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Trade Policy Uncertainty, Financial Frictions, and Monetary Policy

Jingjing Fan, Feng Shi, Junzhu Zhao, and Jingming Zhu*

This paper introduces the foreign tariff uncertainty shock in a small open economy model with financial frictions to examine the fluctuations in the main macroeconomic variables and then analyzes which type of monetary policy performs better in terms of stabilizing the macroeconomic variables. We find that a rise in the foreign tariff uncertainty shock leads to a sizable decline in the main macroeconomic variables except for CPI inflation. In addition, the amplification effect of financial frictions aggravates the volatility in the main macroeconomic variables.The CPI inflation targeting rule performs better than the PPI inflation targeting rule in the sense that the former can stabilize the economy better than the latter following the foreign tariff uncertainty shock.

Key Words: Foreign tariff uncertainty shock; Financial frictions; Inflation targeting.
JEL Classification Numbers: E5, F3, F4.

1. INTRODUCTION

The world has been reshaping itself from an open state to an isolated one recently. The important sign of the transition is the Brexit referendum and the US-China trade war which reverse the world's support for low protections and stable trade agreements. The Brexit referendum and the US-China trade war sparked heated discussions among policymakers and academic researchers and spread trade policy uncertainty globally (Steinberg, 2019; Fajgelbaum and Khandelwal, 2022).[1]

* Fan: China Economics and Management Academy, Central University of Finance and Economics, Beijing, 100081, China. Email: 2019110188@email.cufe.edu.cn; Shi: Corresponding author. Business School, Beijing Language and Cultural University, Beijing, 100083, China. Email: fengshidr@163.com; Zhao: China Economics and Management Academy, Central University of Finance and Economics, Beijing, 100081, China. Email: junzhuzhao@gmail.com; Zhu: China Economics and Management Academy, Central University of Finance and Economics, Beijing, 100081, China. Email: jingming.zhu@foxmail.com.

[1] See Hardley and Limão (2022) for a detailed discussion on trade policy uncertainty.

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To some degree, the transition of the world is triggered by the Great Financial Crisis in 2007-2008. In the aftermath of the crisis, policymakers and academic researchers all agree that financial frictions are a key driver of business cycle fluctuations.[2] As a matter of fact, academic researchers realize the importance of financial frictions in amplifying and propagating macroeconomic fluctuations (Kiyotaki and Moore, 1997; Bernanke, Gertler and Gilchrist, 1999; Iacoviello, 2005), before the onset of the Great Financial Crisis in 2007-2008.

When the world still recovers from the havoc caused by the Great Financial Crisis in 2007-2008, trade policy uncertainty casts another shadow on the recovery of the world economy. The world worries that financial frictions and trade policy uncertainty reinforce each other and aggravate the global economy further. Admittedly, there is a large body of literature on the economic implications of financial frictions and uncertainty respectively. However, the literature on the combined effects of trade policy uncertainty and financial frictions is scant. Thus there is a gap between the policy discussion and what the literature tells us.

In this paper, we aim at filling the gap in the literature by introducing the foreign tariff uncertainty shock in a small open economy, á la Gali and Monacelli (2005) .Unlike Gali and Monacelli (2005) , we allow for financial frictions in the spirit of Kiyotaki and Moore (1997). In addition, the literature on the macroeconomic impacts of trade tensions usually focuses on import tariffs (Farhi et al., 2014; Barbeiro et al., 2019; Caldara et al., 2020). We differ from the literature and consider the macroeconomic impacts of export tariff uncertainty shock. Another novel feature of our paper is production openness which is absent in the standard small open economy model (Gali and Monacelli, 2005). After analyzing the macroeconomic dynamics of the small open economy buffeted by the foreign tariff uncertainty shock in the presence of financial frictions, we examine which type of monetary policy performs better in terms of stabilizing the macroeconomic variables.

We find that a rise in the foreign tariff uncertainty shock leads to a sizable decline in the main macroeconomic variables except for CPI inflation. Financial frictions play a part in amplifying the effects of the foreign tariff uncertainty shock on the volatility in the main macroeconomic variables. In addition, we find that the CPI inflation targeting rule performs better than the PPI inflation targeting rule in the sense that the former can stabilize the economy better than the latter following the foreign tariff uncertainty shock. The foreign tariff uncertainty shock reduces the demand for domestic output and causes a dampening effect on the domestic economy.

[2]See Brunnermeier, Eisenbach and Sannikov (2012) for a survey on macroeconomics with financial frictions.

In the presence of financial frictions, the entrepreneur finances investment spending by using physical capital as a collateral asset. The dampening effect caused by the foreign tariff uncertainty shock triggers the amplification effect of the financial frictions, which reinforces the dampening effect and pushes the economy toward recession further.

In view of the fact that there are many implementable monetary policy rules available for the domestic monetary policymaker. A natural question is which type of monetary policy rule performs better in terms of stabilizing the macroeconomic variables. Under the standard Taylor rule, the nominal interest rate responds to inflation and the output gap. However, there is a distinction between PPI inflation and CPI inflation in open economies, and the standard Taylor rule does not specify which kind of inflation the monetary policymaker should target when the economy goes from closed to open. In a small open economy model with no financial frictions and the foreign tariff uncertainty shock, Gali and Monacelli (2005) draw the conclusion that targeting CPI performs better than targeting PPI in terms of stabilizing the main macroeconomic variables. By contrast, Wei and Xie (2020) find that targeting PPI gives rise to a smaller welfare loss than targeting CPI inflation alone. Thus there is no consensus among researchers about which type of monetary policy rule performs better in terms of stabilizing the macroeconomic variables in a small open economy. We find that the CPI inflation targeting rule performs better than the PPI inflation targeting rule in the sense that the former can stabilize the economy better than the latter, thus our conclusion is consistent with what is found in Gali and Monacelli (2005).

Our research is closed related to two strands of literature: the first on the macroeconomic implications of uncertainty; the second on financial frictions. In view of the fact that each of them is large and rapidly growing, we cannot discuss them extensively. We only give a partial review below.

The literature on uncertainty shock is initiated by Bloom (2009) in which uncertainty shock produces a rapid drop and rebound in aggregate output and employment. In the medium term output, employment, and productivity overshoot as a result of the increased volatility of the uncertainty shock. Fernández-Villaverde et al. (2015) examine how fiscal policy uncertainty affects economic activity. They find that an endogenous increase in markups is key to generating a sizeable adverse effect on economic activity in the presence of fiscal policy uncertainty. Leduc and Liu (2016) introduce the productivity uncertainty shock into a New Keynesian model with labor market search frictions to analyze the impacts of the productivity uncertainty shock on aggregate economic activity. They find that the productivity uncertainty shock resembles an aggregate demand shock in the sense that it increases unemployment and lowers inflation. The key to yielding their result is the option-value channel whose effects are reinforced by the presence of nominal rigidities. Basu and Bundick (2017) find that the uncertainty shock causes significant declines in output, consumption, investment, and employment. During normal times, monetary policy can offset the negative effect of the uncertainty shock. In a two-country New Keynesian model with firms' export participation decisions, Caldara et al. (2020) find that increased uncertainty about higher future tariffs reduces investment and economic activity.[3]

The literature on financial frictions can be divided into two categories: one emphasizing frictions stemming from the inside of financial institutions; the other focusing on the characteristics of the people who borrow from financial institutions. The research on bank runs and rollover crisis centers around the first class of financial frictions. By contrast, the research on collateral constrained borrowers focuses on the second class of financial frictions.[4] Our paper examines the role of collateral constrained borrowers, thus we only review the second category of literature on financial frictions, which typically builds on the financial accelerator framework initiated by Kiyotaki and Moore (1997) and Bernanke et al.(1999). A partial list of the second class of literature on financial frictions includes Iacoviello (2005), Iacoviello and Neri (2010), Jermann and Quadrini (2012), Liu et al. (2013, 2016), Christiano et al. (2014), Gong et al. (2017), Berger et al. (2018).

The rest of the paper is organized as follows. Section 2 lays out the model. Section 3 examines the economic implications of the foreign tariff shock uncertainty. Section 4 concludes.

2. THE MODEL

We consider a small open economy, á la Gali and Monacelli (2005), which has no impact on the rest of the world. The small open economy is inhabited by a continuum of households of unit mass $[0, 1]$. The representative household derives utility from the consumption of both home and imported goods and incurs disutility from the provision of labor services to domestic entrepreneurs. The financial markets are incomplete in the sense that the representative household holds one-period risk-less bonds issued by the domestic entrepreneurs and the foreign country.[5]Following Caldara et al. (2020),we allow for trade frictions and examine the transmission of trade policy uncertainty.

The entrepreneurs borrow from the household to finance the investment spending. In the spirit of Kiyotaki and Moore (1997), the borrowing ca-

[3]See Bloom (2014) and Fernández-Villaverde and Gurron-Quintana (2020) for a detailed review of the literature on uncertainty.

[4]See Christiano et al. (2018) for a discussion of some examples of each.

[5]Since the small economy has no impact on the rest of the world, we can take the rest of the world as a large country which is named as the foreign country for convenience.

pacity of entrepreneurs is constrained by the value of collateral asset which is just the capital held by them. The entrepreneurs input capital and labor to produce the intermediate good which is sold to the retailers in a competitive manner. The retailers differentiate the intermediate good slightly and then sell the differentiated good to a final-good producer. The final-good producer produces the final good using differentiated goods as the input.

2.1. Households

The representative household maximizes the following expected lifetime utility

$$\mathbf{E}_0\sum_{t=0}^{\infty}\beta^t U\left(C_t, N_{ht}\right)=\mathbf{E}_0\sum_{t=0}^{\infty}\beta^t\left\{\frac{\left(C_t-\frac{N_{ht}^{1+\varphi}}{1+\varphi}\right)^{1-\sigma}-1}{1-\sigma}\right\}, \tag{1}$$

in which $\beta \in (0,1)$ is the discount factor, σ denotes the coefficient of relative risk aversion, φ is the inverse of the Frisch elasticity of labor supply, C_t is the consumption aggregate, and N_t is labor services that the representative household provides to the domestic entrepreneurs. Following Caldara et al. (2020),we assume a GHH utility function that is widely adopted in the small open economy model (Mendoza, 1991; Raffo, 2008).

The consumption C_t is a CES composite of domestic and foreign consumption goods C_{Ht} and C_{Ft} which is given by

$$C_t=\left((1-\upsilon)^{\frac{1}{\eta}}C_{Ht}^{\frac{\eta-1}{\eta}}+\upsilon^{\frac{1}{\eta}}C_{Ft}^{\frac{\eta-1}{\eta}}\right) \tag{2}$$

in which parameter $\upsilon \in [0,1]$ denotes the degree of trade openness, and parameter $\eta > 0$ is the elasticity of substitution between domestic and foreign consumption goods.

Solving the household's expenditure-minimization problem gives rise to demands for C_{Ht} and C_{Ft}

$$C_{Ht}=(1-\upsilon)\left(\frac{P_{Ht}}{P_t}\right)^{-\eta}C_t,\ C_{Ft}=\upsilon\left(\frac{P_{Ft}}{P_t}\right)^{-\eta}C_t \tag{3}$$

where P_{Ht} and P_{Ft} are the domestic and foreign final-good prices, and $P_t=\left((1-\upsilon)P_{Ht}^{1-\eta}+\upsilon P_{Ft}^{1-\eta}\right)^{\frac{1}{1-\eta}}$ is the domestic CPI price index. Since the small open economy is assumed to be negligible relative to the rest of the world, there is no distinction between CPI and PPI price levels. Thus, $P_{Ft}=S_tP_t^*$,where P_t^* is the world price index expressed in foreign currency.

The household maximizes equation (1) subject to the following budget constraint

$$P_t C_t + B_t + S_t B_t^* = W_t N_{ht} + R_{t-1} B_{t-1} + S_t R_{t-1}^* B_{t-1}^* + \Gamma_t \tag{4}$$

in which B_t is the one-period bonds issued by the domestic entrepreneurs, B_t^* is the one-period bonds issued by the foreign country, S_t is the nominal exchange rate representing the domestic currency price of one unit of foreign currency, W_t is the nominal wage, R_t is the nominal interest rate on domestic currency bonds purchased in period t, R_t^* is the nominal interest rate on foreign currency bonds purchased in period t, Γ_t denotes aggregate profits accruing to the household from the ownership of domestic firms. The nominal interest rate on foreign currency bonds is determined by an exogenous foreign risk-free rate R_{Ft}^* and a debt-elastic interest premium

$$R_t^* = R_{Ft}^* \exp\left(-\xi \left(B_t^* - \overline{B}^*\right)\right) \tag{5}$$

where $\overline{B}^*$ is the steady-state value of B_t^*.The parameter ξ is positive implying that borrowing cost increases with the deviation of foreign currency debt level from its steady-state value.

The first-order condition for labor supply is given by

$$\frac{W_t}{P_t} = N_{ht}^{\varphi} \tag{6}$$

which implies that the marginal rate of substitution between labor and consumption is equal to the real wage. [6]

The first-order condition with respect to domestic currency bonds gives rise to the Euler equation

$$\frac{\left(C_t - \frac{N_{ht}^{1+\varphi}}{1+\varphi}\right)^{-\sigma}}{P_t} = \beta \mathbf{E}_t \left[\frac{\left(C_{t+1} - \frac{N_{ht+1}^{1+\varphi}}{1+\varphi}\right)^{-\sigma}}{P_{t+1}} R_t \right] \tag{7}$$

The first-order conditions with respect to domestic and foreign currency bonds give rise to the uncovered interest parity condition

[6] Note that the GHH utility function eliminates the wealth effect on labor supply.

$$\mathbf{E}_t\left[\frac{\left(C_{t+1}-\frac{N_{ht+1}^{1+\varphi}}{1+\varphi}\right)^{-\sigma}}{P_{t+1}}\frac{S_{t+1}}{S_t}R_t^*\right]=\mathbf{E}_t\left[\frac{\left(C_{t+1}-\frac{N_{ht+1}^{1+\varphi}}{1+\varphi}\right)^{-\sigma}}{P_{t+1}}R_t\right] \tag{8}$$

2.2. Entrepreneurs

The representative entrepreneur's utility function is given by

$$\mathbf{E}_0\sum_{t=0}^{\infty}\beta_e^t\ln C_{e,t} \tag{9}$$

where $\beta_e \in (0,1)$ is the discount factor of the representative entrepreneur, and $C_{e,t}$ denotes the consumption. We assume that $\beta_e < \beta$. It implies that the entrepreneur is less patient than the household. The consumption C_{et} is also a CES composite of domestic and foreign consumption goods C_{eHt} and C_{eFt} which is given by

$$C_{et}=\left((1-\upsilon)^{\frac{1}{\eta}}C_{eHt}^{\frac{\eta-1}{\eta}}+\upsilon^{\frac{1}{\eta}}C_{eFt}^{\frac{\eta-1}{\eta}}\right) \tag{10}$$

The representative entrepreneur uses the following Cobb–Douglas production to produce the intermediate good i.

$$Y_t^M=A_tK_{t-1}^{\alpha}N_{et}^{1-\alpha} \tag{11}$$

in which Y_t^M is the output, K_{t-1} is the capital input, N_{et} is the labor input, the parameter $\alpha \in [0,1]$ is the output elasticity of the capital input, and A_t is a common technology shock to all domestic entrepreneurs. We assume that A_t follows the AR(1) process $A_t = \rho A_{t-1} + \varepsilon_t$ in which $\rho \in (-1,1)$ measures the persistence of the productivity shock and ε_t is an i.i.d. innovation to the productivity shock with the standard deviation of the innovation being σ.

The representative entrepreneur faces the following budget constraint

$$P_tC_{et}+P_tI_t+R_{t-1}B_{et-1}=P_{Ht}^MY_t^M-W_tN_{et}+B_{et} \tag{12}$$

in which $B_{et}(i)$ is the matured debt level, P_{Ht}^M is the price of the intermediate good i, the investment $I_t(i)$ is a CES composite of domestic and foreign investment goods $I_{Ht}(i)$ and $I_{Ft}(i)$ which is given by

$$I_t = \left((1-\upsilon)^{\frac{1}{\eta}} I_{Ht}^{\frac{\eta-1}{\eta}} + \upsilon^{\frac{1}{\eta}} I_{Ft}^{\frac{\eta-1}{\eta}} \right) \tag{13}$$

The representative entrepreneur has the access to an investment technology to transform the domestic and foreign final goods to capital input. The law of motion of capital stock is

$$K_t = (1-\delta) K_{t-1} + \left[1 - \frac{\phi_K}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right] I_t \tag{14}$$

in which $\delta \in (0,1)$ is the depreciation rate of the capital, $\phi_K > 0$ is the adjustment cost parameter.

In the spirit of Kiyotaki and Moore (1997) and Iacoviello (2005), the representative household faces the costly contract enforcement problem when lending the income to the entrepreneurs. Thus the representative entrepreneur's borrowing capacity is constrained by a fraction of the value of the collateral asset. To be specific, the representative entrepreneur faces the following credit constraint

$$R_t B_{et} \leq \theta \mathbf{E}_t \left[Q_{K,t+1} K_t \right] \tag{15}$$

in which $Q_{K,t+1}$ is the price of the capital, θ is the fraction of the value of collateral assets. When the representative entrepreneur cannot repay the debt, the representative household can take the collateral asset, i.e. the accumulated capital, away from the representative entrepreneur. However, it is costly for the representative household to liquidate the collateral asset, only θ units of the total value of the collateral asset can be recouped.

The representative entrepreneur chooses $C_{et}, N_{et}, B_{et}, K_t$,and I_t to maximize equation (9) subject to equations (11), (12), (14),and (15).The first-order conditions for the representative entrepreneur's optimization problems are given by

$$\mu_{et} = \frac{1}{P_t C_{et}} \tag{16}$$

$$W_t = (1-\alpha) P_{Ht}^M \frac{Y_t^M}{N_{et}} \tag{17}$$

$$\mu_{et} = \mu_{bt} R_t + \beta_e \mathbf{E}_t \left[\mu_{et+1} R_t \right] \tag{18}$$

$$\mu_{kt} = \beta_e \mathbf{E}_t \left\{ \alpha \mu_{et+1} P_{Ht+1}^M \frac{Y_{t+1}^M}{K_t} + (1-\delta) \mu_{kt+1} \right\} + \theta \mu_{bt} \mathbf{E}_t Q_{K,t+1} \tag{19}$$

in which μ_{et} is the Lagrangian multiplier for the budget constraint (12), μ_{bt} is the Lagrangian multiplier for the credit constraint (15), μ_{kt} is the Lagrangian multiplier for the capital accumulation equation (14).

Equation (16) implies that the marginal utility of income is equal to the marginal utility of consumption. Equation (17) implies that the marginal product of labor input is equal to the real wage. Rearranging equation (18) gives rise to

$$\frac{1}{R_t} = \frac{\mu_{bt}}{\mu_{et}} + \beta_e \mathbf{E}_t \frac{\mu_{et+1}}{\mu_{et}} \tag{20}$$

which means that the credit constraint is binding if and only if the interest rate is lower than the representative entrepreneur's intertemporal marginal rate of substitution.

By purchasing one unit of capital at the price $Q_{K,t}$ in period t, the representative entrepreneur can obtain the following return on the capital from period t to $t+1$

$$R_{K,t+1} = \frac{\alpha P^M_{Ht+1} \frac{Y^M_{t+1}}{K_t} + (1-\delta) Q_{K,t+1} - \theta \mathbf{E}_t Q_{K,t+1}}{Q_{K,t} - \theta \mathbf{E}_t \frac{Q_{K,t+1}}{R_t}} \tag{21}$$

According to equations $(19), (20), (21)$, and the price of the capital $Q_{K,t} = \frac{\mu_{kt}}{\mu_{et}}$, we can obtain the following equation

$$1 = \beta_e \mathbf{E}_t \frac{\mu_{et+1}}{\mu_{et}} R_{K,t+1} \tag{22}$$

2.3. Retailers and final-good producer

There is a continuum of monopolistically competitive retailers of unit mass $[0,1]$.Retailers purchase the intermediate good from the representative entrepreneur in the competitive market and then differentiate the product. After differentiating the intermediate good, retailers sell the differentiated goods to the final-good producer.

Let $Y_t(i)$ be the differentiated good sold by the retailer $i \in [0,1]$.The final-good producer uses a CES production function to produce the final good Y_t

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{23}$$

in which $\varepsilon > 1$ is the elasticity of substitution between differentiated goods.

Solving the final-good producer's cost-minimization problem gives rise to

$$Y_t\left(i\right)=\left(\frac{P_{Ht}\left(i\right)}{P_{Ht}}\right)^{-\varepsilon}Y_t \tag{24}$$

in which $P_{Ht}=\left[\int_0^1 P_{Ht}\left(i\right)^{1-\varepsilon}di\right]^{\frac{1}{1-\varepsilon}}$ is the domestic final-good price.

The retailers adjust the prices subject to nominal inertia in the form of quadratic price adjustment costs as in Rotemberg (1982) .In period t, the retailer $i\in[0,1]$ chooses the price $P_{Ht}\left(i\right)$ to maximize the following profit

$$\mathbf{E}_t\sum_{s=0}^{\infty}\beta^s\frac{\lambda_{t+s}}{\lambda_t}\left\{\left[\frac{P_{Ht+s}\left(i\right)}{P_{t+s}}-\frac{P^M_{Ht+s}}{P_{t+s}}\right]Y_{Ht+s}\left(i\right)-\frac{\phi_P}{2}\left(\frac{P_{Ht+s}\left(i\right)}{P_{Ht+s-1}\left(i\right)}-1\right)^2Y_{t+s}\right\} \tag{25}$$

in which $\phi_P\geq 0$ measures the cost of price adjustments. In the symmetric equilibrium with $P_{Ht}\left(i\right)=P_{Ht}$, the optimal price setting behavior is described by the following equation

$$\frac{P^M_{Ht}}{P_t}=\frac{\varepsilon-1}{\varepsilon}\frac{P_{Ht}}{P_t}+\frac{\phi_P}{\varepsilon}\left(\pi_{Ht}-1\right)\pi_{Ht}-\beta\mathbf{E}_t\frac{\lambda_{t+1}}{\lambda_t}\frac{\phi_P}{\varepsilon}\left(\pi_{Ht+1}-1\right)\pi_{Ht+1}\frac{Y_{t+1}}{Y_t}. \tag{26}$$

in which $\pi_{Ht}=\frac{P_{Ht}}{P_{Ht-1}}$ is the domestic PPI inflation. Equation (26) implies that, when there are no price adjustment costs, the real marginal cost is the inverse of the steady-state markup.

2.4. Monetary policy and equilibrium

The monetary policymaker in the small open economy conducts monetary policy according to a Taylor rule given by

$$R_t=\overline{R}\pi_t^{\phi_\pi}\left(\frac{Y_t}{\overline{Y}}\right)^{\phi_y} \tag{27}$$

in which $\overline{R}=\frac{1}{\beta}$ and $\overline{Y}$ are the nominal interest rate and the output in the steady state, respectively, $\pi_t=\frac{P_t}{P_{t-1}}$is the domestic CPI inflation, $\phi_\pi\geq 0$ is the response coefficient of the nominal interest to the CPI inflation, and $\phi_y\geq 0$ is the response coefficient of the nominal interest to the deviation of the output to its steady-state value.

Different from the standard small open economy model, we consider both consumption openness and production openness. [7] The net export of the

[7]Among many others, a nonexhaustive list of the literature includes: Monacelli 2013, Wang and Zou (2015), and Gong et al. (2016, 2017, 2020, 2023).

small open economy is

$$NX_t = \upsilon \left(\frac{(1+\tau_t^*) P_{Ht}}{P_{Ft}} \right)^{-\eta} Y_t^* - \upsilon \frac{P_{Ft}}{P_{Ht}} \left(\frac{P_{Ft}}{P_t} \right)^{-\eta} (C_t + C_{e,t} + I_t) + \frac{S_t \left(R_{t-1}^* - 1 \right) B_{t-1}^*}{P_{Ht}} \quad (28)$$

in which Y_t^* denotes the consumption of the foreign households. Since the small open economy is negligible relative to the rest of the world, the global goods market clearing condition implies that $C_t^* = Y_t^*$.In addition, τ^* is the tariff levied by the foreign government. Following Caldara et al. (2020),we assume that τ^* follows a first-order autoregressive process with stochastic volatility

$$\tau_t^* = (1 - \rho_{\tau^*}) \tau^* + \rho_{\tau^*} \tau_{t-1}^* + \sigma_{\tau^* t} \varepsilon_{\tau t} \quad (29)$$

in which the parameter $\rho_{\tau^*} \in (-1, 1)$ measures the persistence of the foreign tariff shock, $\tau^* > 0$ is the steady-state value of the foreign tariff shock, $\varepsilon_{\tau t}$ is an i.i.d. innovation to the foreign tariff shock which follows a standard normal process, and the term $\sigma_{\tau^* t}$ is a time-varying standard deviation of the innovation which represents a foreign tariff uncertainty shock. Following the literature on the uncertainty, we assume that the foreign uncertainty tariff shock follows the stationary stochastic process

$$\sigma_{\tau^* t} = (1 - \rho_\sigma) \sigma_{\tau^*} + \rho_\sigma \sigma_{\tau^* t-1} + \sigma_{\sigma_{\tau^*}} \varepsilon_{\sigma_{\tau^*} t} \quad (30)$$

in which $\rho_\sigma \in (-1, 1)$ measures the persistence of the foreign tariff uncertainty shock, $\sigma_{\tau^*} > 0$ is the steady-state value of the foreign tariff uncertainty shock, the term $\varepsilon_{\sigma_{\tau^*} t}$ is an i.i.d. innovation to the foreign tariff uncertainty shock which follows a standard normal process, and the parameter $\sigma_{\sigma_{\tau^*}} > 0$ is the standard deviation of the innovation to the foreign tariff uncertainty shock.

In each period, the current account surplus or deficit implies the increase or decrease in the holdings of foreign bonds. Therefore, the stock of foreign bonds moves according to

$$NX_t = S_t \frac{B_t^* - B_{t-1}^*}{P_{Ht}}$$

In a competitive equilibrium, the markets for the final good, labor, and bonds all clear. The final-good market-clearing condition implies that

$$Y_t = C_{Ht} + C_{et} + I_{Ht} + \upsilon \left(\frac{(1+\tau_t^*)\, P_{Ht}}{P_{Ft}} \right)^{-\eta} Y_t^* + \frac{\phi_P}{2} \left(\frac{P_{Ht}}{P_{Ht-1}} - 1 \right)^2 Y_t \tag{31}$$

The labor market-clearing condition implies that the labor demand is equal to the labor supply

$$N_{ht} = N_{et} \tag{32}$$

The bond market-clearing condition implies that

$$B_t = B_{et} \tag{33}$$

Given the foreign variables $\{R_t^*, R_{Ft}^*, P_t^*, Y_t^*\}_{t=0}^{\infty}$,the exogenous shocks $\{A_t, \tau_t^*, \sigma_{\tau^*t}\}_{t=0}^{\infty}$,a competitive equilibrium consists of sequences of prices $\{P_t, W_t, R_t, Q_{K,t}\}_{t=0}^{\infty}$ and allocations $\{C_t,\ C_{e,t},\ I_t,\ N_{ht},\ N_{et},\ B_t,\ B_{et},\ K_t,\ Y_t\}_{t=0}^{\infty}$ such that (i) the allocations solve the optimization problems of the household and the entrepreneur, and (ii) all markets clear.

3. ECONOMIC IMPLICATIONS OF THE FOREIGN TARIFF SHOCK UNCERTAINTY

In this section, we calibrate the model parameters and then simulate the model to examine the impulse responses of macroeconomic variables to the foreign tariff uncertainty shock .

3.1. Calibration

The length of one period is set to be one quarter.The parameter values used in the simulation are given in Table 1. The subjective discount factor of the household β is set to be 0.99, implying that the annual real interest rate is 4% in the steady state. Following Iavoviello (2005) , we set the subjective discount factor of the entrepreneur β_e to be 0.98, implying that the entrepreneur's internal rate of return is twice as large as the annual real interest rate in the steady state. The coefficient of relative risk aversion σ is chosen to be 2 which is the standard value used in the literature. According to Caldara et al. (2020), we set $\varphi = 1$, implying the Frisch elasticity of labor supply is also 1. We calibrate the degree of trade openness υ according to Chinese consumption and import data, with the sample range from 2000:Q1-2021:Q4. The ratio of import to consumption ranges from 0.14 to 0.29, thus we take the average value of 0.22 as the degree of trade openness.

Following Song et al. (2011) ,we set the output elasticity of the capital input α to be 0.5, and the depreciation rate of the capital δ to be 0.025. The

TABLE 1.

Parameter values in the benchmark case

	Parameter	Value
Household's discount factor	β	0.99
Entrepreneur's discount factor	β_e	0.98
Coefficient of relative risk aversion	σ	2
Frisch elasticity of labor supply	φ^{-1}	1
Degree of trade openness	υ	0.22
Output elasticity of the capital input	α	0.5
Depreciation rate of the capital	δ	0.025
Capital adjustment cost parameter	ϕ_K	10
Elasticity of substitution between domestic and foreign consumption goods	η	3
Elasticity of substitution between differentiated goods	ε	10
Price adjustment cost parameter	ϕ_P	105
Fraction of the value of collateral assets	θ	0.89
Response coefficient of the nominal interest to inflation	ϕ_π	1.5
Response coefficient of the nominal interest to output	ϕ_y	0.2

capital adjustment cost parameter ϕ_K is set to be 10 which is consistent with Caldara et al. (2020).According to Davis and Presno (2017) , we set the elasticity of substitution between domestic and foreign consumption goods η to be 3. Consistent with Chang et al. (2019), the elasticity of substitution between differentiated goods ε is set to be 10, implying an average markup of 11%. The price adjustment cost parameter ϕ_P is set to be 105 such that the average duration of price contracts is three quarters. Following Iavoviello (2005) ,we set the fraction of the value of collateral assets θ to be 0.89. The response coefficient of the nominal interest to the CPI inflation ϕ_π and the response coefficient of the nominal interest to the deviation of the output to its steady-state value ϕ_y are set to be 1.5 and 0.2, respectively.

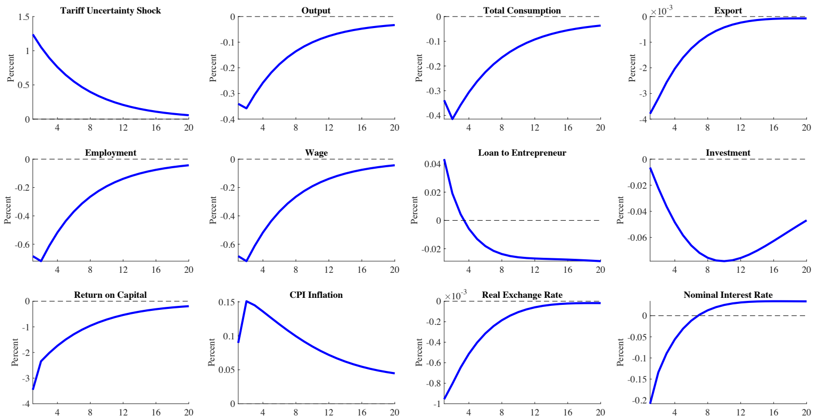
We follow Ruge-Murcia (2012) to use the simulated method of moments to calibrate the parameters associated with the shocks. To be specific, we define the structural parameters $\Theta = \{\rho, \rho_{\tau^*}, \rho_\sigma, \sigma_{\tau^*}, \sigma_{\sigma_{\tau^*}}\}$ and estimate them by using five quarterly Chinese time series: the real per capita output, the real per capital consumption, the real average wage, the real export, CPI inflation. The sample covers the period from 2000:Q1 to 2021:Q4. [8]

3.2. Effects of the foreign tariff uncertainty shock

In the spirit of Pfeifer and Born (2014) and Basu and Bundick (2017) , we perform a third-order Taylor series approximation to the equilibrium sys-

[8]To focus on the effects of the foreign tariff uncertainty shock, we assume that $\sigma = 0$.

FIG. 1. Impulse responses to the foreign tariff shock and the foreign tariff uncertainty shock



tem and then analyze the resulting impulse responses of the main macroeconomic variables to the foreign tariff uncertainty shock. Figure 1 presents the impulse responses of the main macroeconomic variables following the foreign tariff uncertainty shock. As shown in Figure 1, a rise in the foreign tariff uncertainty shock leads to a sizable decline in export which reduces the demand for domestic output. The entrepreneur responds to the decrease in domestic demand by lowering the inputs of capital and labor, with the result that wage and the return on capital fall. The decline in the labor demand and wage leads the household to reduce the demand for domestic output further, implying a new round of recession. In addition, the decrease in capital demand and the return on capital triggers the amplification effect of the financial frictions, which reinforces the previous dampening effect of the foreign tariff uncertainty shock and pushes the economy toward recession further.

However, due to the presence of sticky prices, the retailers face an upward pricing bias following the foreign tariff uncertainty shock. Accordingly, the retailers increase the prices to avoid the losses caused by the foreign tariff uncertainty. Thus the CPI inflation rises when the foreign tariff uncertainty shock occurs. The nominal interest rate adjusts according to the Taylor rule. The rise in the CPI inflation implies that the nominal interest rate goes up, but at the same time, the fall in output brings the nominal interest rate down. In our calibrated model, the latter effect gains the upper hand initially with the result that the nominal interest rate goes down when the foreign tariff uncertainty shock occurs. However, after about seven periods, the former effect dominates so that the nominal interest rate begins to go up. The initial decrease in the nominal interest rate reduces the borrowing cost facing the entrepreneur, thus the entrepreneur increases the borrowing from the household in spite of the fact that the economy is in the recession. When the dampening effect gets larger, the entrepreneur changes the borrowing decision and the borrowing from the household falls. In addition, given the foreign price level, the increase in the domestic price level implies real exchange rate appreciation.

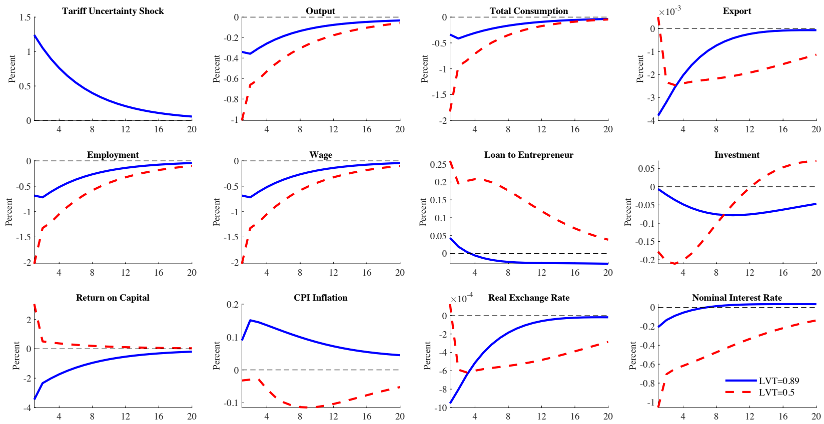
To examine the implications of financial frictions for the economic dynamics, we compare two alternative cases in which the degree of tightness of credit constraint is different. Since the fraction of the value of collateral assets θ measures the degree of tightness of credit constraint, we choose a different value of θ to make a comparison with the benchmark case in which we follow Iavoviello (2005) and set θ to be 0.89. In the counterfactual experiment, we set θ to 0.5 to represent another case in which the credit constraint is tighter. Figure 2 shows the impulse responses of the main macroeconomic variables following the foreign tariff uncertainty shock for two cases. The blue solid line represents the benchmark case and the red dashed line represents the case in which the credit constraint is tighter.

As shown in Figure 2, the degree of fluctuations in the main macroeconomic variables is different when the degree of tightness of credit constraint is different. Generally speaking, when credit constraint is tighter, the degree of fluctuations in the main macroeconomic variables is larger. It is evident that the degree of decrease in output, total consumption, employment, and wage is larger in the counterfactual experiment than that in the benchmark case.

When credit constraint is tighter, the dampening effect of the foreign tariff uncertainty shock is bigger than the benchmark case with the result that the degree of decrease in the demands for domestic output is larger. In this case, the depressing effect of lower demands for domestic output outweighs the upward pricing bias, leading to a decrease in CPI inflation. According to the Taylor rule, the degree of the decrease in the nominal interest rate is larger in the counterfactual experiment, leading to a rise in the borrowing of the entrepreneur from the household. However, due to a greater dampening effect from the lower demands for domestic output, the entrepreneur's investment goes down initially. After about twelve periods, the effect of the rise in borrowing is larger than the dampening effect from the lower demands for domestic output with the result that the entrepreneur's investment begins to increase. The fall in the investment reduces the amount of capital, thus the return on capital rises in the counterfactual experiment.

The degree of depreciation in the nominal exchange rate is larger as a result of the lower nominal interest rate in the counterfactual experiment than in the benchmark case. In spite of the fact the CPI inflation falls in the counterfactual experiment, the real exchange rate still depreciates. Though

FIG. 2. Impulse responses of the main macroeconomic variables to the foreign tariff uncertainty shock for the benchmark case and the counterfactual experiment.



the fall in the CPI inflation cannot counterbalance the depreciation in the nominal exchange rate, it takes effect and the degree of the depreciation in the real exchange rate is smaller in the counterfactual experiment than in the benchmark case. The response of export mirrors the response of the real exchange rate.

3.3. Monetary policy rule

In this section, we consider two types of monetary policy rule and analyze which type of monetary policy rule performs better in the small open economy buffeted by the foreign tariff uncertainty shock. The first rule that we have already analyzed in the benchmark case is the CPI inflation targeting rule. For the sake of convenience, we copy it as follows

$$R_t = \overline{R}\pi_t^{\phi_\pi}\left(\frac{Y_t}{\overline{Y}}\right)^{\phi_y} \tag{27}$$

The second rule, referred to as the PPI inflation targeting rule, has the nominal interest rate to respond to PPI inflation and the deviation of the output to its steady-state value. To be specific, the PPI inflation targeting rule is specified as

$$R_t = \overline{R}\pi_{Ht}^{\phi_\pi}\left(\frac{Y_t}{\overline{Y}}\right)^{\phi_y} \tag{34}$$

We evaluate the performance of the above two monetary policy rules by comparing the volatility in the main macroeconomic variables. We report

TABLE 2.

Properties of simple policy rules

	CPI inflation targeting	PPI inflation targeting
$\sigma(Y)$	0.1032	0.6498
$\sigma(C)$	0.1197	0.7606
$\sigma(N)$	0.2221	0.9653
$\sigma(I)$	0.0195	0.6187
$\sigma(EX)$	0.0011	0.0113
$\sigma(\pi_t)$	0.0342	0.6710
$\sigma(\pi_{Ht})$	0.0407	0.6196

the results in the Table 2.[9] As shown in Table 2, the CPI inflation targeting rule performs better than the PPI inflation targeting rule in the sense that the former can stabilize the economy better than the latter. Gali and Monacelli (2005) draw the same conclusion in a small open economy model with no financial frictions and the foreign tariff uncertainty shock.

4. CONCLUSION

This paper introduces the foreign tariff uncertainty shock in a small open economy model with financial frictions to examine the economic implications of the foreign tariff uncertainty shock for the fluctuations in the main macroeconomic variables and monetary policy. We find that a rise in the foreign tariff uncertainty shock leads to a sizable decline in the main macroeconomic variables except for CPI inflation. In addition, when credit constraint is tighter, the degree of fluctuations in the main macroeconomic variables is larger. In the presence of the foreign tariff uncertainty shock, the CPI inflation targeting rule performs better than the PPI inflation targeting rule in the sense that the former can stabilize the economy better than the latter.

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[9]In Table 2, EX denotes export and its value is $\upsilon\left(\frac{(1+\tau_t^*)P_{Ht}}{P_{Ft}}\right)^{-\eta}Y_t^*$.

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