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Risk premium in a real business cycle framework

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ABSTRACT

A real business cycle framework with financial and informational frictions is developed for a small open economy in order to analyze the implications of risk premium shocks for aggregate fluctuations. The frictions in the dynamic, stochastic, general equilibrium model necessitate financial intermediation and the uncertainty in the production process requires collateralized borrowing in the economy. Sovereign risk exists in the model due to a government that borrows domestically with a partial default risk. The associated risk premium that the government is subject to is captured both endogenously and exogenously, which constitutes one of the major contributions of this study to the literature. It is shown that a positive, temporary risk premium shock leads to an increase in government borrowing and a decrease in government spending due to the rise in the cost of borrowing for the government. The model also predicts a fall in output, labor supply and loans as well as a rise in the default probability of the government. The results confirm the findings of the literature with respect to the expected effects of a positive risk premium shock on a small open economy in a novel framework, where financial and informational frictions as well as sovereign risk as key features of emerging economies are captured and analyzed.

1. Introduction

Risk premium and its implications for business cycles in emerging economies have been studied extensively especially over the last two decades.[2] One strand of literature on this topic focuses on the effects of movements in domestic variables on country risk premium and documents that risk premium responds systematically and countercyclically to the business cycles in emerging economies.[3] Another line of research assumes that risk premium is exogenous to the domestic conditions in emerging countries. Authors advocating this argument relate the risk premium and the world interest rate through some exogenous, stochastic process and attempt to partially explain aggregate volatility in small open economies with interest rate fluctuations.[4]This study proposes a theoretical framework incorporating financial and informational frictions as well as uncertainty to examine aggregate fluctuations in response to risk premium shocks in a small open economy.[5] Risk premium in the model is captured and analyzed both endogenously and exogenously, which constitutes one of the major contributions of this study to the literature.[6]

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1 The author appreciates the valuable comments and suggestions made by anonymous referees.

2 See, among others, Arellano (2008).

3 See, among others, Cline (1995), Cline and Barnes (1997), Edwards (1984) and Eichengreen and Mody (2000).

4 Neumeyer and Perri (2005) provide evidence for the fact that interest rate shocks constitute an important factor for explaining business cycles in emerging economies.

5 For a detailed analysis on the relationships between country risk premium, business cycles and emerging market fundamentals, see Uribe and Yue (2006).

6 The risk premium in the study arises due to the sovereign risk in the economy, which is one of the main characteristics of emerging economies. Sovereign risk is caused by lack of solid macroeconomic infrastructure, vulnerability against external shocks, absence of credible policy makers as well as sound and transparent financial institutions, fragility of the national currency, among other things, that are inherent in emerging economies.

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The real business cycle framework developed and analyzed here is based on the dynamic, stochastic, general equilibrium (DSGE, henceforth) model by Cakici (2012), modified in such a way as to incorporate a government so that sovereign risk and associated risk premium can be investigated.[7] Financial frictions in the model are in the form of restrictions on the composition of deposits held by the domestic financial intermediaries in the economy.[8] More specifically, financial intermediaries are assumed to be able to hold no more than a certain fraction of their total deposits as foreign deposits. Informational asymmetries among the agents in the economy and uncertainty in the production process necessitate financial intermediation and require special attention to the design of the loan contracts between the financial intermediaries and the firms in the model. Sovereign risk exists in the economy due to a government that borrows domestically with a partial default risk. The corresponding risk premium that the government is subject to is captured and analyzed both endogenously, through linking the probability of default to the amount of the government debt, and exogenously, with a risk premium shock.

Risk premium is, by definition, an issue of relevance for emerging economies that are exposed to risks of default on debt due to their lack of adequately developed financial and macroeconomic infrastructure, inherent vulnerabilities and fragilities in the economy as well as confidence problems with respect to policy makers. Therefore, the implications of risk premium shocks for aggregate fluctuations are of special importance for emerging economies that are also facing financial frictions. These two crucial aspects of emerging markets; namely, exposure to default risk and financial frictions, are combined in this study in a DSGE framework with financial intermediation.[9] Abstraction from monetary influence in the framework makes it possible to concentrate on the real implications of risk premium shocks for business cycles.[10]

The default risk has been modeled either exogenously and endogenously in the literature. Mendoza and Yue (2008) explain output dynamics around defaults, countercyclical spreads, high debt ratios and key business cycle moments in a model with simultaneous default on public and private foreign obligations. They attempt to propose a model that reconciles the business cycle models treating default risk exogenously and the sovereign default models treating output fluctuations exogenously. They develop a model of strategic sovereign default with endogenous output dynamics and examine its quantitative predictions.[11] Bi and Leeper (2010) criticize the strategic default literature due to its inability to match the data. More precisely, they argue that the default frequency is predicted by this literature to be far too high and the level of debt at which default occurs far too low. They propose a dynamic stochastic general equilibrium model, where the perceived riskiness of government debt depends partly on the fiscal environment, to study the tradeoffs between short-run fiscal stimulus and long-run sustainability.

Risk premium on government bonds has been analyzed in the literature in terms of its determinants as well as consequences in emerging economies. More specifically, Christensen et al. (2021) examine the role of foreign participation in local sovereign bond market for Mexico and show that recent rises in foreign holdings of sovereign debt have significantly increased its liquidity premium. In another study, Ceballos et al. (2016) employ a dynamic term structure model to estimate the term premium on government debt in Chile for the 2003–2014 period and compute the term premium using alternatives of risk factors that may affect the risk premium including different measures of local inflation and economic growth and controlling for international factors. Pouzo and Presno (2016) analyze the impact of uncertainty on sovereign bond spreads taking into account the perception of international investors about the state of the borrowing economy. To be more precise, the authors develop a general equilibrium model of sovereign debt that captures international investors' concerns about model misspecification regarding the underlying state of the borrowing economy. Investors demand higher returns on their bond holdings to compensate for the default risk in the presence of uncertainty. The authors match the bond spreads dynamics observed in the data as well as other business cycle features for Argentina.

The DSGE model developed and examined here involves Holmstrom and Tirole (1997) type of uncertainty in the production process, financial frictions restricting the amount of foreign borrowing and informational asymmetries among the agents in the economy. Entrepreneurs that run the firms can choose between two different projects for production, both of which are subject to idiosyncratic risk. The projects yield positive output in the case of success and no output in the case of failure. The projects differ with respect to their probabilities of success and the private benefits they provide to the entrepreneurs. It is those private benefits that create incentives for the managers of the firms to engage in activities against the interest of their creditors. The project choices of the entrepreneurs are private information, whereas the project outcomes are verifiable by the financial intermediaries. Households and foreign investors are assumed to lack the ability to verify the project outcomes; therefore, they prefer to lend to firms indirectly, through financial intermediaries, rather than directly.

The Holmstrom–Tirole type of uncertainty in the production process requires special attention to the design of the loan contracts between the firms and the financial intermediaries. To be more precise, there is collateralized borrowing in the economy, where firms use their capital stock as collateral while borrowing from financial intermediaries due to the idiosyncratic risk involved in the production process. The loan contracts specify the rate of interest on loans that is going to be valid in the case of success of the

[7] For a comprehensive analysis of real business cycles in general, see King and Rebelo (1999) and McCandless (2008). Kehoe et al. (2018) discuss the evolution of modern business cycle theory that focuses on the study of DSGE models.

[8] The business cycle implications of financial frictions have long been a topic of interest in the literature. See, among others, Cakici (2011), Fuerst (1995), Gertler (1995) and Von Hagen and Zhang (2008).

[9] See Von Heideken (2009) for an analysis of the implications of financial frictions for business cycles in the US and the Euro Area.

[10] Ali and Anwar (2022), Amano and Shukayev (2012) and Garcia and Gonzalez (2013) analyze the implications of risk premium shocks for monetary policy tools.

[11] The strategic default literature has grown out of the papers by Eaton and Gersovitz (1981) and Eaton et al. (1986). This strand of literature models default on external debt as an optimal and strategic decision made by the government. See, among others, Aguiar and Gopinath (2006) for a recent study following this literature.

firms' production processes and the fraction of the capital stock of the firms to be handed over to the financial intermediaries in the case of failure.

As far as models with financial intermediation are concerned, there is a literature following Kiyotaki and Moore (1997) designing the loan contracts between borrowers and lenders with some durable asset, like land, as collateral.[12] In these models, lenders cannot force borrowers to repay debts unless those debts are secured. In such a context, borrowers' assets like land serve both as factors of production and as collateral for new loans. Kiyotaki and Moore employ such a framework in the dynamic equilibrium model they develop in order to analyze the transmission mechanism in the case of temporary shocks. Kiyotaki and Moore show that small, temporary shocks to technology or income distribution can generate large, persistent fluctuations in output and asset prices.[13] Similar in spirit to the Kiyotaki and Moore framework, the model in this study employs the capital stock of the firms as both factor of production and collateral.

The DSGE model developed in this study is simulated in the case of a positive, temporary risk premium shock. It is shown that a positive, temporary risk premium shock leads to an increase in government borrowing and a decrease in government spending due to the rise in the cost of borrowing for the government. The model also predicts a fall in output, labor supply and loans as well as a rise in the default probability of the government. The results confirm the findings of the literature with respect to the expected effects of a positive risk premium shock on a small open economy in a novel framework, where financial and informational frictions as well as sovereign risk as key features of emerging economies are captured and analyzed.

The rest of the paper is structured as follows: Section 2 presents the model and the system of equations obtained as the solution of the model. The simulation of the model and the impulse response functions are given in Section 3. Finally, Section 4 presents the concluding remarks.

2. The model

The model constructed here is based on the real business cycle framework developed by Cakici (2012), which is a small open economy DSGE model incorporating financial and informational frictions as well as uncertainty in the production process. The economy consists of households, firms, financial intermediaries, foreign lenders, a government and a financial regulator. Abstracting from money in the framework helps to concentrate on the real implications of risk premium shocks for the economy. All decisions are made after, and therefore completely reflect, the current period surprise change in technology. For the timing of the stock variables, like the capital stock, "stock as of the end of the period" convention is used. For instance, K_t denotes the capital stock at the end of period t.[14]

Infinitely lived households, that are assumed to be the owners of the financial intermediaries, maximize their utility functions that depend on consumption, C_t, and hours worked, H_t. They decide on how much to consume, how much labor to supply to the firms, how much to deposit at the financial intermediaries, DD_t, how much to invest on government bonds, GB_t, and how much to invest on foreign bonds, FB_t. At the beginning of each period, households receive their previous period deposits and bond holdings plus the interest payments and make current period deposits and bond holdings decisions. They also supply labor, earn wage income and decide how much consumption to make.

Firms are owned by entrepreneurs, who have a finite but stochastic lifetime. Every period, a certain mass of entrepreneurs receives a signal of death and leaves the economy, whereas new entrepreneurs of equal mass enter the economy next period. In the aggregate, the share of entrepreneurs in the society is constant. Entrepreneurs maximize profits, F_t, by choosing next period's capital stock, K_t, labor demand, N_t, and loans, L_t, they borrow from financial intermediaries. At the beginning of every period, the existing entrepreneurs in the economy pay back the loans they borrowed in the previous period from the financial intermediaries including the interest and borrow new loans for the current period. Entrepreneurs then use these loans to hire labor for production. The new entrants, on the other hand, are assumed to bring along some initial wealth with which they can buy the capital stock they need for production from the financial intermediaries. There is Holmstrom–Tirole type of uncertainty in the production process. Entrepreneurs have two available project choices to produce the single consumption good,[15] both of which are subject to idiosyncratic risk; namely, they yield positive return in the case of success and zero return in the case of failure. The projects differ according to their probabilities of success, with p^H in the case of project "good" and p^L in the case of project "bad". It is the private benefits, PB, that project "bad" yields that create incentives for firm managers to act against the interest of their creditors. Project "good" yields no private benefits. It is assumed that the project outcomes can be perfectly verified by the financial intermediaries while the project choices of the entrepreneurs are unobservable.

Foreign lenders are assumed to supply funds, FD_t, infinitely elastically at a constant interest rate, R^*, that is lower than the domestic loan rate.

Financial intermediaries (FI, henceforth) maximize the expected infinite horizon discounted stream of dividends, B_t, they pay to households. They receive deposits from households, DD_t, and deposits from foreign investors, FD_t. The FI then use these funds to give loans to firms. According to the loan contract between the FI and the firms, the FI gain a net return of $R_{F_t} - 1$ in the case

12 For more information on models with financial intermediation, see Freixas and Rochet (1997).

13 For a detailed analysis on the propagation of aggregate fluctuations, see Bernanke et al. (1996). For output dynamics and propagation mechanisms in real business cycle models, see Cogley and Nason (1995).

14 For the modeling approach used in this study, see Fernandez-Villaverde et al. (2016). In addition, Christiano et al. (2018) provide a recent discussion of the DSGE modeling after reviewing the state of mainstream DSGE models before the Great Recession and describing how DSGE models are estimated and evaluated.

15 The consumption good and the capital good are assumed to be identical for analytical purposes.

of success of the firms' projects and a certain fraction, μ, of the capital stock of the firms in the case of failure. The FI are allowed to hold no more than a certain fraction of their total deposits as foreign deposits. In other words, there is an upper limit on the fraction of total deposits to be held as foreign deposits by the FI. At the beginning of each period, financial intermediaries receive the loans they lent to firms in the previous period inclusive of the interest payments, sell the capital stock they have acquired from firms whose projects failed, and pay back the domestic and foreign deposits they collected in the previous period together with the interest. Additionally, they accept current period deposits from households and foreign lenders and give current period loans to firms.

Finally, the government finances unproductive government purchases, G_t, through collecting taxes and issuing one-period government bonds, GB_t. The government raises tax revenue through an income tax, τ_t, imposed on households. The government debt is subject to partial default risk. More specifically, only with probability p_t^R, the government is able to repay its debt totally and with probability $1 - p_t^R$, it can pay only a certain fraction of its debt, determined by the parameter χ, back to the households. In order to compensate the households for the default risk of the government bonds, the government has to offer some risk premium in addition to the world interest rate prevailing for the foreign bond holdings. The risk premium is determined partly by the exogenous risk premium shock and partly by the default probability of the government, which in turn depends on the amount of the government debt.

2.1. Households

A typical infinitely lived household maximizes an expected utility function of the form

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t [(1-\phi) lnC_t + \phi ln(1-H_t)] \right\}, 0 < \beta, \phi < 1 \tag{1}$$

where β is the discount factor, subject to the budget constraint

$$C_t = (1-\tau_t) W_t H_t + DD_{t-1} R_{H,t-1} - DD_t - GB_t + Z_t - FB_t + FB_{t-1} R^* + B_t \tag{2}$$

where $Z_t = [p_t^R GB_{t-1} R_{t-1}^{GB} + (1-p_t^R)\chi GB_{t-1} R_{t-1}^{GB}]$. GB_t and FB_t denote government bond holdings and foreign bond holdings of households, respectively.

W_t represents the real wage rate and C_t denotes the purchase of the single consumption good that serves as the numeraire. DD_t and B_t represent domestic deposits and dividends from the FI, respectively. The households' problem is also subject to the following nonnegativity constraint:

$$0 \leq DD_t \tag{3}$$

2.2. Firms

There is a certain mass of entrepreneurs in the population that runs the firms in the economy. Each period, π percent of them dies and an equal mass of new entrants are added to the population such that the size of the population remains the same.[16] At the micro level, this means that, with probability π, each entrepreneur receives a signal every period that he will die at the end of the period. Entrepreneurs receiving this signal consume everything that is left of their wealth at the end of the period after paying back their debts.[17] The new entrants bring along some initial wealth with which they can obtain the capital stock they need to start production. They buy this capital stock from the financial intermediaries, which receive capital stock as repayment of loans in the case of failure of the firms' projects. Entrepreneurs, therefore, maximize profits taking into account this probability of death. There is uncertainty involved in the production process of the firm, resulting from the fact that the entrepreneur has two available projects to produce goods, both of which are subject to idiosyncratic risk. More specifically, the entrepreneur has two project choices that differ according to their probabilities of success and the private benefits they provide to the entrepreneur, and there is positive output in the case of success of the projects while there is no output in the case of failure. p^H and p^L denote the probabilities of success of the "good" and the "bad" project, respectively, where $0 < p^L < p^H < 1$. The entrepreneur gets PB amount of private benefits per capital stock if he chooses the project "bad" whereas there is no private benefit obtained from the project "good". The entrepreneur's payoffs from the projects can be summarized as follows:

In the case of "good project":

$$p^H [Y_t - R_{Ft} L_t] + (1-p^H)[0 - \mu(1-\delta) K_{t-1}]$$

[16] This assumption is needed in order to be able to prevent the entrepreneurs from accumulating too much profits that would invalidate the borrowing constraint of the firms. In the literature, part of profits accumulated by the firms is, alternatively, distributed to the households, that are assumed to own the firms, as dividends (see, among others, Feldstein and Green (1983)). However, in the current context, there are informational asymmetries in the sense that households are not able to observe firms' profits. Therefore, the assumption that firms are owned by households and that they distribute part of their profits to households as dividends is not reasonable here.

[17] The fact that entrepreneurs receiving the signal of death have to pay back their debt at the end of the period before they leave the economy is also stated in the loan contract between the firms and the financial intermediaries since there is no other mechanism in the model that protects the financial intermediaries against the probability of death of the entrepreneurs.

In the case of "bad project":

$$p^L[Y_t - R_{Ft}L_t] + (1-p^L)[0 - \mu(1-\delta)K_{t-1}] + PBK_t$$

where L_t represents loans that firms borrow from financial intermediaries at a gross interest rate of R_{Ft}. μ is the parameter measuring the fraction of the capital stock of firms to be handed over to financial intermediaries in the case of failure of the projects. This is going to be mentioned in more detail below.

The production function of the firm is given by

$$Y_t = K_{t-1}^{\alpha}(A_t N_t)^{1-\alpha} \tag{4}$$

with A_t denoting technology, the shock process of which is a unit root with drift in the log of technology, given as

$$lnA_t = \gamma + lnA_{t-1} + \epsilon_{A,t}, \qquad \epsilon_{A,t} \sim N(0, \sigma_A^2) \tag{5}$$

The capital accumulation and the profit functions of the firm can first be written from a micro perspective such that the capital stock accumulated and the profits made are captured separately for the cases of success and failure of the projects, which might then be used to obtain the capital accumulation equation and the profits made by the firms at the macro level. Let F_t^s and K_t^s (F_t^f and K_t^f) denote the profit and the capital stock, respectively, accumulated by a single entrepreneur in the case of success (failure) of the projects. Then, the profit and the capital stock are given as

$$F_t = F_t^s p^H + F_t^f(1-p^H) \tag{6}$$

and

$$K_t = K_t^s p^H(1-\pi) + K_t^f(1-p^H) \tag{7}$$

The profits made in the case of success of the projects, which are invested, and therefore transferred to the next period, by the entrepreneurs, are given by the following equation:

$$F_t^s = Y_t - \pi R_{Ft}L_t - (1-\pi)R_{F,t-1}L_{t-1} \tag{8}$$

The corresponding capital stock in the case of success of the projects is, therefore, given as

$$K_t^s = F_t^s + (1-\delta)K_{t-1} \tag{9}$$

In the case of failure of the firms' projects, there is no output produced; therefore, profits are

$$F_t^f = -\mu(1-\delta)K_{t-1} \tag{10}$$

whereas the capital stock is given as

$$K_t^f = F_t^f + (1-\delta)K_{t-1} = (1-\mu)(1-\delta)K_{t-1} \tag{11}$$

Plugging Eqs. (9) and (11) into Eq. (7), the capital accumulation equation at the macro level is obtained:

$$K_t = p^H[\pi\mu(1-\delta)K_{t-1} + (1-\pi)(I_t + (1-\delta)K_{t-1})] + (1-p^H)(1-\mu)(1-\delta)K_{t-1}, \qquad 0 < \delta < 1 \tag{12}$$

K_t represents the level of physical capital to be employed in the production process at time t+1, determined by the firm at time t. Eq. (12) is the capital accumulation equation at the macro level in the sense that π represents here the mass, out of a group of entrepreneurs, that dies each period, rather than the probability of death of a single entrepreneur, as in the micro sense. Therefore, the first term in the parenthesis on the right-hand side of the equation, $\pi\mu(1-\delta)K_{t-1}$, stands for the capital stock held by the new entrants at the beginning of every period (recall the assumption that an equal mass, π, of new entrepreneurs enter the economy each period so that the total size of the population remains unchanged). The second term represents the amount of capital stock accumulated by the successful entrepreneurs continuing to live and produce; the net-of-depreciation amount of capital stock of the current period, $(1-\delta)K_{t-1}$, plus the amount of investment, I_t. Investment is equal to the real profits made by the successful entrepreneurs in the economy. The last term on the right-hand side of the equation gives the amount of the capital stock of the unsuccessful entrepreneurs that cannot make positive real profits due to the fact that there is no output in the case of failure of the firms' projects.

The profits, F_t, maximized by the entrepreneurs every period are given as

$$F_t \le p^H Y_t - p^H \pi R_{Ft}L_t - p^H(1-\pi)R_{F,t-1}L_{t-1} - (1-p^H)\mu(1-\delta)K_{t-1} \tag{13}$$

where δ is the constant physical depreciation rate of capital. Given that the firm chooses the project "good" (which will be the case as long as the incentive constraint stated below holds), with probability p^H the firm is able to make use of the loans it borrows from the FI to hire N_t amount of labor, which it can employ together with the capital stock it has, K_{t-1}, to produce Y_t amount of output. The entrepreneur makes in this case an interest payment to the FI for the loans at the rate specified in the loan contract, R_{Ft}. In the case of failure, there is no output produced and the entrepreneur has to transfer a certain amount of its capital stock, which it used as collateral in order to be able to borrow from the FI, to the FI. Due to the fact that capital stock is employed in the production process and therefore subject to depreciation independent of the project outcome of the firm, it is the net-of-depreciation amount of capital stock, the fraction of which is to be handed over to the FI in the case of failure. The period t loans of the firm, L_t, and the period t wage payments, $W_t N_t$, cancel out above.

Entrepreneurs' maximization problem is subject to the constraint reflecting the fact that the firm finances its wage payments with the loans it borrows from the FI. Hence, it obeys

$$W_t N_t \leq L_t \tag{14}$$

There is also an incentive constraint for the entrepreneur to choose the project "good":

$$Y_t - R_{Ft} L_t \geq \frac{PBK_t}{(p^H - p^L)} \tag{15}$$

As long as this constraint holds, the entrepreneur maximizes profits given in Eq. (13) that is written for the case of project "good". The incentive constraint also gives the borrowing constraint of the firm

$$R_{Ft} L_t \leq Y_t - \frac{PBK_t}{(p^H - p^L)} \tag{16}$$

from which the loan demand, L_t^d, is obtained:

$$L_t^d = \frac{Y_t - \frac{PBK_t}{(p^H - p^L)}}{R_{Ft}} \tag{17}$$

The loan supply, on the other hand, is determined according to the outside options of the financial intermediaries. More specifically, the financial intermediaries continue to supply loans to the firms as long as their return on the loans is greater than that on the alternative options available in the economy. Under the assumption that financial intermediaries can lend to and borrow from one another as well, this implies that their return on loans must be greater than the return from depositing at another financial intermediary; that is,

$$p^H R_{Ft} + (1 - p^H) \frac{\mu(1-\delta)K_{t-1}}{L_t} \geq R_{Ht} \tag{18}$$

which constitutes the loan supply, L_t^s, equation. The loan market equilibrium condition is obtained through equating the loan supply and the loan demand equations.

2.3. Financial intermediaries

The FI maximize the expected infinite horizon discounted stream of dividends they pay to households. They receive deposits from households, DD_t, and deposits from foreign investors, FD_t. FI then use these funds to give loans to firms. According to the loan contract between the FI and the firms, FI gain a net return of $R_{Ft} - 1$ in the case of success of the firms' projects and a certain fraction, μ, of the capital stock of the firms in the case of failure. They are allowed to hold no more than a certain fraction of their total deposits as foreign deposits. In other words, there is an upper limit on the fraction of foreign deposits over total deposits to be held by the FI, which represents the degree of financial openness in the economy.

The objective of the representative financial intermediary is to maximize the expected infinite horizon discounted stream of dividends it pays to households:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^{t+1} \frac{B_t}{C_{t+1}} \right\} \tag{19}$$

subject to first the budget constraint

$$B_t \leq [p^H \pi R_{Ft} L_t + p^H (1-\pi) R_{F,t-1} L_{t-1} + (1-p^H)\mu(1-\delta)K_{t-1}] - R_{H,t-1} DD_{t-1} - R^* FD_{t-1} \tag{20}$$

where $FD_t \geq 0$ is the foreign deposits collected by the FI. The net present value of future dividends is discounted by the marginal utility of consumption due to the fact that the FI are owned by households and that an extra unit of dividend is valued by households to the extent that it enables future consumption. Current period deposit holdings and loans cancel out in the budget constraint.

The second constraint the FI faces, namely the balance sheet constraint, requires that the liabilities of the FI are less than or equal to its assets, with deposits as the liabilities and loans as the assets

$$D_t \leq L_t \tag{21}$$

where $D_t = DD_t + FD_t$ and $FD_t = \psi D_t$, $DD_t = (1-\psi) D_t$.

ψ represents the financial openness parameter assumed to be controlled by the financial regulator and varies between 0 and 1. Higher levels of ψ imply higher degrees of financial openness.

2.4. Government

The government in the economy finances unproductive government purchases denominated in the consumption good, G_t, through raising tax revenues and issuing one-period government bonds, GB_t. Tax revenues are obtained by a flat rate tax, τ_t, on labor income. Government debt is subject to a partial default risk, with an endogenous default probability $1 - p_t^R$. To be more precise, probabilistically, the government might not be able to repay its debt completely. The government budget constraint is then given as

$$\tau_t W_t N_t + GB_t = [p_t^R GB_{t-1} R_{t-1}^{GB} + (1 - p_t^R)\chi GB_{t-1} R_{t-1}^{GB}] + G_t \tag{22}$$

where p_t^R is the probability with which the government will be able to repay its debt totally and χ denotes the percentage of the government debt to be repaid in the case of default. R_t^{GB} represents the gross nominal interest rate on government bonds, which is determined by the following equation:

$$R_t^{GB} = R^* + RP_t \tag{23}$$

RP_t stands for the "risk premium" that the government has to pay in addition to the world interest rate, R*, in order to compensate the households, that also have the option of holding foreign bonds, for the risk of default on the government debt. Risk premium is determined partly by the probability of default by the government, $1 - p_t^R$, and partly by a shock to the risk premium:

$$RP_t = \frac{(1 - p_t^R)}{p_t^R} + \epsilon_{RP,t}, \qquad \epsilon_{RP,t} \sim N(0, \sigma_{RP}^2) \tag{24}$$

where $\epsilon_{RP,t}$ denotes the risk premium shock. The probability of default, $1-p_t^R$, is a function of the amount of the government debt[18]:

$$(1 - p_t^R) = \frac{e^{GB_t} - 1}{e^{GB_t} - 1/2} \tag{25}$$

2.5. System of equations

In a stochastic setting, the solution of the model is not a series of numbers that match a given set of equations, as in a deterministic setting. In a stochastic environment, the best thing agents can do is to specify a decision, policy or feedback rule for the future, in other words, their optimal actions contingent on each possible realization of shocks. Therefore, it is a function satisfying the model's equilibrium conditions that is being searched. The system of equations consists of the first-order conditions of the agents' optimization problems and the market-clearing conditions of the goods, labor and credit markets.[19]

The first-order conditions of the household's optimization problem are:

$$\frac{(1 - \phi)}{C_t} = \frac{\phi}{W_t(1 - H_t)} \tag{26}$$

from the maximization of the household's utility function with respect to consumption,

$$\frac{\beta R_{Ht}}{W_{t+1}(1 - H_{t+1})} = \frac{1}{W_t(1 - H_t)} \tag{27}$$

from the maximization with respect to deposits and

$$\frac{1}{W_t(1 - H_t)} = \frac{\beta[R_t^{GB}(p_t^R - \frac{2e^{GB_t}GB_t}{(e^{GB_t}-1/2)^2}) + \chi R_t^{GB}(1 - p_t^R + \frac{2e^{GB_t}GB_t}{(e^{GB_t}-1/2)^2})]}{W_{t+1}(1 - H_{t+1})} \tag{28}$$

from the maximization with respect to government bonds.

Combining (26) and (27) gives

$$\frac{1}{C_t} = \frac{\beta R_{Ht}}{C_{t+1}} \tag{29}$$

From the firm's optimization problem, there is the binding borrowing constraint

$$R_{Ft} L_t(p^H - p^L) = Y_t(p^H - p^L) - PBK_t \tag{30}$$

and the equilibrium condition that the marginal product of labor equals the real wage

$$K_{t-1}^{\alpha}(1 - \alpha)(A_t N_t)^{-\alpha} A_t = W_t \tag{31}$$

[18] Alternative ways have been proposed in the literature to endogenize default rates. Uribe (2006), for instance, suggests a framework where future default rates are predicted by current and past fiscal deficits.

[19] For further inquiry on macroeconomic modeling, see Romer (2018).

that are among the equations constituting the solution of the model.

Finally, the maximization problem of the FI yields

$$\frac{p^H \pi R_{Ft} C_{t+2}}{(1-\psi)} = C_{t+1}\beta[R_{Ht} + \frac{\psi}{(1-\psi)}R^* - \frac{p^H(1-\pi)R_{Ft}}{(1-\psi)}] \tag{32}$$

All markets clear at the equilibrium. The following equations represent equilibrium in the goods, labor and credit markets, respectively:

$$C_t + I_t + G_t + NX_t = Y_t \tag{33}$$

$$N_t = H_t \tag{34}$$

$$DD_t + FD_t = L_t \tag{35}$$

NX_t denotes net exports, the return on which is used for the net interest payment on foreign borrowing minus the change in the amount of foreign borrowing in a given period. Therefore,

$$NX_t = \frac{\psi}{1-\psi}[(R^*-1)DD_{t-1} - DD_t + DD_{t-1}] \tag{36}$$

Combining (14) and (26) with (34) gives

$$(\frac{\phi}{1-\phi})\frac{C_t}{1-N_t} = \frac{L_t}{N_t} \tag{37}$$

which constitutes another equation of the system.

The model, however, needs to be made stationary first so that it can be linearized around the steady-state and that it returns to the steady-state after a shock.[20] The problem of non-stationarity arises because of having stochastic trend in technology. In the absence of shocks, real variables grow with A_t (except N_t which is stationary since there is no population growth). Detrending is carried out as follows (where hats above variables denote stationarity and $a_t = A_t/A_{t-1}$):

$\hat{q}_t = q_t/A_t$ where $q_t = [Y_t, C_t, I_t, NX_t, K_t, L_t, W_t, DD_t, GB_t, G_t]$.

The stationary system of equations is as follows:

$$(1-\phi)(1-N_t)W_t = \phi C_t \tag{38}$$

$$\beta R_{Ht} C_t = C_{t+1} a_{t+1} \tag{39}$$

$$\frac{1}{W_t(1-H_t)} = \frac{\beta[R_t^{GB}(p_t^R - \frac{2e^{GB_t}GB_t}{(e^{GB_t}-1/2)^2}) + \chi R_t^{GB}(1-p_t^R + \frac{2e^{GB_t}GB_t}{(e^{GB_t}-1/2)^2})]}{W_{t+1}(1-H_{t+1})a_{t+1}} \tag{40}$$

$$R_{Ft} L_t (p^H - p^L) = Y_t(p^H - p^L) - PBK_t \tag{41}$$

$$K_{t-1}^{\alpha}(1-\alpha)a_t^{-\alpha}N_t^{-\alpha} = W_t \tag{42}$$

$$p^H \pi R_{Ft} C_{t+2} a_{t+2} = C_{t+1}\beta[(1-\psi)R_{Ht} + \psi R^* - p^H(1-\pi)R_{Ft}] \tag{43}$$

$$C_t + I_t + G_t + NX_t = Y_t \tag{44}$$

$$W_t N_t = L_t \tag{45}$$

$$Y_t = K_{t-1}^{\alpha} a_t^{-\alpha} N_t^{1-\alpha} \tag{46}$$

$$K_t a_t = p^H[\pi\mu(1-\delta)K_{t-1} + (1-\pi)(I_t a_t + (1-\delta)K_{t-1})] + (1-p^H)(1-\mu)(1-\delta)K_{t-1} \tag{47}$$

$$NX_t a_t = \frac{\psi}{1-\psi}[R^* DD_{t-1} - DD_t a_t] \tag{48}$$

$$DD_t = (1-\psi)L_t \tag{49}$$

[20] In the case of linearization up to the first order, agents behave as if future shocks were equal to zero (since their expectation is null), due to certainty equivalence. In the linearization up to second order, agents make their decisions knowing that the future value of innovations are random but will have zero mean. This is not the same thing because of Jensen's inequality. For more detailed information, see DYNARE User Guide.

$$[\tau_t W_t N_t + GB_t]a_t = [p_t^R GB_{t-1} R_{t-1}^{GB} + (1-p_t^R)\chi GB_{t-1} R_{t-1}^{GB}] + G_t a_t \tag{50}$$

$$R_t^{GB} - R^* = \frac{(1-p_t^R)}{p_t^R} + \epsilon_{RP,t} \tag{51}$$

$$(1-p_t^R) = \frac{e^{GB_t} - 1}{e^{GB_t} - 1/2} \tag{52}$$

Given the Eqs. (38)–(52) and the shock process (24), the expected future paths of the variables $[Y_t, C_t, I_t, NX_t, L_t, N_t, DD_t, K_t, W_t, R_{Ht}, R_{Ft}, GB_t, R_t^{GB}, G_t, p_t^R]$, namely, the impulse response functions, conditional on a positive, temporary risk premium shock in period 1 are obtained next.

3. Results

3.1. Simulation

The procedure of making the model stationary is followed by linearization and simulation.[21] The solution to the system of equations obtained in the previous section is a set of equations relating variables in the current period to the past state of the system and current shocks, that satisfy the original system. These are referred to as "the policy functions". The (approximate) policy functions are obtained by first rewriting the system in terms of past variables, current and future shocks, and then linearizing it around the steady states. The model is linearized up to first order. In the linearization up to first order, future shocks enter the linearized system of equations only with their first moments (which are zero in expectations); therefore, they drop out when taking expectations of the equations. Impulse response functions are then acquired simply through iterating the policy functions starting from some initial values (given by the steady states).[22]

For simulations, the following values are assigned to the structural parameters of the model: α=0.32, β=0.99, ϕ=0.76, δ=0.025, γ=0.003.[23] The parameter representing the degree of financial openness in the economy, ψ, is set to 0.5. The gross interest rate on foreign deposits, R^*, used in the simulations is equal to 1.08. The fraction of the capital stock to be handed over to the financial intermediaries by the firms in the case of failure of the projects, μ, is set to 0.6. The probability of death of the entrepreneurs, π, is taken as 0.7. The probabilities of success of the "good" and the "bad" projects, p^H and p^L, are equal to 0.9 and 0.1, respectively. The parameter representing the private benefits of the entrepreneurs in the case of bad projects, PB, is assigned the value 0.5. The flat tax rate, τ_t, on labor income is equal to 0.9 in the simulation results presented. Finally, the parameter representing the percentage of the government debt to be repaid in the case of default, χ, is set to 0.5. In the next section, the impulse response functions of the variables are presented.

3.2. Impulse response functions

Fig. 1 presents the impulse responses of the key variables in the model in the case of a positive, temporary risk premium shock in period 1. The positive risk premium shock leads directly to an increase in the interest rate on government bonds, which raises the cost of borrowing for the government. As a result, the government has to decrease its spending and increase its borrowing further in order to be able to meet the rise in the cost of borrowing. As government borrowing increases, the probability of default on the government debt also rises. The results confirm the expected effects of a positive risk premium shock on a small open economy in a novel DSGE framework with financial intermediation, where financial and informational frictions as well as sovereign risk as key features of emerging economies are captured and analyzed.

Fig. 2 displays the impulse response functions of the remaining variables in the case of a positive, temporary risk premium shock. The model predicts an immediate fall in output, labor supply, domestic deposits and loans while consumption and investment exhibit an increase in response to the shock. The positive risk premium shock that increases the interest rate on government bonds leads to the fact that households rather invest on government bonds than deposit at the FI, which explains the fall in domestic deposits and the corresponding decrease in loans, labor supply and output. The procyclical behavior of labor supply and the countercyclicality of trade balance are consistent with the findings of the real business cycle literature.[24] The adverse effect of a positive risk premium shock on an economy in the form of contraction in output, a well-established fact in related literature, is confirmed in this study in a real DSGE framework with financial and informational frictions, where sovereign risk premium is captured and analyzed both endogenously and exogenously.

[21] The linearization and the simulation of the model are carried out using DYNARE, which is a pre-processor and a collection of MATLAB routines that has been developed by Adjemian et al. (2022) to support modern macro modeling.

[22] The impulse response functions presented in the next section depict the responses of the variables in terms of deviations from the steady states.

[23] For the parameter values, Dib (2003) and Mendoza (1991) are followed. Dib (2003) employs quarterly Canadian data for the calibration and the estimation in his small-open-economy DSGE model.

[24] See, among others, Mendoza (1991).

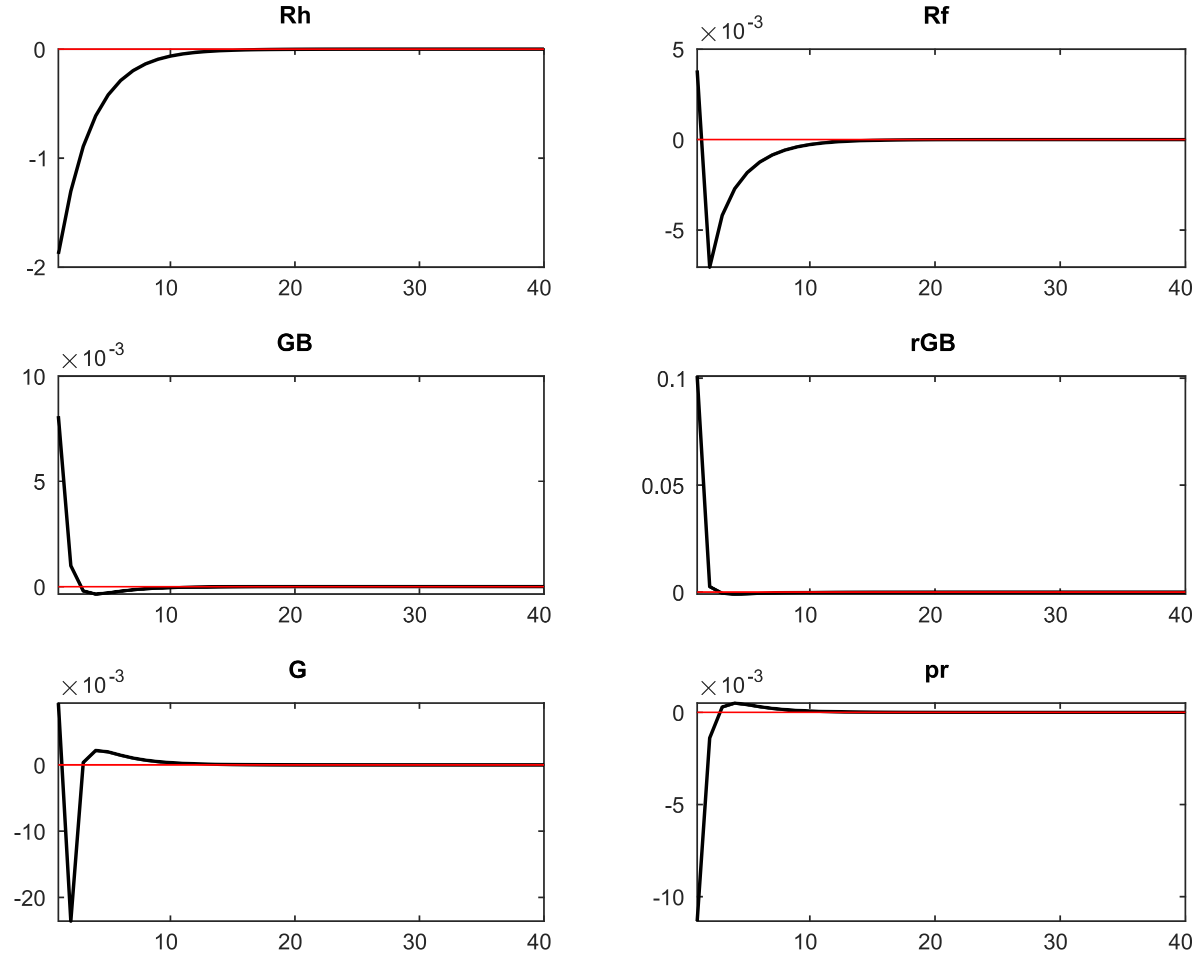

Fig. 1. Positive risk premium shock (1/2).

4. Conclusion

Implications of risk premium shocks for business cycles in a small open economy are analyzed in this study using a real business cycle framework. A DSGE model with financial and informational frictions is developed, where the frictions in the model necessitate financial intermediation and the Holmstrom–Tirole type of uncertainty in the production process requires collateralized borrowing in the economy. Sovereign risk exists in the model due to a government that borrows domestically with a partial default risk. The associated risk premium that the government is subject to is captured both endogenously and exogenously, which constitutes one of the major contributions of this study to the literature. More precisely, risk premium in the model is determined partly by the endogenous link between the probability of default and the amount of the government debt, and partly by the exogenous risk premium shock.

Risk premium is, by definition, an issue related to emerging economies that are exposed to risks of default on debt due to their lack of adequately developed financial and macroeconomic infrastructure, inherent vulnerabilities and fragilities in the economies as well as confidence problems with respect to policy makers. Therefore, the implications of risk premium shocks for aggregate fluctuations are of special importance for emerging economies that are also facing financial frictions. These two crucial aspects of emerging markets; namely, exposure to default risk and financial frictions, are combined in this study in a DSGE framework with financial intermediation. Informational asymmetries among the economic agents and uncertainty in the production process necessitate financial intermediation and collateralized borrowing in the economy. Abstraction from monetary influence in the framework makes it possible to concentrate on the real implications of risk premium shocks for business cycles.

The DSGE model developed in this study is simulated in the case of a positive, temporary risk premium shock. It is shown that a positive, temporary risk premium shock leads to an increase in government borrowing and a decrease in government spending due to the rise in the cost of borrowing for the government. The model also predicts a fall in output, labor supply and loans as well as a rise in the default probability of the government. The results confirm the findings of the literature with respect to the expected effects of a positive risk premium shock on a small open economy in a novel framework, where financial and informational frictions as well as sovereign risk as key features of emerging economies are captured and analyzed.

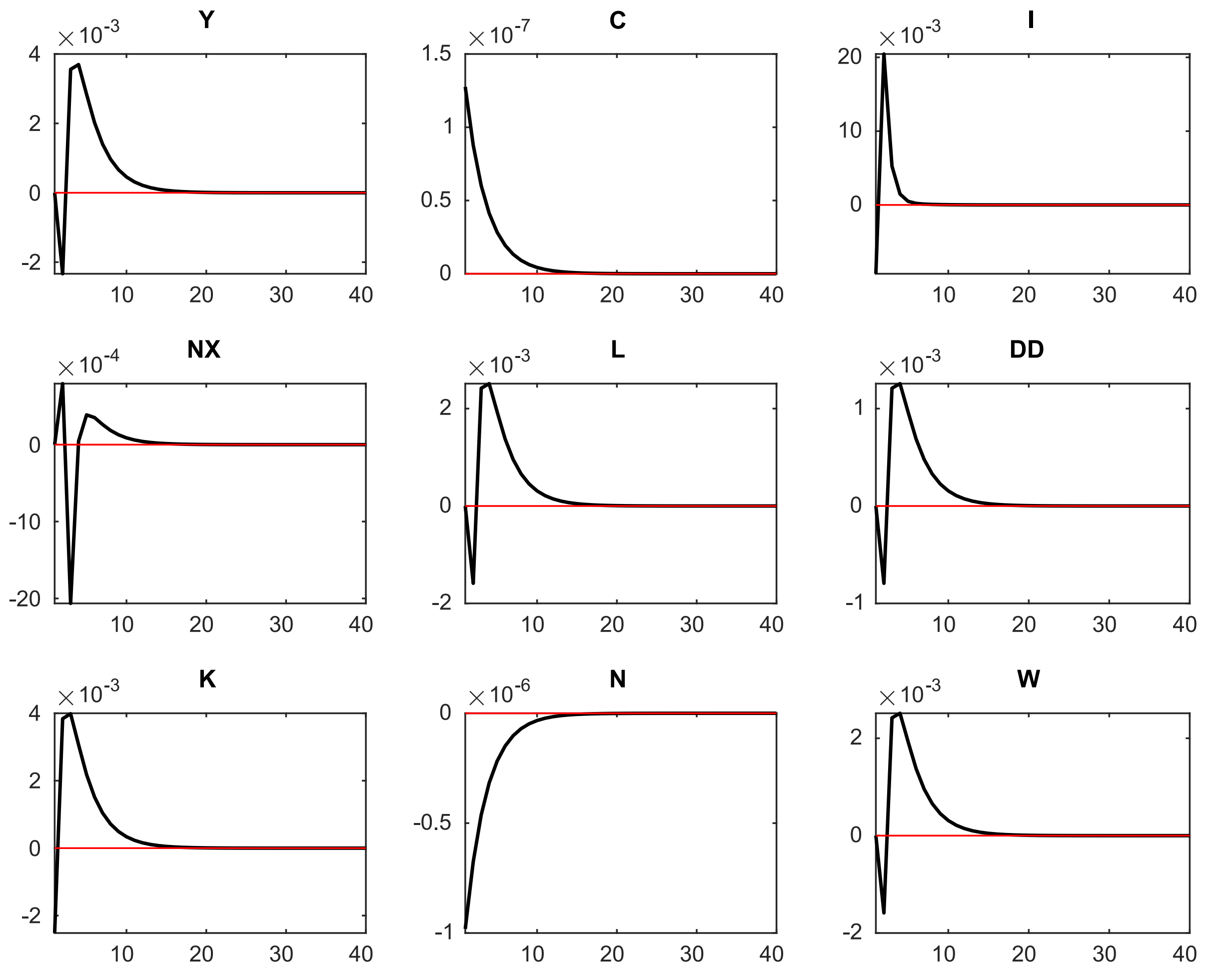

Fig. 2. Positive risk premium shock (2/2).

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