

Prolonged Monetary Easing in the United States and Financial Instability in Emerging Countries^{*}

Kazuhiro Teramoto[†]

1 Introduction

Since late 2008, the Federal Reserve (Fed) has pursued a series of unconventional monetary policies (UMPs) in which forward guidance was used to shape expectations that accommodative monetary policies will continue for years to come. The impact of the recent UMPs on market interest rates is shown in Figure 1, which plots U.S. Treasury constant maturity rates. The figure indicates that both short-term and long-term interest rates declined sharply in 2008-2009 and that long-term interest rates were pushed down further after additional bouts of quantitative easing (QE), QE2 in November 2010 and QE3 in September 2012.

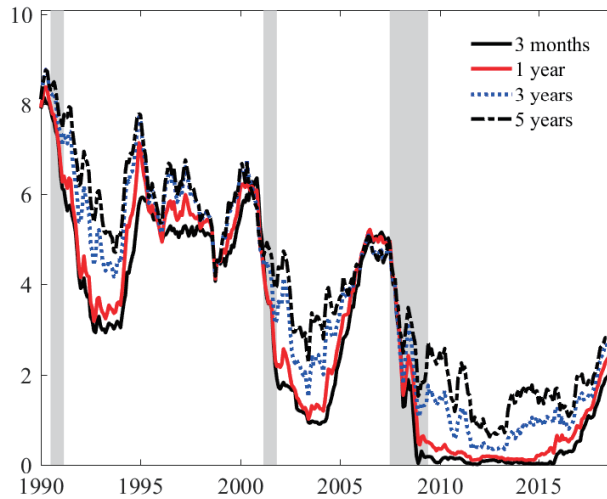
Although the decline in long-term interest rates suggests that these policies were successful in shaping expectations, one of the issues that has gained growing attention is concerns that prolonged periods of low interest rates may give rise to excessive risk-taking and financial instability — ‘risk-taking channel’ of monetary policy.¹⁾ As well as the influence on risk-taking behavior of domestic financial institutions, as highlighted by Rajan (2014), Bruno and Shin (2015a) and Olaberría (2015), there is growing concern that the UMPs in the United States have fueled capital inflows into emerging market economies (EMEs) and increased financial fragility associated with abrupt reversals of foreign capital flows.²⁾ Figure 2 plots net portfolio investment flows into six large emerging countries (Brazil, India, Indonesia, Turkey, South Africa, and Mexico) and the 3-month U.S. dollar London Interbank Offered Rate. The figure clearly shows that capital flows into EMEs increased after the UMPs were commenced.

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[†] Graduate School of Economics, Hitotsubashi University. Email: k.teramoto@r.hit-u.ac.jp

- 1) This term was first coined by Borio and Zhu (2012). See for example Maddaloni and Peydró (2011), Angeloni, Faia, and Duca (2015), and Dell’Ariccia, Laeven, and Suarez (2017) for the empirical evidence on risk-taking channel of monetary policy using the U.S. data. Jeremy Stein also pointed out this channel in his speech on February 7, 2013 (Stein, 2013).
- 2) A recent empirical research by Cecchetti, Griffoli, and Narita (2017) uses firm-level data for bank and nonbank financial institutions to study the impact of prolonged monetary policy easing in the United States on risk-taking behavior of domestic financial institutions and vulnerabilities of financial systems in other countries. They find that prolonged easing in the U.S. monetary policy increases the vulnerability of financial firms abroad as much as domestic easing.

Figure 1: The U.S. Treasury constant maturity rate



Note: The figure shows the U.S. Treasury constant maturity rate for 3 months (solid black), 1 year (solid red), 3 years (dotted blue), and 5 years (broken black). The shaded areas correspond NBER recessions.
 Source: Board of Governors of the Federal Reserve System (<https://www.federalreserve.gov/data.htm>).

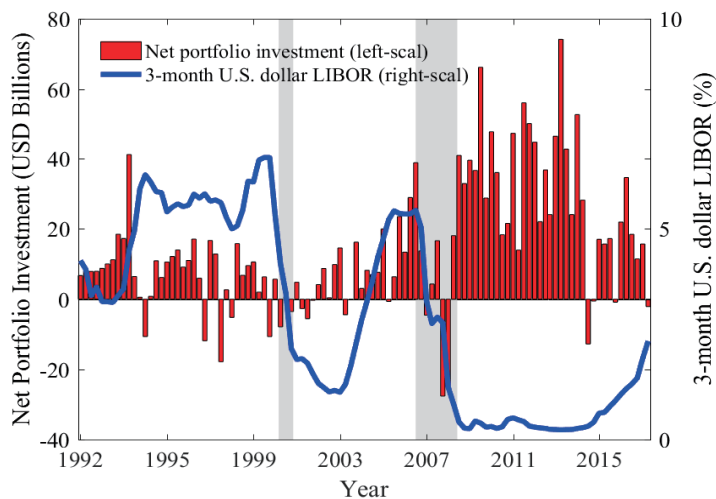
This study first examines how much the prolonged low interest rates in the United States increase financial instability in EMEs. To this end, two different U.S. monetary policy regimes, a conventional and an unconventional regime, are incorporated into a small open economy dynamic stochastic general equilibrium (SOE-DSGE) model with world interest rate shocks. For the analysis, the world interest rate is assumed to follow the U.S. short-term interest rate. The U.S. short-term interest rate is approximated by a two-state Markov process whose transition probabilities differ depending on the monetary policy regime. In the conventional regime, the short-term interest rate is tightened and eased frequently, while, in the unconventional regime, the U.S. central bank commits itself to maintaining a low interest rate when it lowers the current interest rate.

The model I present in this study is a variant of the two-sector SOE-DSGE model proposed by Mendoza (2002). That is, its fundamental structure is similar to Mendoza's model in that households face an international credit constraint, where a fraction of the value of current income is pledged as collateral and that an occasionally binding credit constraint induces emerging market crises. However, the current model differs from Mendoza's in that it considers a production economy and takes working capital constraints into account by assuming that the international credit constraint limits not only the borrowing capacity of households but also the capacity of firms to obtain loans for working capital to finance wage bills. Such working capital constraints increase the impact of world interest rate shocks on EMEs because a rise in world interest rate increases the financial burden associated with working capital loans, tightens the borrowing capacity³⁾ of households and reduces the aggregate demand.

Following the quantitative studies by Bianchi (2011) and Mendoza (2010), this study conducts stochastic simulations. Comparing the outcomes of stochastic simulations with the two different policy regimes makes it

3) See Uribe and Yue (2006) and Mendoza (2010) for the econometric and quantitative evidence on the role of world interest shocks through working capital constraints in the business cycle fluctuation in EMEs.

Figure 2: Net portfolio investment in the Fragile Five plus Mexico and the U.S. interest rate



Note: The vertical axis on the left shows net capital inflows resulting from transactions in equity securities and debt securities into the Fragile Five (Brazil, India, Indonesia, Turkey, and South Africa) plus Mexico measured in billions of U.S. dollars. A positive value indicates capital inflows into these countries. The solid line shows the 3-month U.S. dollar London Interbank Offered Rate (right axis). The shaded areas correspond NBER recessions.

Sources: IMF Balance of Payments Database (<http://data.imf.org/?sk=7A51304B-6426-40C0-83DD-CA473CA1FD52>); and ICE Benchmark Administration Limited (IBA), 3-Month London Interbank Offered Rate (LIBOR), based on U.S. Dollar, retrieved from FRED, Federal Reserve Bank of St. Louis (<https://fred.stlouisfed.org/series/USD3MTD156N>).

possible to examine how and to what extent persistently low interest rates in the United States influence debt accumulation in EMEs and the incidence of sudden capital reversals from EMEs. Moreover, in order to analyze the spillover effects of forward guidance, the role of expectations of a continuation of the low interest rate in the financial stability of EMEs is examined. For that purpose, this study conducts a counterfactual experiment by simulating how the absence of expectations of a low world interest rate affects financial stability. More specifically, this experiment is conducted using the decision rule in the conventional regime and shocks are generated from the Markov process in the unconventional regime. If financial stability substantially improved, this would imply that forward guidance (i.e., expectations of a persistently low interest rate) plays a more important role in increasing financial instability in EMEs than the realization of a persistently low interest rate.

This study also examines the impact of UMPs in the United States on the efficiency of risk-taking in EMEs. As in many other models of emerging market crises (e.g., Bianchi, 2010; Mendoza, 2010; Benigno, Chen, Otko, Rebucci, and Young, 2013; Brunnermeier and Sannikov, 2015), the model presented in this study incorporates a credit constraint à la Kiyotaki and Moore (1997). In the presence of this type of credit constraint, risk-taking can be inefficient because of credit externalities, that is, private agents fail to internalize the effects of their borrowing decisions on their borrowing capacity via the credit market. As noted by Caballero and Krishnamurthy (2003), Lorenzoni (2008), Bianchi (2011), and Dávila and Korinek (2017), such externalities can generate overborrowing.

Specifically, to quantify the impact on the efficiency of risk-taking, this study computes an optimal Pigouvian tax in line with recent theoretical studies on credit externalities (e.g., Jeanne and Korinek, 2010; Bianchi, 2011; Dávila and Korinek, 2017). Since the optimal tax rate mirrors the wedge between the privately and socially optimal

allocations, comparing the tax rates between economies facing different U.S. monetary policy regimes shows the effect of UMPs on the efficiency of risk-taking. Furthermore, this study investigates to what extent the effectiveness of macroprudential policies differs depending on the U.S. monetary policy regime.

Addressing these issues contributes to the debate on whether the large capital inflows into EMEs in recent years are explained by push factors (e.g., accommodative monetary policy in advanced countries) or pull factors (e.g., inefficient risk-taking in EMEs). If push factors play a major role, this suggests that central banks in advanced countries should take into account spillover effects on other countries especially when easing monetary policy. On the other hand, if pull factors play a major role, EMEs should tighten macroprudential policies especially when advanced countries ease their interest rates. By examining to what extent macroprudential policies to correct inefficient risk-taking in EMEs can reduce financial instability, this study contributes to understanding which of the two types of factors — push or pull — play a more important role and helps to provide policy recommendations.

The main findings of this study are as follows. First, in the unconventional regime, debt accumulation and financial instability in EMEs increases considerably. Specifically, when the U.S. interest rate is currently low and an adverse productivity shock hits the small open economy (SOE), the probability of a major financial crisis⁴⁾ is 3.29 times higher in the unconventional regime than in the conventional regime (the probability increases from 2.17 percent to 7.15 percent). Second, expectations of a continuation of a low interest rate play an important role in increasing financial instability: the counterfactual simulation indicates that the probability of a major financial crisis would remain less than 1 percent in the absence of expectations of a continuation of a low interest rate even in the unconventional regime. Third, prolonged monetary easing in the United States magnifies credit externalities and increases inefficiency of risk-taking in EMEs. Fourth, in the unconventional regime, macroprudential policies do not work to reduce financial instability: in the presence of optimal macroprudential taxation, the probability of a financial crisis in response to rising interest rates remains 3.28 percent in the unconventional regime, while it is 0.44 percent in the conventional regime. These results suggest that push factors play a more important role in the recent increased financial fragility in EMEs.

This study is related to the long-standing literature on the spillover effects of U.S. monetary policy on international capital flows. A number of studies have argued that push factors played an important role in the capital flows to EMEs around the time of the emerging market crises in Latin America and Asia in the 1990s as well as the 2007-08 global financial crisis (e.g., Calvo, Leiderman, and Reinhart, 1993, 1996; Fratzscher, 2012). A theoretical study in this field is that by Bianchi, Liu, and Mendoza (2016), who use the canonical DSGE model of emerging market crises and show that good news about future fundamentals in EMEs under high global liquidity (i.e., a low world interest rate) increases financial instability and raises credit externalities. Moreover, a large body of empirical research has shown that changes in U.S. monetary policy have a significant impact on real economic performance in emerging and developing countries through credit markets (e.g., Uribe and Yue, 2006; Rajan, 2006; Bruno and Shin, 2015a,b; Ioannidou, Ongena, and Peydró, 2015; Anaya, Hachula, and Offermanns, 2017; Cecchetti, Griffoli, and Narita, 2017). The present study is distinct from these studies in that it aims to understand the role of expectations of a continuation of high global liquidity in financial instability in EMEs. In addition, it seeks to provide policy

4) A financial crisis is defined as net capital outflows in excess of 4 percent of GDP and a major financial crisis is defined as net capital outflows in excess of 10 percent of GDP.

recommendations to mitigate negative spillovers of UMPs in the United States.

The present study is also closely related to a string of studies that examine the effects of international financial market conditions on the business cycle in EMEs. Caballero and Krishnamurthy (2001) show that the interaction between international and domestic collateral constraints make EMEs more vulnerable to adverse shocks. Mendoza (2010) examines the quantitative implications of linkages between credit market conditions and macroeconomic fluctuations using a full-blown DSGE model with occasionally binding international credit constraints. Another study focusing on occasionally binding credit constraints is that by Aiyagari and Gertler (1999), who analyze sudden and large corrections of asset prices in the presence of margin requirements for stock traders. Gertler, Gilchrist, and Natalucci (2007) explore how different exchange rate regimes influence the propagation of an abrupt tightening in international financial markets, while Brunnermeier and Sannikov (2015) examine the impact of inefficient risk-taking using a two-country model with incomplete international risk-sharing.

The remainder of the paper proceeds as follows. Section 2 presents the SOE-DSGE model and the specification of the U.S. monetary policy regimes. Section 3 finds a constrained efficient allocation of this economy and the optimal macroprudential tax. Section 4 then calibrates the model and presents the results of stochastic simulations. Finally, Section 5 provides concluding remarks.

2 Model

For the analysis, I build a SOE model with two types of goods: tradable and non-tradable goods. Non-tradable goods are all consumed domestically, while tradable goods are available for both domestic consumption and international transactions. The price of tradable goods serves as the numéraire. All domestic agents have access to foreign capital, but the menu available is limited to a one-period, non-state-contingent bond.

Households: There is a continuum of infinitely-lived households consisting of two types of workers: in each household, a certain share $\gamma \in (0, 1)$ of workers produce tradable commodities y_t^T , while the remaining share produce non-tradable goods y_t^N . The labor supply of each sector in each household, $\bar{\ell}_t^T$ and $\bar{\ell}_t^N$, is normalized to 1, i.e., $\bar{\ell}_t^T = \int_0^\gamma \bar{\ell}_t^T(f)df = 1$ and $\bar{\ell}_t^N = \int_{1-\gamma}^1 \bar{\ell}_t^N(f)df = 1$ for all t . All households own firms that have the same linear production technology with regard to labor input:

$$y_t^s = a_t^s \ell_t^s \text{ for } s = T \text{ and } N,$$

where the productivity shock a_t^s for $s = \{T, N\}$ is common across all households.

Preferences are homogeneous across households and consumption is a composite of tradable goods c_t^T and non-tradable goods c_t^N taking the following constant elasticity of substitution form:

$$c(c_t^T, c_t^N) = \left[\omega \left(c_t^T \right)^{-\eta} + (1 - \omega) \left(c_t^N \right)^{-\eta} \right]^{-1/\eta},$$

where $1/(1 + \eta)$ represents the elasticity of substitution between tradable and non-tradable goods and $\omega \in (0, 1)$ stands for the share of tradable goods in the bundle.

Each household chooses consumption and bond holdings $\{c_{t+j}^T, c_{t+j}^N, b_{t+j+1}\}_{j=0}^\infty$ so as to maximize the expected utility,

$$\mathbb{E}_t \left[\sum_{j=0}^{\infty} \beta^j u \left(c(c_{t+j}^T, c_{t+j}^N) \right) \right],$$

subject to the budget constraint

$$c_t^T + p_t^N c_t^N + q_t b_{t+1} = b_t + w_t^T \bar{\ell}_t^T + w_t^N \bar{\ell}_t^N + \pi_t + \Pi_t^L, \quad (1)$$

where \mathbb{E}_t stands for the expectation operator conditional on information available in period t and $\beta \in (0, 1)$ is the subjective discount factor. Importantly, domestic agents in the country are assumed to be sufficiently impatient to borrow from foreign investors around the steady state ($R_t < \beta^{-1}$).⁵⁾ The instantaneous utility $u(\cdot)$ satisfies constant relative risk aversion with a degree of relative risk aversion of σ . The amount of bonds held at the beginning of period t , b_t is denominated in terms of tradable goods. The price of bonds issued in period t , in equilibrium, satisfies $q_t = 1/R_t$, where R_t represents the world interest rate determined in the rest of economy. The relative price of non-tradable goods p_t^N is endogenously determined in the domestic goods market. The second and third terms of the right-hand side of (1), $w_t^T \bar{\ell}_t^T + w_t^N \bar{\ell}_t^N$, represent labor earnings. The fourth term, π_t , represents net profits of the firm, while the last term, Π_t^L , represents the dividends paid by domestic short-term loan companies.

Each firm chooses labor demand $\{\ell_t^T, \ell_t^N\}_{t=0}^\infty$ to maximize the profit given by

$$\pi_t = y_t^T + p_t^N y_t^N - (w_t^T \ell_t^T + w_t^N \ell_t^N) - \theta(R_t - 1)(w_t^T \ell_t^T + w_t^N \ell_t^N), \quad (2)$$

Here, it is assumed that fraction $\theta \in (0, 1)$ of the wage bill must be paid at the beginning of the period and the firm is then required to get intra-temporal working capital loans from domestic short-term loan companies; the last term of (2), $\theta(R_t - 1)(w_t^T \ell_t^T + w_t^N \ell_t^N)$, represents the net payments to short-term loan companies for working capital loans. The working capital constraint increases the impact of world interest rate shocks on macroeconomic fluctuations in the SOE. As highlighted by Uribe and Yue (2006) and Mendoza (2010), incorporating this constraint is necessary when examining the effect of world interest rate shocks on the business cycle in EMEs.

Competitive labor markets require that

$$a_t^T = w_t^T [1 + \theta(R_t - 1)],$$

and

$$p_t^N a_t^N = w_t^N [1 + \theta(R_t - 1)],$$

meaning that the marginal benefit of employing one additional unit of labor equals the marginal cost.

In addition, following Mendoza (2002) and Bianchi (2011), each household is subject to a Kiyotaki-Moore-style borrowing constraint, where fraction κ of the value of produced goods denominated in the international unit of account can be pledged as collateral:

$$b_{t+1} - \theta R_t (w_t^T \bar{\ell}_t^T + w_t^N \bar{\ell}_t^N) \geq -\kappa(y_t^T + \kappa^N p_t^N y_t^N), \quad \text{where } \kappa \in (0, 1). \quad (3)$$

Constraint (3), as in Mendoza (2010) and Mendoza and Bianchi (2011), means that the total amount of inter-temporal debt and intra-temporal working capital loans households (including firms owned by households) can raise is limited by the amount of collateral they have. The parameter $\kappa^N \in (0, 1]$ reflects the value foreign investors

5) There are different specifications to close a stationary SOE, e.g., the endogenized time preference conceived by Uzawa (1969) and Epstein (1983), the debt-elastic interest rate, and the convex portfolio adjustment cost. See Schmitt-Grohe and Uribe (2003) for details.

attach to non-tradable goods as collateral relative to tradable goods. For simplicity, in the benchmark simulation, the same weights are attached to non-tradable and tradable goods, i.e., $\kappa^N = 1$. Note that households' borrowing capacity $\kappa(y_t^T + p_t^N y_t^N)$ increases as the real exchange rate appreciates, since the real exchange rate is given by

$$rex_t \equiv 1/P_t = \left[\omega^{\frac{1}{1+\eta}} + (1-\omega)^{\frac{1}{1+\eta}} (p_t^N)^{\frac{\eta}{1+\eta}} \right]^{-\frac{1+\eta}{\eta}},$$

which implies that a rise in the relative price of non-tradable goods brings about an appreciation in the real exchange rate, that is, an improvement in the terms of trade. This specification of the credit constraint hence reflects the stylized facts documented in Bruno and Shin (2015b) that EMEs with a stronger local currency in terms of the real exchange rate tend to have more cross-border loans in their banking sector.

International risk sharing through real exchange rate fluctuations is incomplete due to a lack of asset variety and the credit constraint. The restriction of assets available to one period and non-state contingent bonds is, to some extent, consistent with the situation observed in a typical EME, where financial institutions borrow by issuing foreign currency-denominated bonds with a relatively short maturity.

World Interest Rate: The world interest rate is assumed to follow U.S. short-term interest rates. Also, movements in U.S. short-term interest rates are approximated using a two-state Markov process, and two types of U.S. monetary policy regime with different transition probabilities are considered: a conventional and an unconventional regime. In the conventional regime, the interest rate is tightened and eased at frequent intervals. On the other hand, in the unconventional regime, the monetary authority commits itself to maintaining a low interest rate when it lowers the current interest rate. Throughout the analysis, the transition probability matrix of the world interest rate is specified as follows:

(i) Conventional regime

$$\begin{bmatrix} Pr(R_{t+1} = R^{high} | R_t = R^{high}) & Pr(R_{t+1} = R^{high} | R_t = R^{low}) \\ Pr(R_{t+1} = R^{low} | R_t = R^{high}) & Pr(R_{t+1} = R^{low} | R_t = R^{low}) \end{bmatrix} = \begin{bmatrix} 0.5 & 0.5 \\ 0.5 & 0.5 \end{bmatrix}$$

(ii) Unconventional regime

$$\begin{bmatrix} Pr(R_{t+1} = R^{high} | R_t = R^{high}) & Pr(R_{t+1} = R^{high} | R_t = R^{low}) \\ Pr(R_{t+1} = R^{low} | R_t = R^{high}) & Pr(R_{t+1} = R^{low} | R_t = R^{low}) \end{bmatrix} = \begin{bmatrix} 0.5 & 0.15 \\ 0.5 & 0.85 \end{bmatrix}.$$

The difference between the two regimes lies in the transition probability from the low interest rate. In the conventional regime, the interest rate is equally likely to rise or to remain at the current low rate. In contrast, in the unconventional regime, the probability that the interest rate will remain low is 85 percent. This probability implies the expected duration of monetary easing is around six and a half years. That is, once monetary easing begins, it is expected to be maintained for another five and a half years. This number is chosen to match the fact that the extremely accommodative monetary policy that began in 2008 lasted until around October 2014.

Domestic Short-term Loan Companies: The SOE has domestic short-term loan companies that issue working capital loans. The settlement of these loans is completed within a particular period: the loan companies lend $\theta w_t^T \ell_t^T$ units of tradable goods and $\theta w_t^N \ell_t^N$ units of non-tradable goods at the beginning of period t and receive $\theta R_t w_t^T \ell_t^T$ units of tradable goods and $\theta R_t w_t^N \ell_t^N$ units of non-tradable goods at the end of period t . The net return, $\Pi_t^L = \theta(R_t - 1)(w_t^N \ell_t^N + w_t^T \ell_t^T)$, is distributed to the household.

Market Clearing: Let C_t^N , C_t^T , and B_t denote aggregate non-tradable consumption, tradable consumption, and outstanding bonds in the economy in period t . Goods market clearing is given by $C_t^N = y_t^N$ and $C_t^T = y_t^T - (q_t B_{t+1} - B_t)$. The first equality shows that all non-tradable output is consumed domestically, while the second shows that tradable output is used for domestic consumption and international trade. Consequently, the trade-balance is given by $q_t B_{t+1} - B_t$ and the current account is given by $B_{t+1} - B_t$. In addition, the labor market clears at $\ell_t^s = 1$ for $s \in \{T, N\}$ for all t .

Characterizing Equilibrium: Since all agents are homogeneous, $B_t = b_t$ and $C_t^s = c_t^s$ for $s \in \{N, T\}$. Given B_0 , the sequence of allocation and prices $\{C_t^T, C_t^N, B_{t+1}, p_t^N, w_t^T, w_t^N, \mu_t\}_{t=0}^\infty$ are characterized by the following private optimality conditions and the market clearing conditions:

$$p_t^N = \left(\frac{1 - \omega}{\omega} \right) \left(\frac{C_t^T}{C_t^N} \right)^{\eta+1},$$

$$u_1(C_t^T, C_t^N) = \beta R_t \mathbb{E}_t [u_1(C_{t+1}^T, C_{t+1}^N)] + \mu_t, \quad (4)$$

$$B_{t+1} \geq -\kappa(y_t^T + \kappa^N p_t^N y_t^N) + \theta R_t (w_t^T + w_t^N),$$

$$C_t^T = y_t^T - \left(\frac{1}{R_t} B_{t+1} - B_t \right),$$

$$C_t^N = y_t^N,$$

$$w_t^T = y_t^T [1 + \theta(R_t - 1)]^{-1}, \quad (5)$$

and

$$w_t^N = p_t^N y_t^N [1 + \theta(R_t - 1)]^{-1}, \quad (6)$$

where μ_t denotes the Lagrange multiplier for the borrowing constraint (3) and $\mu_t > 0$ only when the constraint binds.

The system of equations above successfully generates infrequent and asymmetric economic downturns amplified by a mechanism like Irving Fisher's debt deflation. In equilibrium, once the credit constraint binds, falling spending on tradable goods brings about a decline in the relative price of non-tradable goods and a devaluation of collateral, which tightens the credit constraint and forces agents to further reduce spending.

3 Credit Externalities and Macroprudential Policies

This section presents a framework to discuss to what extent differences in the U.S. monetary policy regime affect the efficiency of the decentralized equilibrium allocation. As shown by Caballero and Krishnamurthy (2003), Lorenzoni (2008), and Dávila and Korinek (2017), in the presence of a credit constraint à la Kiyotaki and Moore (1997), private agents fail to internalize the effects of their borrowing decisions on their borrowing capacity via the credit market, and therefore such externalities, called credit externalities, are responsible for inefficient risk-taking.⁶⁾

6) Such externalities along with this type of credit constraint are conceptually related to the inefficiency of the incomplete financial market economy introduced by Geanakoplos and Polemarchakis (1986).

This study, following the approach taken in the literature, computes a constrained efficient allocation of this economy. For convenience, let $P_t = (p_t^N, w_t^T, w_t^N)'$ and $Y_t = (y_t^T, y_t^N, R_t)'$. Then the credit constraint this country faces is given by

$$B_{t+1} \in \mathcal{B}(P_t; Y_t) \text{ where } \mathcal{B}(P_t; Y_t) = \{x \in \mathbb{R} \mid x \geq -\kappa(y_t^T + \kappa^N p_t^N y_t^N) + \theta R_t (w_t^T + w_t^N)\}$$

and equations (4), (5) and (6) are summarized by

$$P_t = \mathcal{G}(Y_t, C_t^T).$$

Note that the credit limit $\mathcal{B}(P_t; Y_t)$ depends on the market-determined prices P_t and hence these prices are affected by the borrowing decisions. Using these notations, the constrained efficient allocation is defined as follow.

Definition 1 (The constrained efficient allocation). The constrained efficient allocation is the allocation $\{C_t^{ce,T}, C_t^{ce,N}, B_{t+1}^{ce}\}_{t=0}^{\infty}$ that maximizes

$$\mathbb{E}_t \left[\sum_{j=0}^{\infty} \beta^j u(C_{t+j}^{ce}) \right], \text{ where } C_t^{ce} = \left[\omega (C_t^{ce,T})^{-\eta} + (1 - \omega) (C_t^{ce,N})^{-\eta} \right]^{-1/\eta}$$

subject to

$$\begin{aligned} C_t^{ce,T} &= y_t^T - \frac{1}{R_t} B_{t+1}^{ce} + B_t^{ce}, \\ C_t^{ce,N} &= y_t^N, \end{aligned}$$

and

$$B_{t+1}^{ce} \in \mathcal{B}(\mathcal{G}(Y_t, C_t^{ce,T}); Y_t).$$

In other words, both the decentralized equilibrium allocation and the constrained efficient allocation satisfy the resource constraints and the credit constraint, but in the constrained efficient allocation the relative price of nontradable goods is no longer given for households.

In the context of the current model, the constrained efficient allocation solves

$$V^{ce}(B_t^{ce}, Y_t) = \max_{C_t^{ce,T}, C_t^{ce,N}, B_{t+1}^{ce}} u(C_t^{ce}) + \beta \mathbb{E}_t [V^{ce}(B_{t+1}^{ce}, Y_{t+1})]$$

subject to

$$\begin{aligned} C_t^{ce,T} &= y_t^T - \frac{1}{R_t} B_{t+1}^{ce} + B_t^{ce}, \\ C_t^{ce,N} &= y_t^N, \end{aligned}$$

and

$$B_{t+1}^{ce} \geq -[\kappa - \Theta(R_t)] y_t^T - [\kappa^N - \Theta(R_t)] \left(\left(\frac{1 - \omega}{\omega} \right) \left(\frac{C_t^{ce,T}}{C_t^{ce,N}} \right)^{\eta+1} y_t^N \right), \quad (7)$$

where $\Theta(R_t) = \theta R_t [1 + \theta(R_t - 1)]^{-1}$. As a result, the Euler equation in the constrained efficient allocation becomes:

$$u_1(C_t^{ce,T}, y_t^N) = \beta R_t \mathbb{E}_t [u_1(C_{t+1}^{ce,T}, y_{t+1}^N)] + \mu_t^{ce} - \mu_t^{ce} \Psi_t + \beta R_t \mathbb{E}_t [\mu_{t+1}^{ce} \Psi_{t+1}] \quad (8)$$

where

$$\Psi_t = [\kappa \kappa^N - \Theta(R_t)] \frac{\partial p_t^N}{\partial C_t^{ce,T}} y_t^N \quad (9)$$

where μ_t^{ce} is the Lagrange multiplier for the credit constraint (7) and Ψ_t measures how an increase in tradable consumption relaxes the borrowing limit through the change in the relative price of nontradable goods. Hence, the additional term $\mu_t^{SP} \Psi_t$ captures the internalized price effect.

Next, following Jeanne and Korinek (2010), Bianchi (2011), Benigno et al. (2013) and Dávila and Korinek (2017), a macroprudential Pigouvian tax is introduced so as to internalize credit externalities. For the purpose of this study, the tax takes the form of a tax on the issuance of debt, which is the simplest tax scheme considered as a macroprudential policy tool in the literature. Therefore, the price of one period bonds is discounted by $1 + \tau_t$. It is assumed that the government distributes the tax revenue in each period through a lump sum transfer, so that the household's budget constraint is modified as follows:

$$c_t^T + p_t^N c_t^N + \frac{q_t}{1 + \tau_t} b_{t+1} = b_t + y_t^T + p_t^N y_t^N - \theta(R_t - 1)(w_t^T \ell_t^T + w_t^N \ell_t^N) + \pi_t + \Pi_t^L + T_t$$

where T_t is the lump sum transfer, which satisfies

$$T_t = -\frac{\tau_t}{1 + \tau_t} b_{t+1}.$$

Provided the tax policy is carried out, the Euler equation is given by

$$u_1(C_t^T, y_t^N) = \beta R_t (1 + \tau_t) \mathbb{E}_t [u_1(C_{t+1}^T, y_{t+1}^N)] + \mu_t. \quad (10)$$

The optimal tax rate τ_t^* is set so that the decentralized equilibrium allocation becomes the constrained efficient allocation. By comparing (8) and (10), the optimal tax rate is set as follows:

$$\tau_t^* = \frac{\beta R_t \mathbb{E}_t [\mu_{t+1}^{ce} \Psi_{t+1}] - \mu_t^{ce} \Psi_t}{\beta R_t u_1(C_{t+1}^{T,ce}, y_{t+1}^N)} \text{ for } \mu_t^{ce} = 0.$$

and $\tau_t^* = 0$ otherwise.

Note that since τ_t^* stands for the wedge between the privately and socially optimal allocation (i.e., the wedge between the decentralized equilibrium allocation without and with the macroprudential Pigouvian tax), the optimal tax rate mirrors the degree of inefficiency of risk-taking. Therefore, by computing the optimal tax rate, the welfare analysis of this study examines how UMPs affect the wedge as well as the lifetime welfare of the households.

4 Quantitative Analysis

This section calibrates the model following Bianchi (2011) calibrating a similar model using data for Argentina and then quantitatively investigates the impact of prolonged monetary easing in the United States on the macroeconomic performance and welfare of EMEs.⁷⁾

4.1 Calibration

Table 1 summarizes the calibrated parameters. The length of a period is one year. The parameter for the degree of relative risk aversion σ is set to 2.0, which is the value commonly used in the existing studies. The demand elasticity of substitution between tradable and non-tradable goods $1/(1 + \eta)$ is set to a conservative value of 0.83. The share of tradables in the consumption bundle is set to 31 percent of total consumption ($\omega = 0.31$), matching the figure for Argentina. Meanwhile the subjective discount rate β is set to 0.91. The remaining two parameters determine the degree of financial development of the economy. In the benchmark case, the model is calibrated such that EMEs' degree of financial development is similar to that of countries with relatively developed financial markets. It is assumed that each agent can pledge fraction $\kappa = 0.55$ of the total value of produced goods as collateral to foreign investors. This specification ensures that the average net foreign assets (NFA)-to-GDP ratio is -29 percent in the conventional regime.⁸⁾ Further, the fraction of the wage bill required to be paid in advance, θ , is set to 0.19. This implies that the mean ratio of working capital loans to GDP (WC-GDP ratio) becomes 20 percent, which is the same WC-GDP ratio as used in Mendoza (2010).

In order to compare the impact of persistently low interest rates on EMEs with different degrees of financial development, the model is also calibrated such that the degree of financial development is not very advanced by attaching different values to the parameters θ and κ . Two types of less financially developed economies are considered: an economy with a WC-GDP ratio of 20 percent, labeled "Alternative 1," and another with a WC-GDP ratio of 10 percent, labeled "Alternative 2." The average NFA-to-GDP ratio is set to -17 percent for both economies.

Next, the specification of the three shocks is described. The productivity shock is specified using the first-order vector autoregression (VAR) process given by

$$\begin{bmatrix} \log(a_t^T) \\ \log(a_t^N) \end{bmatrix} = \begin{bmatrix} 0.901 & 0.495 \\ -0.453 & 0.225 \end{bmatrix} \begin{bmatrix} \log(a_{t-1}^T) \\ \log(a_{t-1}^N) \end{bmatrix} + \varepsilon_t, \quad \varepsilon_t \sim N(0, Cov(\varepsilon_t)),$$

where

$$Cov(\varepsilon_t) = \begin{bmatrix} 0.00219 & 0.00162 \\ 0.00162 & 0.00167 \end{bmatrix}.$$

The coefficient and covariance-variance matrices are based on the estimation results in Bianchi (2011) using World Bank data on Argentina. In conducting the quantitative experiment, the VAR(1) stochastic process is discretized into a Markov process of 16 states following the method proposed by Terry and Knotek II (2011). As for the Markov process for the world interest rate, R^{high} is set to 1.07 and R^{low} is set to 1.02. It is also assumed that both stochastic processes are independent.

7) See the Appendix for details on the algorithm.

8) See Lane and Milesi-Ferretti (2007) for the empirical evidence on how large the average NFA-to-GDP ratio for major EMEs.

Table 1: Calibrated parameter values

Parameter	Interpretation	Value	Source or targeted variable
σ	Risk aversion	2.0	Standard value in SOE-DSGE models
$1/(1 + \eta)$	Elasticity of substitution	0.83	Conservative value
ω	Weight of tradables	0.31	Share of tradable output = 31%
β	Discount factor	0.91	Bianchi (2011)
Benchmark			
θ	Working capital costs	0.19	Mendoza (2010): WC-GDP ratio = 20%
κ	Credit coefficient	0.55	Average NFA-GDP ratio = -29%
Alternative 1: less financially developed country with <i>strong</i> working capital constraint			
θ		0.19	WC-GDP ratio = 20%
κ		0.39	Average NFA-GDP ratio = -17%
Alternative 2: less financially developed country with <i>weak</i> working capital constraint			
θ		0.10	WC-GDP ratio = 10%
κ		0.29	Average NFA-GDP ratio = -17%

4.2 The Borrowing Decision and Debt Accumulation

The section shows the differences between the borrowing decision in the conventional and the unconventional regime. Figure 3 displays the policy functions regarding bond purchases given the outstanding amount of bonds in response to a one standard deviation adverse productivity shock to both the tradable and the non-tradable sector in the benchmark economy. Specifically, panel (a) presents the result for the conventional regime, while panel (b) shows that for the unconventional regime. The dotted blue line shows the decision rule when the world interest rate is high and the solid red line shows that when the world interest rate is low.

The policy function domain is divided into three regions: a currently binding, a precautionary, and a never-binding region.⁹⁾ In the currently binding region, the economy is heavily indebted, so that the borrowing constraint currently binds. Since the policy function lies above the 45 degree line, capital outflows to repay outstanding debt exceed capital inflows. The positive net foreign capital outflows forces households to cut down spending on consumption and triggers a debt deflation spiral. Therefore, the larger the amount of outstanding debt is, the less household can borrow.

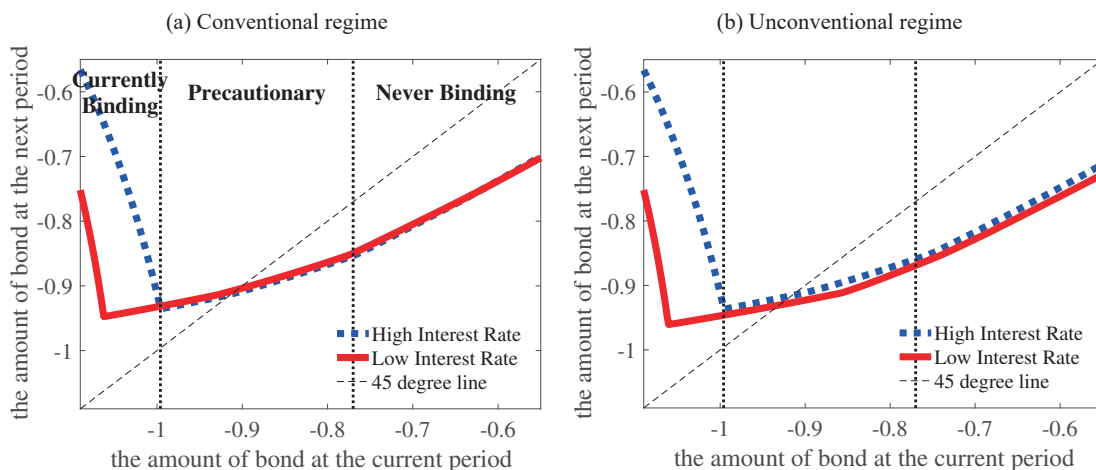
The precautionary region lies between the two kinks in the policy function. In this region, the borrowing constraint is not currently binding (i.e., $\mu_t = 0$), but there is a positive probability that it will be binding in the next period (i.e., $\mathbb{E}_t \mu_{t+1} > 0$). Then, the Euler equation is given by

$$u_1(C_t^T, y_t^N) = \beta^2 R_t \mathbb{E}_t [R_{t+1} u_1(C_{t+2}^T, y_{t+2}^N) + \mu_{t+1}] \quad \text{with } \mathbb{E}_t \mu_{t+1} > 0$$

in which μ_t stands for the marginal benefit from relaxing the borrowing constraint by reducing an additional unit of outstanding debt. Households therefore reduce spending on consumption for self-insurance against becoming credit constrained in the future.

9) In terms of the terminology used by Bianchi (2011), the three regions correspond to the constrained, tax, and non-tax regions.

Figure 3: Decision rules for bond holdings in response to a negative productivity shock



Note: The figures present the policy functions for bond holdings in response to a negative one standard deviation productivity shock in the benchmark economy. The (red) solid line and the (blue) dotted line respectively show the decision rule when the world interest rate is currently low and when it is high. Panel (a) shows the decision rules for the conventional monetary policy regime, while panel (b) shows those for the unconventional regime.

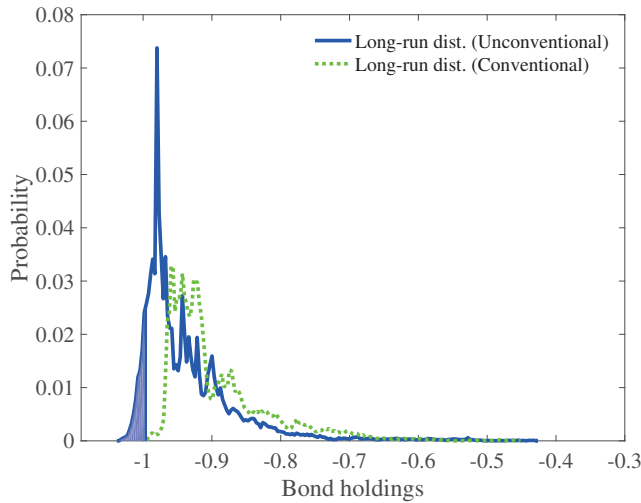
In the never-binding region, the amount of outstanding debt is sufficiently low and the credit constraint is slack not only in the current period but in the next period. Therefore, in this region, the credit constraint is less likely to bind in near future, so that households accumulate debt faster than in other the two regions.

There are quantitatively non-negligible differences in the borrowing rule between the conventional and the unconventional regime, particularly when the world interest rate is low (i.e., the solid lines in Figure 3). Careful comparison of the solid lines in both panels shows that in the unconventional regime (panel (b)) the line is always below the dotted line, while in the conventional regime (panel (a)) both lines intersect. This shows that households tend to borrow more in the unconventional regime when the world interest rate is low. This is because the degree of precautionary saving against an increase in the world interest rate differs in the two regimes. In both regimes, the risk of becoming credit constrained increases as the world interest rate rises; however, in the unconventional regime, households expect that it is less likely that the world interest rate will rise. They therefore tend to be less cautious about a potential credit contraction triggered by a rise in the world interest rate.

In order to see how U.S. monetary policy affects households' borrowing decision, a stochastic simulation over 90,000 periods is conducted.¹⁰⁾ The long-run distributions of the amount of bonds held in the unconventional regime (solid blue line) and the conventional regime (dotted green line) are drawn in Figure 4. The distribution in the unconventional regime has a thicker tail on the left side (indicated by the shaded area). The probability that the amount of debt is greater than the maximum amount of debt that can be held in the conventional regime is 9.29 percent. This indicates that unconventional monetary policy in the United States stimulates debt accumulation in EMEs in terms of both quantity and speed.

10) For the simulation, shocks are generated for 91,000 periods and the first 1,000 periods are discarded.

Figure 4: Long-run distribution of bond holdings (Benchmark)



Note: The solid (blue) line and the dotted (green) line represent the long-run distribution of bonds held in the unconventional and conventional regime, respectively.

4.3 The Incidence and Severity of Financial Crises

Next, the incidence and severity of financial crises is investigated. In this study, in line with other studies (e.g., Bianchi, 2011; Mendoza, 2010; Benigno et al., 2013), a period of financial crisis is defined based on the size of net capital outflows. Specifically, a financial crisis here is defined as a period when the credit constraint binds and the ratio of net capital outflows to GDP exceeds 4 percent. In order to consider the severity of a crisis, an additional definition used in this study is that of a ‘major financial crisis,’ which is defined as a period in which the ratio of net capital outflows to GDP exceeds 10 percent.

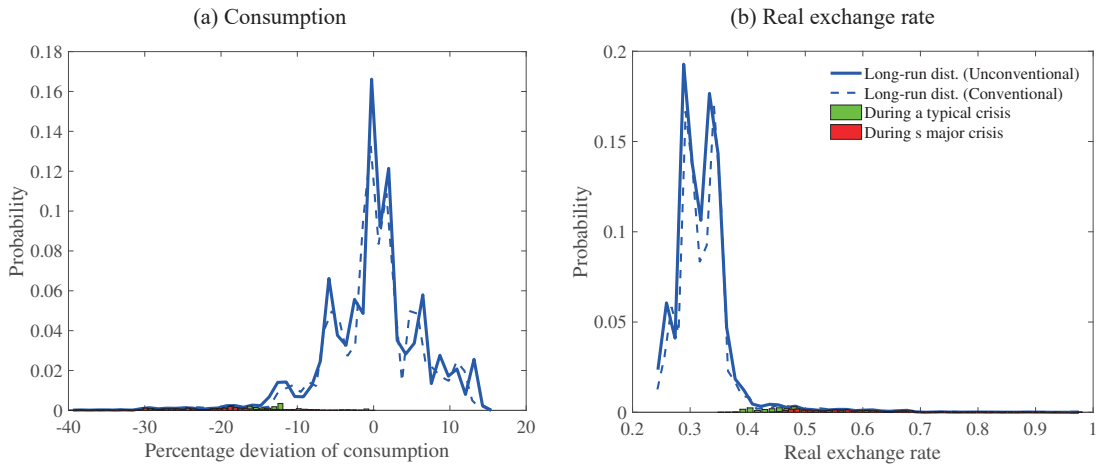
Table 2 shows the probability of a financial crisis based on the simulation results, with the first column labeled (A) showing the probability under the conventional regime and the second column labeled (B) showing the probability under the unconventional regime. The third column labeled (B)/(A) shows the ratio of the two probabilities. The first two rows of the table present the long-run probability of each type of financial crisis. The figures indicate that the probability of a typical financial crisis is essentially the same under the two types of regime, but the probability of a major financial crisis is 61 percent higher under the unconventional than the conventional regime (1.36 percent versus 2.18 percent). More importantly, a persistently low interest rate makes EMEs susceptible to domestic adverse shocks and a rise in the world interest rate. The next two rows in the table show the probabilities of a financial crisis when the world interest rate is low and a negative productivity shock of more than one standard deviation hits both sectors (i.e., $\log(a_t^s) \leq -\sigma^s$ for $s = \{T, N\}$). The probabilities are almost three times as high under the unconventional regime as under the conventional regime. Specifically, the probability of a typical financial crisis increases from 4.39 percent to 12.74 percent, while that of a major crisis increases from 2.17 percent to 7.15 percent. The last two rows of the table show the probabilities of a financial crisis in response to a rise in the world interest rate. The results suggest that the risk of a major financial crisis in EMEs in response to rising world interest rates is more than twice as high in the unconventional regime as in the conventional regime.

Table 2: Probability of financial crisis (Benchmark)

Monetary policy regime	(A) <i>Conventional</i>	(B) <i>Unconventional</i>	(B)/(A)
Typical financial crisis	3.16%	3.45%	1.09
Major financial crisis	1.36%	2.18%	1.61
<i>Prob(· $\log(a^N) \leq -\sigma^N, \log(a^T) \leq -\sigma^T, R = R_{low}$)</i>			
Typical financial crisis	4.39%	12.74%	2.90
Major financial crisis	2.17%	7.15%	3.29
<i>Prob(· $R = R_{high}, R_{-1} = R_{low}$)</i>			
Typical financial crisis	7.26%	8.24%	1.14
Major financial crisis	2.54%	7.01%	2.76

Note: The table shows the long-run probability and the conditional probability of each type of financial crisis under each type of regime.

Figure 5: Long-run distribution of consumption and the real exchange rate



Note: Panel (a) shows the long-run distribution of the percentage deviation of consumption from the average, while panel (b) shows the long-run distribution of the real exchange rate. The solid line shows the distribution under the unconventional regime, while the broken line shows that under the conventional regime. The green and red bars show the density during a typical and a major financial crisis, respectively.

Next, let us briefly examine the validity of the definition of a financial crisis. Figure 5(a) presents the long-run distribution of the percentage deviation of consumption from the average, while Figure 5(b) presents the long-run distribution of the real exchange rate. The solid line shows the distribution in the unconventional regime and the dotted line shows the distribution in the conventional regime. The green and red bars indicate the densities for a typical financial crisis and a major financial crisis, respectively. The figure shows that consumption declines substantially and the real exchange rate depreciates considerably during a financial crisis; moreover, the magnitude of these responses is more severe during a major financial crisis.

Table 3: Counterfactual simulation

Decision rule	Probability of crisis (%)		Long-run distribution		
	Typical crisis	Major crisis		Average	Std. dev.
Counterfactual: WITHOUT expectations					
Conventional	2.09	0.91	CONS	0.992	0.056
			GDP	3.175	0.394
			RER	0.320	0.045
			CA	0.000	0.051
			BONDS	-0.895	0.068
For comparison: WITH expectations					
Unconventional	3.45	2.18	CONS	0.991	0.064
			GDP	3.173	0.425
			RER	0.322	0.053
			CA	0.000	0.068
			BONDS	-0.935	0.074

Note: “CONS”, “GDP”, “RER”, “CA”, and “BONDS” stand for aggregate consumption, gross domestic product, the real exchange rate, the current account balance, and net foreign assets, respectively.

4.4 Expectation versus Realization of a Low Interest Rate

This section investigates whether it is the realization or expectation of a persistently low interest rate that is more important in increasing financial fragility under the unconventional regime. To identify the role of expectations, I conduct a counterfactual simulation and examine how the absence of expectations of a low world interest rate affects financial stability. Technically speaking, the counterfactual simulation is conducted using the policy function in the conventional regime and shocks generated from the Markov process in the unconventional regime. Table 3 compares the probability of financial crisis and the first and second moments of the long-run distribution of aggregate consumption, GDP, the real exchange rate, the current account, and net foreign assets with and without expectations of a persistently low world interest rate.

The simulation reveals that expectations regarding future interest rates play an essential role in the impact of UMPs on financial stability in EMEs. The results in the table indicate that, even with a persistently low world interest rate, without expectations of a continuation of the low interest rate, the risk of a financial crisis would remain low. However, with such expectations, the probability of a major financial crisis increases from 0.91 percent to 2.18 percent. In addition, more debt is accumulated and aggregate consumption, GDP, the real exchange rate, and the current account balance are more volatile. The simulation thus shows that the increased financial fragility in EMEs under UMPs is caused not by the persistently low world interest rate but by expectations of a continuation of the low interest rate.

4.5 Welfare of EMEs and Macroprudential Policies

As discussed in Section 3, due to credit externalities, there is a gap between the privately and socially optimal allocation. This section examines the spillover effects of UMPs from a welfare perspective and then seeks to provide policy recommendations.

Table 4: Welfare gain and wedge

Monetary policy regime	Conventional	Unconventional
Welfare gain		
Long-run average	0.093%	0.116%
... low interest rate	0.094%	0.117%
... high interest rate	0.092%	0.115%
Wedge (τ^*)		
Long-run average	4.57%	5.73%
... low interest rate	4.96%	5.79%
... high interest rate	4.18%	5.55%

4.5.1 Welfare Gain and Wedge

Following the literature on the welfare cost of business cycles, the welfare gain from correcting credit externalities is calculated as the amount of compensation in terms of permanent consumption required to achieve the same lifetime utility as that which would be achieved from possible paths of consumption in the constrained efficient allocation. Thus, using the parameter Ω , the welfare gain is computed as

$$\mathbb{E}_t \left[\sum_{j=0}^{\infty} \beta^j \frac{[(1 + \Omega(B_t, Y_t))C_{t+j}^{de}(B_t, Y_t)]^{1-\sigma}}{1-\sigma} \right] = \mathbb{E}_t \left[\sum_{j=0}^{\infty} \beta^j \frac{[C_{t+j}^{ce}(B_t, Y_t)]^{1-\sigma}}{1-\sigma} \right],$$

where $\Omega(B_t, Y_t) \geq 0$ is the welfare gain in state (B_t, Y_t) , and $\{C_{t+j}^{de}(B_t, Y_t)\}_{j=0}^{\infty}$ and $\{C_{t+j}^{ce}(B_t, Y_t)\}_{j=0}^{\infty}$ are the consumption paths given the current state (B_t, Y_t) in the decentralized equilibrium and the constrained efficient allocation, respectively. Figure 6 shows the welfare gain measured by $\Omega(B_t, Y_t)$ in the unconventional regime (solid lines) and that in the conventional regime (broken lines) given a one standard deviation adverse productivity shock and a low world interest rate. As can be seen, the solid lines are about 0.01-0.05 percentage points above the broken lines. This implies that the welfare loss due to credit externalities is larger in the unconventional regime.¹¹⁾

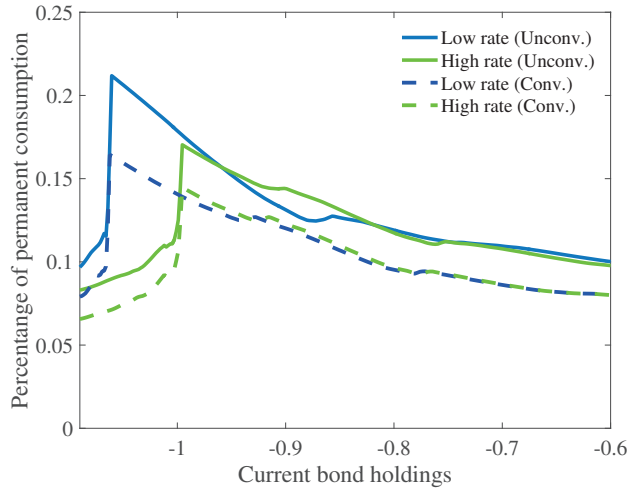
Further, let us examine the wedge between the privately and socially optimal allocation as an indicator for the degree of inefficiency of risk-taking. As mentioned in Section 3, the wedge is equal to the optimal Pivovgian tax rate τ_t^* .

Table 4 shows the average welfare gain and the average wedge in the conventional and the unconventional regime.¹²⁾ The table shows the long-run average of the welfare gain and of the wedge as well as the conditional average welfare gain and wedge when the world interest rate is low and when it is high. The table indicates that the welfare gain from correcting credit externalities is greater in the unconventional regime than in the conventional regime: the average of the welfare gain is around 0.02 percentage points higher (0.116 percent versus 0.093 percent) in the unconventional regime than in the conventional regime. This implies that a persistently low interest

11) The simulation indicates that the welfare gain $\Omega(B_t, Y_t)$ is greater in the unconventional regime in all states, even though Figure 6 shows the result regarding only the welfare gain in the state where the productivity levels are both one standard deviation below the mean.

12) The average welfare gain and the average wedge are calculated by weighting $\Omega(B, Y)$ and the wedge in each state by the density of the long-run distribution.

Figure 6: Welfare gain under one standard deviation negative productivity shock



Note: The figure shows the welfare gain from correcting credit externalities in each state of nature. The blue lines show the results for a negative one standard deviation productivity shock when the world interest rate is low, while the green lines show the results when it is high. “Conv.” refers to the conventional regime, while “Unconv.” refers to the unconventional regime.

Table 5: Distribution of regions

Region	Binding	Precautionary	Never-binding
Conventional regime	4.07%	80.56%	15.37%
Unconventional regime	5.67%	88.37%	5.46%

rate exacerbates the negative externalities in EMEs. Moreover, the wedge becomes larger in the unconventional regime: the average optimal tax rate is around 1 percentage point higher (5.73 percent versus 4.57 percent) in the unconventional regime than in the conventional regime. These findings suggest that UMPs are likely to magnify inefficient debt accumulation in EMEs.

The larger average welfare gain in the unconventional regime is due to the following two effects. First, as shown in Figure 6, the welfare gain is greater in every state in the unconventional regime. The second effect comes from the difference in the shape of the long-run distribution of bond holdings. Table 5 shows the probability that the current state is in the binding, precautionary, and never-binding region and indicates that the probability of being in the precautionary region is higher in the unconventional regime than in the conventional regime. This increases the average welfare gain since, as shown in Figure 6, the welfare gain is greater in the precautionary region than in the other regions.

4.5.2 Effectiveness of Macroprudential Policies

Table 6 reports to what extent the optimal macroprudential tax policy reduces the susceptibility to a financial crisis in each regime, with the second and third columns comparing the probabilities of crisis with and without the optimal

Table 6: Probability of financial crisis with and without the macroprudential Pigouvian tax

Monetary policy regime	Conventional regime		Unconventional regime	
	(A) Without tax	(B) With tax	(A) Without tax	(B) With tax
Probability of financial crisis in the long run				
Typical financial crisis	3.16%	0.26%	3.45%	0.49%
Major financial crisis	1.36%	0.04%	2.18%	0.21%
<i>Prob(\cdot $y^N \leq \bar{y}^N - \sigma^N$, $y^T \leq \bar{y}^T - \sigma^T$, $R = R_{low}$)</i>				
Typical financial crisis	4.39%	0.17%	12.74%	0.17%
Major financial crisis	2.17%	0.17%	7.15%	0.03%
<i>Prob(\cdot $R = R_{high}$, $R_{-1} = R_{low}$)</i>				
Typical financial crisis	7.26%	0.44%	8.24%	3.28%
Major financial crisis	2.54%	0.04%	7.01%	1.28%

Note: "Without tax" and "With tax" respectively refer to the decentralized equilibrium without and with the optimal macroprudential Pigouvian tax.

macroprudential Pigouvian tax under the conventional monetary policy regime and the fourth and fifth columns comparing those under the unconventional monetary policy regime. Meanwhile, the rows report the various probabilities of crisis, with the first set of rows reporting the unconditional probabilities of financial crisis. The next set of rows reports the probabilities in response to a negative productivity shock of more than one standard deviation to both sectors when the world interest rate is low, while the last set of rows reports the probabilities in response to a rise in the world interest rate.

As shown in the top and middle set of rows of Table 6, the macroprudential Pigouvian tax policy decreases the probability of a financial crisis in the long run and also in the case of negative domestic productivity shocks to less than 0.5 percent regardless of the underlying U.S. monetary policy regimes. However, the tax policy is ineffective in the case of a rise in the interest rate if U.S. monetary policy follows the unconventional regime: the probability of a financial crisis in the event of a rise in interest rates is halved but still remains substantially high even when the optimal macroprudential Pigouvian tax is imposed (3.28 percent for a typical crisis and 1.28 percent for a major crisis). Why is the tax ineffective in the unconventional regime? The optimal tax rate is set to maximize welfare from a long-term perspective. Since in the unconventional regime a rise in the interest rate occurs less frequently, the risk of crisis brought about by a rising interest rate is less important than in the conventional regime.

4.6 Effects of UMPs on Less Financially Developed EMEs

Table 7 shows the effects of UMPs on less financially developed EMEs, i.e., countries for which the ratio of external debt to GDP is smaller than in the benchmark. The table shows the results of two alternative simulations: one for a country which is assumed to have an average NFA-GDP ratio of 17 percent and an average working capital loans-to-GDP ratio of 20 percent, which is labeled "Alternative 1," and another for a country with an average NFA-GDP ratio of 17 percent and an average working capital loans-to-GDP ratio of 10 percent, which is labeled "Alternative 2," as shown in Table 1.

The results are as follows. First, the average tax rate as well as the welfare gain from using the Pigouvian tax are small regardless of the underlying monetary policy regime, showing that less financially developed EMEs suffer

Table 7: Impact of UMPs on less financially developed EMEs

Monetary policy regime	(A) <i>Conventional</i>	(B) <i>Unconventional</i>	(B)/(A)
Alternative 1: less financially developed EMEs with atext <i>strong</i> working capital constraint			
Average tax rate	1.27%	1.32%	
Average welfare gain	0.007%	0.009%	
Probability of typical financial crisis			
Long-run	1.78%	3.16%	1.77
Adverse productivity shocks	3.68%	13.86%	3.77
Rising interest rates	3.30%	8.15%	2.47
Alternative 2: less financially developed EMEs with atext <i>weak</i> working capital constraint			
Average tax rate	1.29%	1.39%	
Average welfare gain	0.007%	0.009%	
Probability of typical financial crisis			
Long-run	1.97%	3.03%	1.54
Adverse productivity shocks	5.76%	14.57%	2.53
Rising interest rates	3.06%	6.02%	1.97

less from credit externalities. This result is not surprising, since these countries have a smaller κ , which is one of the most important variables governing the wedge between the privately and socially optimal allocation.¹³⁾

Second, the effects of UMPs on the probability of a financial crisis are larger in EMEs with a stronger working capital constraint. Specifically, in Alternative 1, the probability of a financial crisis in the event of an adverse technology shock¹⁴⁾ is 3.77 times greater in the unconventional regime than in the conventional regime, while in Alternative 2 it is 2.53 times greater in the unconventional regime. This is because the stronger the working capital constraint is, the larger is the impact of world interest rate shocks on borrowing capacity.

5 Conclusion

This study considered the influence of the prolonged low interest rate policy and forward guidance conducted in the United States on the financial stability of emerging market economies (EMEs). To this end, two different U.S. monetary policy regimes, a conventional and an unconventional regime, were added into a small open economy model incorporating credit externalities in order to quantitatively examine the impact of unconventional monetary policy (UMP) on the efficiency of risk-taking and financial stability of EMEs as well as the effectiveness of macroprudential policies.

The analysis showed that UMP substantially increases financial instability in EMEs and that expectations of a persistently low interest rate play an important role in increasing financial instability. Specifically, when the world interest rate is low and a negative technology shock hits EMEs, the probability a major financial crisis is 3.3 times higher in the unconventional regime than in the conventional regime. According to the counterfactual simulation, even if the world interest rate is persistently low, the probability would become less than half without expectations

13) Recall that the effect of internalizing credit externalities Ψ , is increasing in κ , as seen in equation (9).

14) More precisely, this is the probability of financial crisis when the world interest rate is low and a negative productivity shock of more than one standard deviation hits both sectors.

of a continuation of the low interest rate. This implies that forward guidance plays a critical role in the financial stability of EMEs.

From a welfare perspective, this study showed that risk-taking in EMEs is less efficient in the unconventional regime than in the conventional regime since UMP increases the effect of credit externalities. On average, the tax rate required to correct credit externalities is around 1 percentage point higher in the unconventional regime. The analysis also found that macroprudential policies might not work to reduce financial instability under UMP: even if the macroprudential Pigouvian tax is optimally imposed, the probability of a financial crisis in response to rising interest rates remains 3.28 percent in the unconventional regime, while it is 0.44 percent in the conventional regime. These results suggest that push factors play a more important role in the recent increased financial fragility in EMEs and, in order to prevent such fragility, monetary authorities in advanced countries should take into account the spillover effects on EMEs, especially when easing interest rate.

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A Numerical Approach

1. Discretize the VAR(1) process with respect to productivity shocks and world interest rate shocks into a Markov chain following Tauchen and Hussey (1991) or Terry and Knotek II (2011). In this study, four states for each type of goods and two states for the world interest rate are set. (for a total of 32 states).
2. Set the grids for bond holdings.
3. Solve the decentralized equilibrium using so-call time iteration method, as briefly described below.

The following four conditions are used to obtain the equilibrium price $\mathcal{P}^N(b, y)$ and the policy functions $C^T(b, y)$, $\mathcal{B}'(b, y)$, where $y = (y^T, y^N, R)$:

$$\mathcal{P}^N(b, y) = \left(\frac{1 - \omega}{\omega} \right) \left(\frac{C^T(b, y)}{y^N} \right)^{\eta+1}, \quad (11)$$

$$u_1 \left(C^T(b, y), y^N \right) \geq \beta R \mathbb{E}_{y'|y} u_1 \left(C^T(\mathcal{B}'(b, y), y'), y'^N \right), \quad (12)$$

$$\mathcal{B}'(b, y) \geq -\kappa \left(\mathcal{P}^N(b, y) y^N + y^T \right) + \theta R \left(w^T + w^N \right), \quad (13)$$

and

$$\frac{1}{R} \mathcal{B}'(b, y) + C^T(b, y) = b + y^T, \quad (14)$$

where $w^T = y^T [1 + \theta(R - 1)]^{-1}$ and $w^N = \mathcal{P}^N(b, y) y^N [1 + \theta(R - 1)]^{-1}$.

1. Guess $\widehat{\mathcal{P}^N}(b, y)$, $\widehat{C^T}(b, y)$, and $\widehat{\mathcal{B}'(b, y)}$.
2. Using (11), (12), (13), and (14), compute $\mathcal{P}^N(b, y)$, $C^T(b, y)$, and $\mathcal{B}'(b, y)$ based on the following rules:
 - (a) Assume (13) binds in all states; $\mathcal{B}'(b, y) = -\kappa \left(\widehat{\mathcal{P}^N}(b, y) y^N + y^T \right) + \theta R \left(w^T + w^N \right)$, and compute $C^T(b, y)$ from (14).
 - (b) Through piecewise linear interpolation, compute $\widehat{C^T}(\mathcal{B}'(b, y), y)$.
 - (c) For each (b, y) , let $U(b, y) = u_1 \left(C^T(b, y), y^N \right) - \beta R \mathbb{E}_{y'|y} u_1 \left(\widehat{C^T}(\mathcal{B}'(b, y), y'), y'^N \right)$.
 - (d) If $(U(b, y) \geq 0)$, then go to (f).
 - (e) If $(U(b, y) < 0)$, then, making use of root-finding methods, find such $C^T(b, y)$ and $\mathcal{B}'(b, y)$ that satisfy $U(b, y) = 0$ and equation (14).
 - (f) Set the equilibrium price $\mathcal{P}^N(b, y)$ from (11).

3. If the distance between $(\mathcal{P}^N(b, y), C^T(b, y), \mathcal{B}'(b, y))$ and $(\widehat{\mathcal{P}^N}(b, y), \widehat{C^T}(b, y), \widehat{\mathcal{B}'(b, y)})$ becomes sufficiently close, the equilibrium has been found. Otherwise, $(\widehat{\mathcal{P}^N}(b, y), \widehat{C^T}(b, y), \widehat{\mathcal{B}'(b, y)})$ are updated using the following rules with $\lambda \in (0, 1)$

$$\widehat{\mathcal{P}^N}(b, y) \leftarrow (1 - \lambda)\mathcal{P}^N(b, y) + \lambda\widehat{\mathcal{P}^N}(b, y)$$

$$\widehat{C^T}(b, y) \leftarrow (1 - \lambda)C^T(b, y) + \lambda\widehat{C^T}(b, y)$$

$$\widehat{\mathcal{B}'(b, y)} \leftarrow (1 - \lambda)\mathcal{B}'(b, y) + \lambda\widehat{\mathcal{B}'(b, y)}$$

and the procedure goes back to step (ii).