicate those of household consumption and foreign trade must balance in the case of $\theta = 0$, imports and exports rises in the same magnitude as household consumption.

Consider model RBC in the case of $\theta = 0.5$. Its dynamic structure is similar as in the case of $\theta = 0$. Foreign investors and entrepreneurs jointly share ex post changes in the land price $(q_t - E_{t-1}q_t)$. Due to leakage of capital gains on the entrepreneurs' land stock to foreign investors, a 1% positive TFP shock makes the ex post return on mutual funds exceed its expected value to a smaller extent than in the case of $\theta = 0$. The smaller wealth effect induces households to reduce their labor supply to a smaller extent and thus, aggregate output of domestic final goods rises more. The smaller wealth effect also induces households to raise their consumption and deposits to a smaller extent. Thus, the domestic interest rate decline less than in the case of $\theta = 0$. As entrepreneurs finance their project investment using domestic and foreign funds and the foreign interest rate is constant, the average cost of their external funds declines to a smaller extent. Thus, their land demand rises less and so does the period-0 land price. As foreign investors benefit from capital gains, net exports rise to cover the unexpected increase in the interest payment to foreign investors in period 0. As the responses of imports follow roughly those of household consumption, exports rise, too. Major macroeconomic aggregates are driven by the household wealth effect and their labor-consumption decision.

Figure 4 shows the unconditional standard deviations of endogenous variables normalized by that of the TFP shock σ_a in model RBC (dashed line) and in model MH (solid line). The horizontal axis denotes $\theta \in [0, 1]$.

Consider first the effects of financial openness on macroeconomic volatility in model RBC. As θ rises from 0 to 0.85, foreign investors bear an larger share of capital gains (losses) in the case of positive (negative) TFP shocks. Thus, the difference between the ex post repayment of entrepreneurs to the mutual funds and its expected value is decreasing in θ. As the wealth effect related to household deposit returns declines, the negative responses of labor supply and the positive responses of household consumption and deposits to TFP shocks are decreasing, too. Thus, aggregate output of domestic final goods responds more, while imports and the domestic interest rate respond less. As the investment of domestic final goods in the projects of entrepreneurs (aK) is constant, the rise in the volatility of aggregate output of domestic final goods and the decline in the volatility of household consumption imply that exports respond more to TFP shocks.

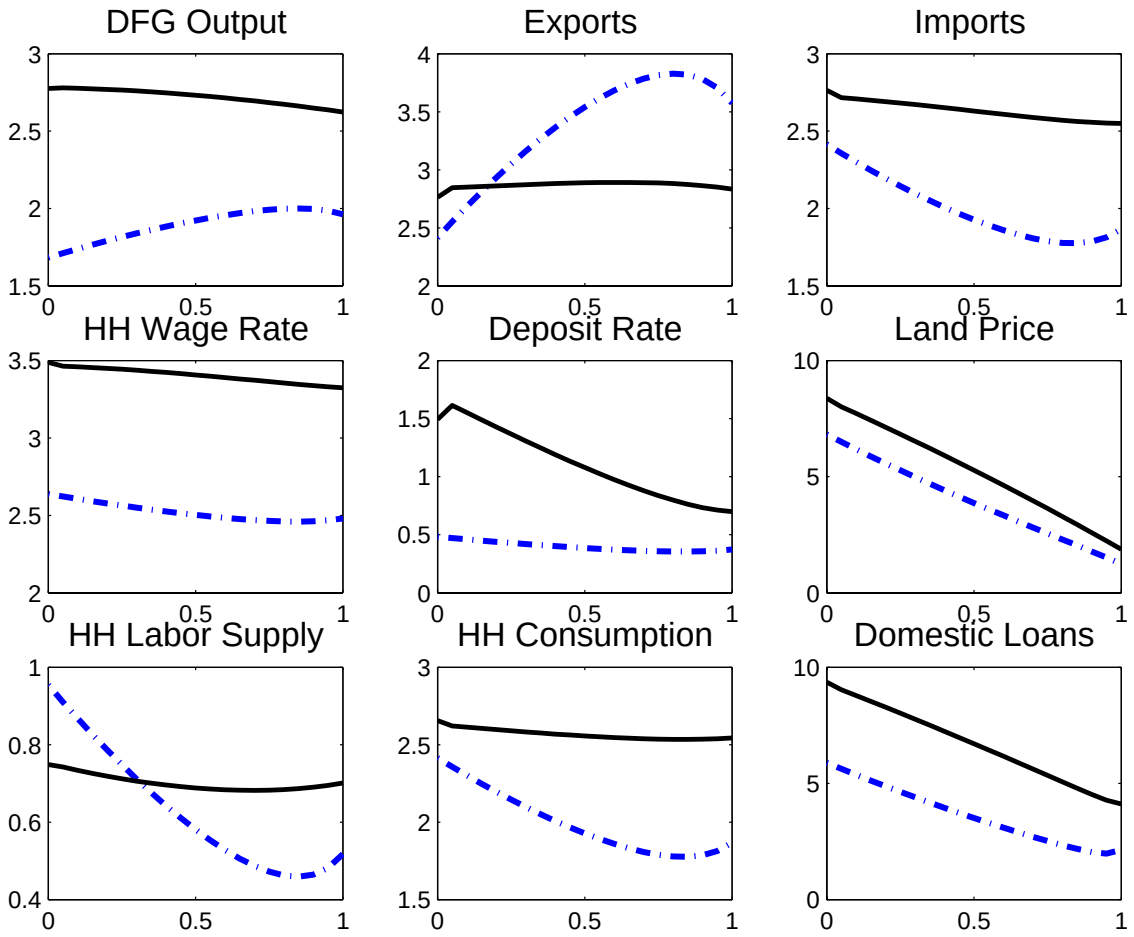

Figure 4: Foreign Openness and Macroeconomic Volatility: TFP shocks

The steady state value of domestic lending declines in θ, as entrepreneurs substitute more foreign funds for domestic funds. The share of household deposits in household wealth declines in θ, too. As long as $\theta < 0.85$, household deposit returns still play a dominant role. However, as $\theta > 0.85$, the household wage income dominates in their total wealth and changes in ex post deposit returns have smaller effects on household consumption-labor decision. For $\theta \in (0.85, 1]$, the volatility patterns of output, consumption, labor, and foreign trade are opposite to the case of $\theta \in (0, 0.85]$.

Figure 5 shows the impulse responses of model MH in the cases of $\theta = 0$ (dashed line) and $\theta = 0.5$ (solid line) to a TFP shock.

Consider now model MH in the case of $\theta = 0$. There are two endogenous state variables, $\{k_t^e, R_t^m\}$. Note that the distinction between entrepreneurs and households matters for aggregate output in model MH. Given a 1% positive TFP shock, extra sales revenues improve the post-repayment wealth of entrepreneurs, $p^G[R(v_0 - E_{-1}v_0) + (q_0 - E_{-1}q_0) + \tilde{b}]k_{-1}^e$. Thus, entrepreneurs borrow more from the mutual funds and expand their project investment. The land price rises to clear the market in period 0 and capital

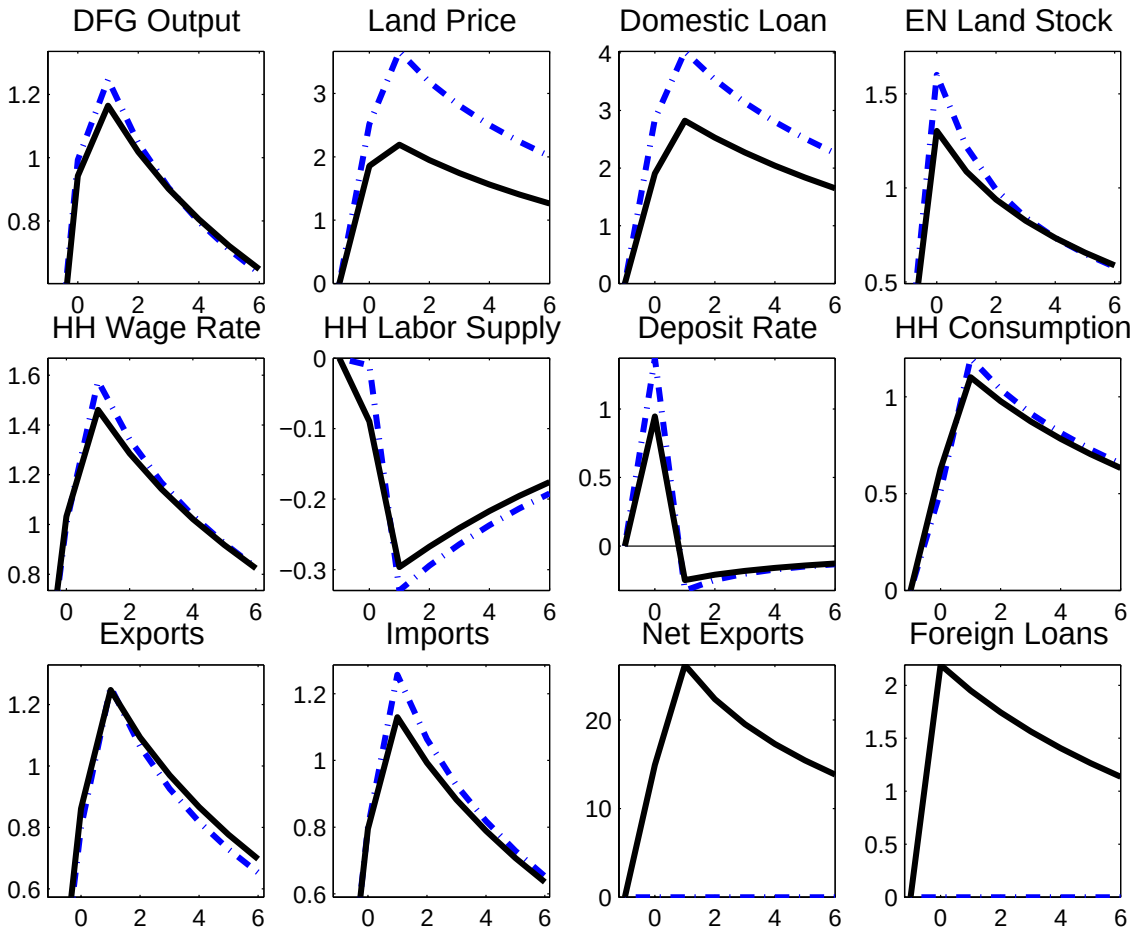

Figure 5: Impulse Responses to a TFP shock: Model MH

gains further improves entrepreneurial net worth. The land holding of entrepreneurs rises and so does their demand for loans. Note that in model MH, the demand effect dominates in the credit market in the sense that the domestic interest rate rises.

As entrepreneurs bear most of the aggregate risk related to the TFP shock in model MH, the difference between the ex post return on mutual funds and its expected value is almost negligible. Capital gains and extra sales revenues still improve household wealth by the amount of $(q_0 - E_{-1}q_0)k_{-1} + (v_0 - E_{-1}v_0)G(k_{-1}) > 0$ in period 0. The rise in the domestic interest rate induces households to increase their deposits, while the rise in the land price induces households to reduce their land holding in period 0. As the wealth effect is weaker than in model RBC, the consumption-leisure substitution induces households to raise their consumption and reduce labor supply to a smaller extent in period 0. Thus, aggregate output of domestic final goods rises to a larger extent. The capital gains on the entrepreneurs' land stock which are transferred to households in model RBC are now captured by entrepreneurs. Thus, the weaker rise in household wealth explains the responses of their labor supply and aggregate output.

The deposits made in period 0 improve household wealth significantly in period 1. Households increase their period-1 consumption to an even larger extent than in period 0. They also increase period-1 deposits for the purpose of consumption smoothing. The rise in the supply of deposits reduces the domestic interest rate. In the meantime, the consumption-leisure substitution induces households to reduce their labor supply. Due to the asset reallocation from households to entrepreneurs in period 0, aggregate output of intermediate goods rises in period 1. Despite the decline in the household labor supply, aggregate output of domestic final goods rises to a larger extent in period 1 than in period 0 in model RBC. Domestic loan contracts specify a non-contingent liabilities for successful entrepreneurs and entrepreneurs bear unexpected price changes. The enhanced land reallocation further amplifies the effect of a TFP shock on output.

Consider model MH in the case of $\theta = 0.5$. Domestic agents pledge half of the expected value of their land stock to foreign investors. In addition, entrepreneurs can pledge part of the expected project value for domestic loans. Given a 1% positive TFP shock, the entrepreneurs' excess demand for land pushes up the land price. Due to the leakage of capital gains to foreign investors, the additional improvement in entrepreneurial net worth related to capital gains is smaller than in the case of $\theta = 0$. Thus, the weaker rise in the entrepreneurial net worth and their demand for land results in a smaller increase in the land price. Similarly, the smaller rise in the entrepreneurs' demand for domestic loans leads to a smaller rise in the domestic interest rate.

As specified in the financial contract between foreign investors and households, foreign investors keep all of the capital gains on the land stock of households. According to equation (10), the households' wealth consists of the net value of their land stock, sales revenues, deposit returns, and wage income. Without capital gains, household wealth rises less than in the case of $\theta = 0$. The smaller rise in the domestic interest rate induces households to raise their deposits less. Thus, households increase consumption and reduce labor supply to a larger extent. Aggregate output of domestic final goods rises to a smaller extent. Due to the smaller wealth effect related to the deposit return in period 1, households increase their period-1 consumption and deposits less. Note that the rise in θ enhances the responses of household consumption and labor in period 0 but weakens their responses in the following periods.

See figure 4 for the effect of financial openness on macroeconomic volatility in model MH. Due to the leakage of capital gains (losses) to foreign investors, the entrepreneurs' demand for land and external funds responds less to TFP shocks as θ rises from 0 to 1. There are two effects. First, the land price becomes less volatile and so does the aggregate foreign borrowing, which are similar as in model RBC; second, aggregate output of intermediate goods responds less to TFP shocks, while aggregate output of intermediate goods does not respond to the TFP shock in model RBC. Furthermore, household consumption responds more in the shock period but less in the following periods. The

overall effects of θ on the volatility of household consumption are non-monotonic. Due to the consumption-leisure substitution, household labor supply responds more strongly to TFP shocks in the shock period and less in the following periods. The volatility of household labor supply is also non-monotonic in θ. Altogether, aggregate output of domestic final goods becomes less volatile in θ, while aggregate output of domestic final goods becomes more volatile as θ rises from 0 to 0.7 in model RBC.

3.3 Impulse Responses to ToT Shocks

Figure 6 shows the impulse responses of model RBC in the cases of $\theta = 0$ (dashed line) and $\theta = 0.5$ (solid line) to a ToT shock.

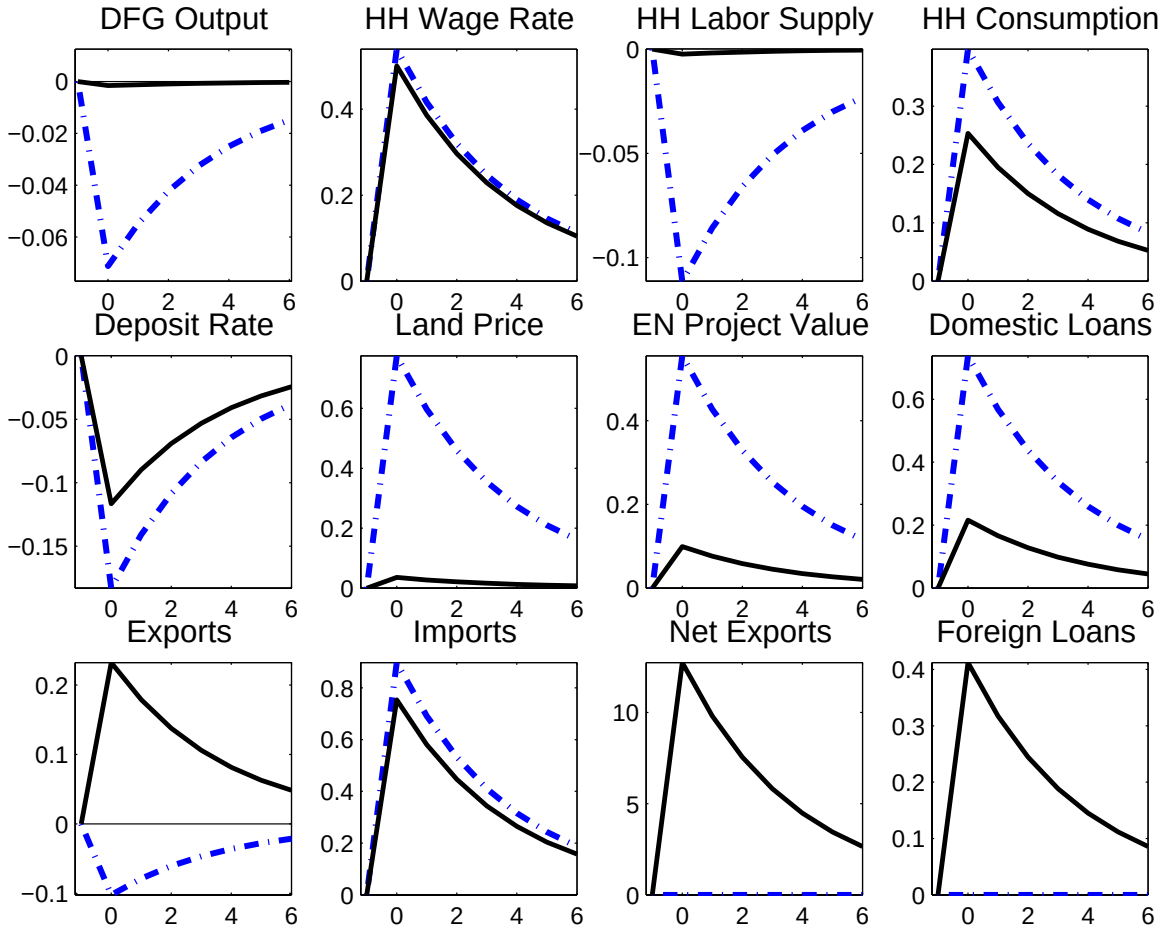

Figure 6: Impulse Responses to a ToT shock: Model RBC

Consider model RBC in the case of $\theta = 0$. According to equations (8) and (9), a 1% positive ToT shock raises the price of domestic final goods and reduces the price of foreign final goods by 0.5% in period 0, respectively. The increase in the marginal products of labor and intermediate goods pushes up the wage rate and the price of intermediate goods. Thus, a positive ToT shock has similar effects as a positive TFP shock. The

positive wealth effect induces households to increase consumption and deposits and to reduce their labor supply in period 0. The domestic interest rate and aggregate output of domestic final goods decline. Entrepreneurs increase their demand for loans and land. The rise in the land price further improves the ex post return on mutual funds and enhances the wealth effect on household decision on consumption, labor, and deposit.

Consider model RBC in the case of $\theta = 0.5$. Given a 1% positive ToT shock, the wage rate and the price of intermediate goods rise, as in the case of $\theta = 0$; in addition, according to equation (3), the effective foreign interest rate $r_0^f = \frac{r_t^* E_0 p_1 s_1}{p_0 s_0}$ rises by 0.115%, which is absent in the case of $\theta = 0$. Despite the rise in foreign borrowing by 0.4%, foreign borrowing in terms of domestic composite consumption, $p_0 s_0 Z_0^*$, actually declines by 0.1%. Thus, the land price responds less than in the case of $\theta = 0$.

Household wealth consists of their deposit returns and the wage income. Due to the rise in the prices of land and intermediate goods, the period-0 return on household deposits exceeds its expected value. Thus, household consumption rises and so do the period-0 imports. Due to the leakage of capital gains to foreign investors, the wealth effect is much smaller than in the case of $\theta = 0$ and thus, households only reduce their labor supply slightly. As a result, aggregate output of domestic final goods also declines slightly. Intuitively, in the case of $\theta = 0.5$, foreign investors extract half of capital gains and provide funds at a higher interest rate in terms of domestic consumption composite. Thus, the output effect of ToT shock is weakened by these two factors.

Figure 7 shows the unconditional standard deviations of major endogenous variables in model MH (solid line) and in model RBC (dashed line) normalized by that of the ToT shock. The horizontal axis denotes $\theta \in [0, 1]$.

Consider the effects of financial openness on macroeconomic volatility in model RBC. As θ rises from 0 to 1, entrepreneurs finance their project investment using more foreign funds. Thus, the effects of ToT shocks are partially offset by the increasing leakage of capital gains (losses) to foreign investors and changes in the effective foreign interest rate. Household consumption, labor, output, and the land price become less volatile as θ rises from 0 to 0.55. As θ rises from 0.55 to 0.65, the volatility of household consumption becomes further smaller. Due to the substitution between consumption and leisure, household labor supply responds positively to the ToT shock and it becomes increasingly volatile. Note that as θ exceeds 0.55, entrepreneurs have more foreign loans than domestic loans, $p_t s_t Z_t^* > z_t$. Thus, the overall cost of external funds becomes larger in the case of the positive ToT shock. Thus, entrepreneurs reduces their project investment and the land price declines rather than rises in the case of $\theta \in [0, 0.55)$. As θ rises from 0.55 to 1, the land price becomes more volatile.

As θ rises from 0.65 to 1, more land is pledged to foreign investors. Mutual funds suffer less from capital losses in the case of positive ToT shocks and so does household wealth. As a result, households increase their consumption in period 0 more strongly.

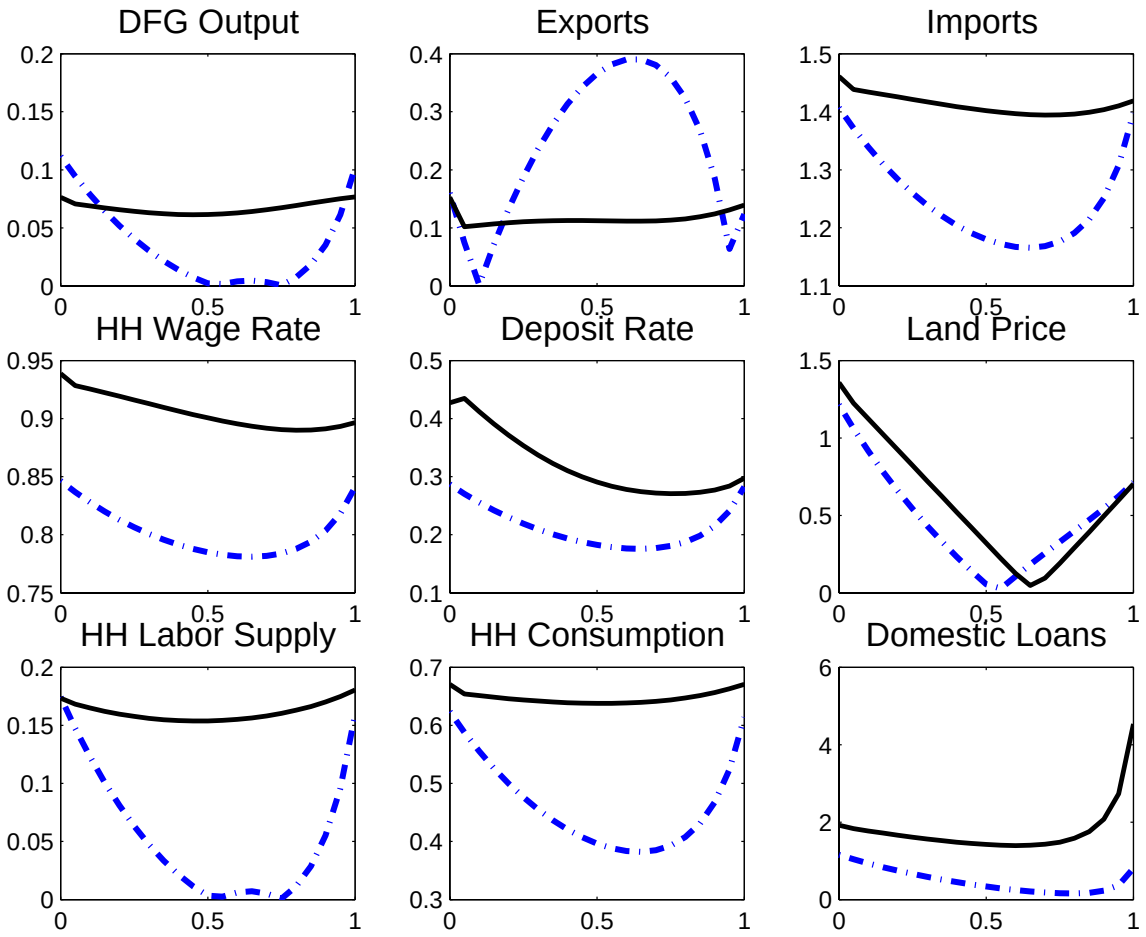

Figure 7: Foreign Openness and Macroeconomic Volatility: ToT shocks

As long as $\theta \in (0.65, 0.75)$, the wealth effect dominates and households still reduce their labor supply in period 0 in the case of positive ToT shocks. As θ rises from 0.75 to 1, the consumption-leisure effect dominates and households raise their labor supply more strongly in the shock period. Thus, household labor supply becomes more volatile in θ. Aggregate output has the similar volatility pattern as household labor supply.

Figure 8 shows the impulse responses of model MH in the cases of $\theta = 0$ (dashed line) and $\theta = 0.5$ (solid line) to a ToT shock.

Consider model MH in the case of $\theta = 0$. Given a 1% positive ToT shock, as entrepreneurs bear most of the aggregate uncertainty using their net worth, the ex post rate of return on mutual funds does not rise as much as in model RBC. Due to the weaker wealth effect, the household labor supply declines to a smaller extent than in model RBC and so does aggregate output.

The rise in the price of domestic final goods also raises that of intermediate goods and the sales revenues of entrepreneurs. Thus, entrepreneurs increase their demand for land and the land price rises. Capital gains further improves entrepreneurial net worth. The

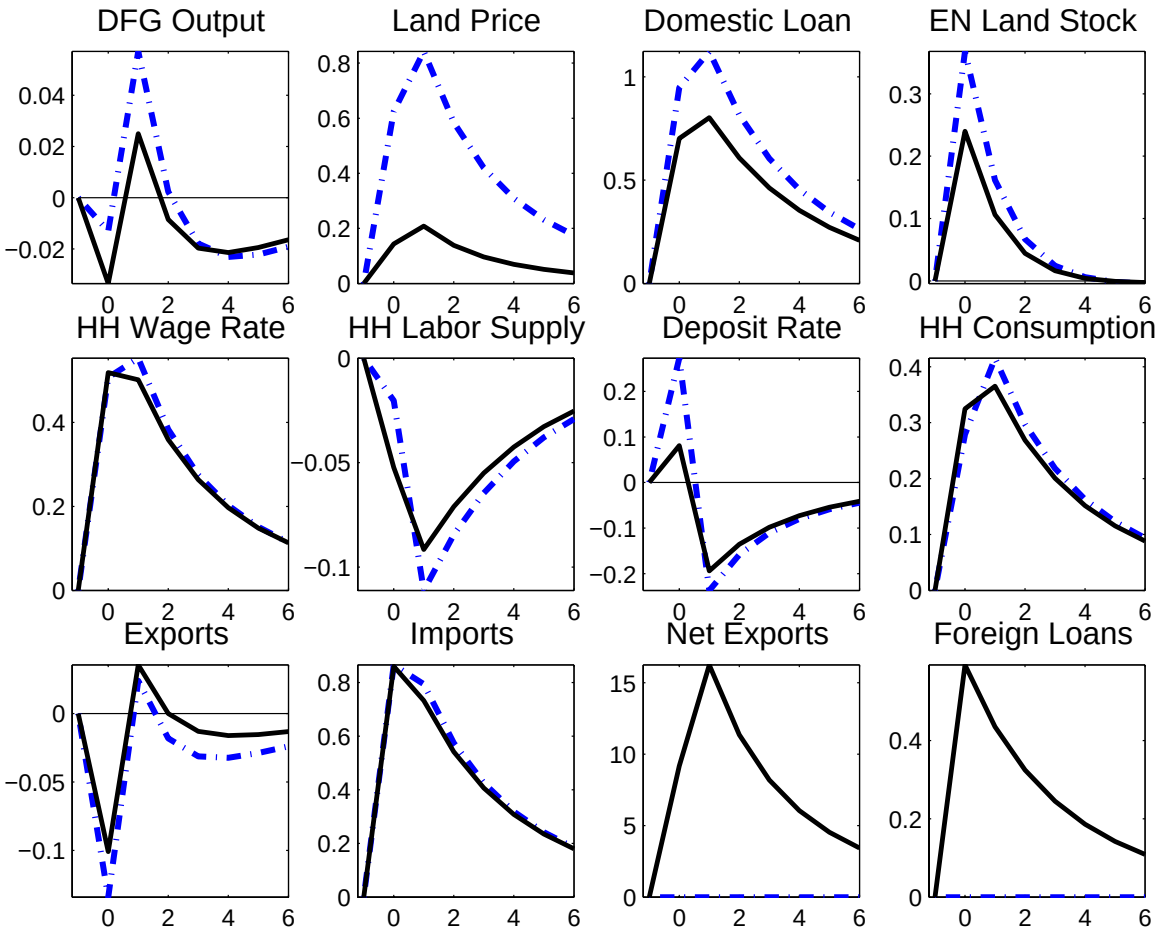

Figure 8: Impulse Responses to a ToT shock: Model MH

extra demand of entrepreneurs for loans pushes up the domestic interest rate. Capital gains also improve household wealth and thus, households increase their consumption.

Due to the rise in the period-0 deposits, the households' wealth is above its steady state value in period 1. They increase consumption and deposits further. The rise in the supply of deposits reduces the domestic interest rate in period 1. Households also reduce their labor supply. The asset reallocation from households to entrepreneurs in period 0 increases aggregate output of intermediate goods in period 1. Altogether, aggregate output of domestic final goods rises rather than declines in model RBC.

The distinction between households and entrepreneurs matters for macroeconomic volatility. An improvement in the terms of trade (a decline in s_t) raises the prices of domestic final goods and intermediate goods. As domestic loans are written in terms of composite consumption, the rise in the price of intermediate goods reduces the effective domestic liabilities of entrepreneurs with successful projects. Thus, the asset reallocation in the case of a positive ToT shock actually results from debt inflation.

Consider model MH in the case of $\theta = 0.5$. Given a 1% positive ToT shock, the

extra sales revenues improves entrepreneurial net worth. Due to debt inflation mentioned above, entrepreneurs can expand their project investment. The rise in their land demand pushes up the land price. As foreign investors share capital gains with entrepreneurs, entrepreneurial net worth rises in a smaller magnitude than in the case of $\theta = 0$ and so does the land price and the domestic interest rate. Together with the rise in the effective foreign interest rate, the overall cost of external funds is higher for entrepreneurs than in the non-stochastic steady state. Thus, the period-0 land stock of entrepreneurs rises to a smaller extent than in the case of $\theta = 0$.

As foreign investors bear all of the capital gains on the land stock of households, household wealth does not increase as much as in the case of $\theta = 0$. Households also suffer from the rise in the effective foreign interest rate in period 0 and thus they reduce their land investment. As the domestic interest rate rises to a smaller extent than in the case of $\theta = 0$, households increase their deposits to a smaller extent. They also reduce their labor supply and increase consumption to a larger extent than in the case of $\theta = 0$. Thus, aggregate output of domestic final goods declines more in period 0.

See figure 7 for the effect of financial openness on macroeconomic volatility in model MH. As foreign investors share capital gains (losses), changes in the effective foreign interest rate partially offset the effects of ToT shocks, in comparison with the case of $\theta = 0$. As θ rises from 0 to 0.45, household labor supply responds to ToT shocks more in the shock period but less in the following periods. The overall volatility of household labor supply declines in θ and so does the volatility of household consumption.

The rise in θ enables both households and entrepreneurs to borrow more abroad. On the one hand, the net value of the household land holding in the non-stochastic steady state, $(1 - \theta)E_{t-1}q_t k_{t-1}$, declines in θ; on the other hand, entrepreneurs borrow less from the mutual funds and thus household deposits also decline in θ. The net value of household land holding and household deposits are mainly unaffected by ToT shocks. As θ exceeds 0.45, these two components in household wealth become less important. Thus, households reduce their labor supply both in and after the shock periods to a larger magnitude in the case of positive ToT shocks.

As θ rises from 0 to 1, foreign investors share a larger share of capital gains (losses) with entrepreneurs in the case of positive (negative) ToT shocks. Thus, the land investment of entrepreneurs becomes less volatile in θ and so does aggregate output of intermediate goods. As θ rises from 0 to 0.45, both the households labor supply and asset reallocation become less volatile. Thus, aggregate output becomes less volatile in θ. As θ rises from 0.45 to 1, the effect of the household labor supply dominates so that aggregate output becomes more volatile in θ.

4 Final Remarks

This paper shows how financial openness can affect macroeconomic volatility via foreign borrowing in a small, open economy. We investigate the model dynamics with respect to three types of exogenous shocks: the foreign-interest-rate shock, the productivity shock, and the terms-of-trade shock, respectively. As financial openness improves, the normalized unconditional standard deviations of major macroeconomic aggregates display non-monotonic patterns with respect to the three shocks in the models with and without domestic financial frictions. Furthermore, their volatility patterns vary less in the model with domestic financial frictions than in the model without domestic financial frictions. If the empirical data of countries with different degree of financial openness are pooled together, we might not be able to estimate a significant linear relationship between financial openness and macroeconomic volatility, because the underlying relationship is rather flat and non-monotonic. In this sense, our model may explain the lack of empirical evidence on financial openness and macro volatility.

We will confront our model with empirical data and check the robustness of such non-monotonic volatility patterns.

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Zentrum für Europäische Integrationsforschung
Center for European Integration Studies
Rheinische Friedrich-Wilhelms-Universität Bonn

Walter-Flex-Strasse 3
D-53113 Bonn
Germany

Tel.: +49-228-73-1732
Fax: +49-228-73-1809
www.zei.de