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Daisuke Ida

ida-dai@andrew.ac.jp

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桃山学院大学
Momoyama Gakuin University

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Asset price stabilization and cost channel in a two-country new Keynesian model

Daisuke Ida*

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Abstract

This paper studies the role of asset price stabilization in a two-country model with incomplete loan rate pass-through. We find that when financial market imperfections are present in the foreign country, world equilibrium determinacy is achieved if home and foreign central banks set smaller weights on asset price stabilization. When the foreign central bank reacts more aggressively to inflation in its own country, it can cause the worldwide rational expectations equilibrium (REE) to become more determinate by placing a more aggressive weight on asset price stabilization. However, irrespective of any combinations of inflation and asset price stabilization in the foreign country, the worldwide REE becomes indeterminate if the home central bank reacts more aggressively to domestic asset prices.

Keywords: Incomplete pass-through of the loan rate; Cost channel; Asset price stabilization; Monetary policy; Two-country model;
JEL classification: E52; E58; F41

*Department of Economics, Momoyama Gakuin University, 1-1, Manabino, Izumi, Osaka 594-1198, Japan. Tel.: +81-725-54-3131. E-mail: ida-dai@andrew.ac.jp

1 Introduction

The objective of this paper is to explore the role of asset price stabilization in a two-country new Keynesian (NK) model with incomplete pass-through of the loan rate. A large number of studies have focused on the role of asset price stabilization in monetary policy analyses. Some studies point out that monetary policy should react to a fluctuation in asset prices that deviate from their fundamental values (Cecchetti et al., 2003; Haugh, 2008). There are studies that assert that the central bank does not have to stabilize fluctuations in asset prices if monetary policy includes a strong reaction to inflation rate. (Bernanke and Gertler, 1999; Carstrom and Furest, 2007; Faia and Monacelli, 2007; Gertler and Leahy, 2002; Iacoviello, 2005). Contrary to these studies, some studies argue that the central bank may obtain gains from asset price stabilization (see Airaudo et al., 2013; Gali, 2014; Gambacorta et al., 2014; Kannan et al., 2012; Pfajfar and Santoro, 2014).

These papers focused mainly on the case of a closed economy. But the aftermath of the global financial crisis, which originated in the United States (US), revealed that a change in asset prices in one country can spill over into other countries. However, it is unclear whether central banks aim to stabilize asset prices may render the world economy indeterminate. The Taylor principle is required to satisfy the unique rational expectations equilibrium (REE) in a closed economy (Bullard and Mitra, 2002). Llosa and Tuesta (2009) showed that the presence of a cost channel renders the determinacy condition needed to achieve the unique REE more complicated. While Linnemann and Schabert (2006), Bullard and Singh (2008), and Bullard and Schaling (2009) investigated the determinacy condition in an open economy model, these papers abstracted the role of the cost channel.

Recently, Mcknight and Mihailov (2015) examined the role of real money balances in a two-country sticky price model. They showed how a departure from the separable utility function between consumption and real money balances significantly changed the world determinacy condition under forecast-based monetary policy rules. Ida (2019) examined the impact of an incomplete loan rate pass-through using a two-country model

and found that an incomplete loan rate pass-through significantly affected the worldwide equilibrium determinacy.

The results obtained in this paper are summarized as follows. First, we find that when financial market imperfections are present in the foreign country, world equilibrium determinacy is achieved—as long as home and foreign central banks set smaller weights on asset price stabilization. Worldwide equilibrium determinacy is not achieved when financial market imperfections are considerably severe in the foreign country. This result indicates that a smaller weight on asset price stabilization becomes an effective tool for stabilizing the effect of a sunspot shock on the real economy.

Second, we explore the case in which home and foreign central banks cooperatively employ a stronger response to inflation rates, which leads to a unique worldwide REE. If the foreign central bank reacts more aggressively to inflation in its own country, it can make the worldwide REE more determinate by placing a more aggressive weight on asset price stabilization. However, irrespective of any combinations of inflation and asset price stabilization in the foreign country, the worldwide REE becomes indeterminate if the home central bank reacts more aggressively to domestic asset prices.

Third, this paper shows that even in the case in which an interest rate response to asset prices in each country can be effective, home and foreign central banks fail to achieve the worldwide equilibrium determinacy if either the home or foreign central bank reinforces a policy reaction to its own output gap. In contrast to previous studies, this study emphasizes that a larger weight on asset price stabilization in both countries easily makes the worldwide REE indeterminate when either central bank responds too strongly to its own output gap in a two-country model. Nistico (2012) showed the effectiveness of reacting to asset price growth in a perpetual youth NK model, whereas Di Giorgio and Nistico (2007) argued that such a rule may lead to equilibrium instability in a two-country NK model with wealth effects. On the other hand, this paper shows the gain that can be realized from the foreign central bank stabilizing its asset price growth in that it can expand worldwide determinacy regions.

Fourth, we also examine how the presence of asset price stabilization in each country

affects the transmission mechanism of structural shocks and volatility in macrovariables. In contrast to the case in which the central bank does not react to stock prices, volatility in both output and stock prices declines when each central bank stabilizes its own asset prices. On the other hand, in such a case, each central bank has to accept an increase in its own inflation. Thus, even when central banks employ asset price stabilization as a policy rule, they will not be able to overcome the policy trade-off between inflation and output stabilization. Importantly, we demonstrate that worldwide volatility can be reduced when the foreign central bank only stabilizes its asset price growth.

Finally, we mention the introduction of financial market imperfections as motivated by the work of Chowehury et al. (2006). The objective of this paper is to show equilibrium determinacy when both home and foreign central banks simultaneously react to its own asset prices in a two-country model with incomplete pass-through of the loan rate. To do this, it is useful to employ a tractable two-country NK model.[1] Of course, the proposed model recognizes that the introduction of financial market imperfections motivated by Chowehury et al. (2006) is actually a shortcut. Nevertheless, in this paper, we would like to address the fact that this shortcut does have some merits in this paper. First, we can construct a tractable two-country NK model due to a simple expression of loan rate dynamics. Such simplification renders the international transmission mechanism of structural shocks intuitively understandable. Second, as argued in previous studies, the loan rate curve in this paper corresponds to the reduced form of a microfoundated loan rate curve (Kobayashi, 2008; Teranishi, 2015). Third, as mentioned by Chowdhury et al, (2006), the specification might simply be regarded as a reduced-form of a financial accelerator effect.

The remainder of this study is constructed as follows. Section 2 briefly reviews the literature related to this study. Section 3 describes a log-linearized two-country NK

[1]Several scholars have focused on the role of the credit channel or the collateral channel in a medium-scale open economy (Dedola and Lombardo, 2012; Devereux and Yetman, 2010; Faia, 2008). Kolsa and Lombardo (2011) analyzed optimal monetary policy in a medium-scale two-country model with a credit channel, as argued by Bernanke et al. (1999). However, the models considered in the above studies appear to be large-scale and, therefore, feature more complicated structures.

model in the presence of financial market imperfections. Section 4 calibrates the deep parameters. Section 5 reports the main results of this paper. Section 6 briefly concludes.

2 Related literature

This section briefly reviews the literature related to our study and clarifies how this study is related to previous studies in terms of examining the role of asset price stabilization.[2] It has been a subject of debate whether or not central banks should react to fluctuations in asset prices. Bernanke and Gertler (1999) asserted that, based on the framework developed by Bernanke et al. (1999), the central bank should not stabilize asset prices unless they affect an increase in future inflation expectations. On the contrary, Cecchetti et al. (2003) argued that the central bank should respond to asset prices as a precaution because the bursting of asset price bubbles can cause a severe economic stagnation. Gali (2014) argued that optimal monetary policy would consider the balance between stabilization of the real economy and stabilization of the bubble itself, in the presence of asset price bubbles, in an over-lapping generations model with nominal rigidities.

In terms of the theoretical aspects of the NK model, no consensus regarding this issue has been reached.[3] For instance, several studies support the assertion of Bernanke and Gertler (1999) (see Carlstrom and Fuerst, 2007; Gilchrist and Saito, 2002; Faia and Monacelli, 2007; Iacoviello, 2005).[4] These studies argue that the central bank can stabilize the economy if it reacts strongly to the inflation rate. Thus, the response to

[2]This paper focuses on the role of asset price stabilization whereas several other papers consider the role of macro-prudential policy in an open economy (e.g., Davis and Presno, 2017). We would like to consider the relationship between asset price stabilization and macro-prudential policy as a future work.

[3]Castelnuovo and Nistico (2012) argued that the inclusion of a stock-price gap in the monetary policy rule is consistent with post-WWII stock market boom and bust cycles by using a dynamic stochastic general equilibrium (DSGE) model with Bayesian techniques.

[4]Nistico (2012) showed that in a Blanchard-Yaari NK model, responding to a deviation in stock prices from their target levels induces equilibrium indeterminacy, whereas responding to a growth in stock prices can avoid the indeterminacy problem. See Piergallini (2006) and Nistico (2012) for a detailed derivation of the Blanchard-Yaari NK model.

asset prices in the policy rule is redundant when the central bank aggressively raises the policy rate in response to inflation.

On the other hand, there are previous studies that assert that the central bank can obtain gains from asset price stabilization (see Airaudo et al., 2013; Gambacorta et al., 2014; Kannan et al., 2012; Pfajfar and Santoro, 2014).[5] For instance, Airaudo et al. (2013) showed that a mild response to asset prices in a monetary policy rule can achieve a unique REE and rule out non-fundamental volatility in an NK model with financial market imperfections. As suggested by Kannan et al. (2012), when the model contains heterogeneities of households, the central bank can obtain gains by implementing an augmented monetary policy rule that contains both asset price stabilization and a macro-prudential tool such as a credit growth rate.

The above studies focused on the case of a closed economy model. However, the global crisis, which originated in the US, led to severe economic stagnation, mainly centered around the economies of developed countries. As far as we know, very few studies have examined whether or not central banks should react to asset prices in *an open economy NK model*. It is unclear whether the home central bank should aim to stabilize asset prices, given a foreign monetary policy rule. Also, should the home central bank react to both home and foreign asset prices?

Lim and McNeris (2007) examined the role of asset price stabilization in a small open economy. They focused on the Tobin's Q channel that implied the effect of Tobin's Q on the real economy through a firm's investment decisions. They argued for the effectiveness of asset price stabilization in monetary policy rules under the Tobin's Q channel. Di Giorgio and Nistico (2007) answered these questions in a two-country NK model.[6] According to their model, the stock market is constructed only in the foreign country. Therefore, their question is whether the home central bank should stabilize the movement in *foreign* asset prices. They showed that the inclusion of foreign asset

[5]See also Airaudo (2013a, 2013b).

[6]Their model is based on the Blanchard-Yaari NK model because they focused on the effect of the wealth channel of stock prices on the real economy.

prices in domestic monetary policy rules can lead to preferable outcomes in terms of equilibrium determinacy and the volatility of macrovariables.

Ida (2011) examined the effectiveness with which the home central bank can respond to both home and foreign asset prices in a two-country model. Ida (2013) explored the role of asset price stabilization in a two-country model with local currency pricing and illustrated the gains from employing asset price stabilization. Ida (2011, 2013) also focused on the role of Tobin's Q channel in a two-country model. According to his study, the gain from such a monetary policy rule is not realized if the monetary policy rule contains a strong response to output. Ida (2015) compared a Taylor rule and asset price growth with several alternative rules, such as nominal gross domestic product growth targeting, exchange rate targeting, and so on. However, the above studies did not focus on the case in which each central bank takes stabilization of its own asset prices into consideration in a two-country model.

The contribution of this paper is to demonstrate worldwide equilibrium determinacy when both home and foreign central banks simultaneously react to their own asset prices in a two-country model with incomplete pass-through of the loan rate. This paper is related to Di Giorgio and Nistico (2007), Ida (2011, 2013), and Pfajfar and Santoro (2014). Our study differs as follows. First, while Di Giorgio and Nistico (2007) explored the case of wealth effects of foreign asset prices, this paper focuses on the supply side of asset price fluctuations. Furthermore, in contrast to Di Giorgio and Nistico (2007), this paper considers the role of incomplete loan rate pass-through associated with the cost channel. Second, while Di Giorgio and Nistico (2007) demonstrated how an asset price rule in the home country affects equilibrium determinacy in each country, we show the case in which each central bank stabilizes its own asset prices and thus changes worldwide equilibrium determinacy. Third, Pfajfar and Santoro (2014) demonstrated that the gain from employing an asset price rule occurs in the presence of incomplete pass-through of the loan rate, whereas this paper asks the question whether or not each central bank should aim to stabilize its own asset prices in a two-country model with financial market imperfections. Fourth, in contrast to Ida (2011, 2013), this paper

considers the relationship between the degree of imperfect pass-through of the loan rate and asset price stabilization in terms of worldwide equilibrium determinacy.

3 A two-country NK model with incomplete pass-through of loan rates

This paper incorporates the simple financial market friction associated with a cost channel into a two-country framework. The model in this paper is based on Ida (2015).[7] Consider an economy with two large symmetrical countries: home and foreign. There are two production sectors in each country. The final goods sectors are characterized by perfect competition. The firms in intermediate goods sectors face monopolistic competition and Calvo-type (1983) nominal price rigidity.

In addition, for intermediate firms to pay employee wages, they must borrow funds from financial intermediaries that are located in the home country. Following Ravenna and Walsh (2006) and Chowdhury et al. (2006), this paper introduces the role of financial intermediaries into the model. Financial intermediaries receive deposits from domestic households and lend funds to domestic firms. When financial intermediaries lend funds to intermediate goods producers, they incur a monitoring cost.

Our model assumes that there are complete markets in both countries and that households in both countries can trade a state-contingent bond both domestically and internationally. Moreover, this paper presumes that only final goods are traded. Finally, unless otherwise noted, analogous equations hold for the foreign country. Foreign variables are expressed with an asterisk.

3.1 A log-linearized two-country model

The log-linearization of the system is implemented around the steady state. A log-linearized variable around the steady state is expressed by $\hat{H}_t = \log(H_t/\bar{H})$, where $\bar{H}$

[7]The technical appendix provides a detailed derivation of a two-country NK model with incomplete pass-through of the loan rate. See also Ida (2015, 2019).

represents a steady-state value. Additionally, to express in terms of log-deviation from their flexible price equilibrium counterparts, we introduce the following notation:

$$q_t = \hat{Q}_t - \hat{Q}_t^f;\ y_t = \hat{Y}_t - \hat{Y}_t^f;\ \eta_t = \hat{\Gamma}_t - \hat{\Gamma}_t^f,$$

where $\hat{Q}_t$ denotes asset prices, $\hat{Y}_t$ represents aggregate output, and $\hat{\Gamma}_t$ denotes the dividend. The superscript f denotes the log-deviation of the natural level.

The log-linearized Euler equation for stock prices is given as follows:

$$q_t = (1-\beta)\eta_t + \beta E_t q_{t+1} - \beta(\hat{R}_t - E_t\pi_{t+1}), \tag{1}$$

The parameter β denotes the discount factor. The second term on the right-hand side indicates that future stock prices affect current stock prices. The third term on the right-hand side of Equation (1) is the real interest rate. As we will show, stock prices in the home country are indirectly influenced by movements in the foreign output gap through domestic dividends.

The log-linearization of dividends from firms to stockholders is expressed as follows:

$$\hat{\Gamma}_t = \hat{Y}_t - (\theta-1)\hat{\varphi}_t.$$

Parameter θ is the elasticity of substitution for individual goods, which parameter satisfies $\theta > 1$. Using the definition of the dividend gap and substituting the real marginal cost into the above equation, we obtain

$$\eta_t = [1-(\theta-1)(\sigma+\phi-\chi)]y_t - (\theta-1)\chi y_t^* - (\theta-1)\hat{R}_t^L, \tag{2}$$

where $\chi = \vartheta\Omega^{-1}$, $\vartheta = 2\gamma(1-\gamma)(\sigma a-1)$, and $\Omega = 4\gamma(1-\gamma)(\sigma a-1)+1$. The parameter a denotes elasticity of substitution between domestic and foreign consumption goods and the parameter γ represents the degree of trade openness. σ and ϕ are positive parameters, which are explained in section 4. $\hat{R}_t^L$ denotes the loan rate associated with the presence of the cost channel.

In contrast to the framework set forth by Pfajfar and Santoro (2014), there is a spillover effect in an open economy on firm's dividends to domestic stockholders. This effect is captured by the second term of the right-hand side. Thus, it follows from

Equation (2) that the foreign output gap influences the domestic dividends through the terms of trade and consumption risk-sharing. For instance, the foreign output gap reduces domestic dividends when the parameter σa takes a value above unity. The foreign output gap increases domestic dividends when the parameter σa takes a value less than unity. These effects disappear when the parameter σa takes unity. Thus, the foreign output gap affects domestic stock prices through domestic dividends—as long as the parameter σa is not unity.

Next, the log-linearized lending rate is given as follows:

$$\hat{R}_t^L = (1 + \psi_r)\hat{R}_t + \nu_t, \tag{3}$$

where ψ_r represents the degree of lending rate pass-through.[8] An exogenous loan rate shock ν_t is incorporated into the model. The financial market disturbance ν_t follows an AR (1) process given by $\nu_t = \rho_\nu \nu_{t-1} + \epsilon_t^\nu$ with $0 \leq \rho_\nu < 1$, where ϵ_t^ν is an i.i.d shock with constant variance σ_ν^2.

It follows from Equation (3) that the lending rate deviates from the policy rate as pass-through of the lending rate becomes incomplete: the higher the value of the parameter ψ_r, the more incomplete the interest rate pass-through becomes. As indicated in the closed economy model, it is possible that when the economy faces severe financial market imperfections, monetary tightening might easily increase the inflation rate through the supply side effect of monetary policy. Note that, as in Ravenna and Walsh (2006), a wedge between the lending rate and the policy rate disappears when $\psi_r = 0$ if an exogenous loan rate shock is not present.

Inflation adjustment is depicted by the new Keynesian Phillips curve (NKPC), which plays an important role in inflation dynamics. Following Calvo (1983), price rigidity is assumed to exist in the intermediate goods sector. Thus, a fraction $1 - \omega$ of all firms adjusts their prices, whereas the remaining fraction of firms ω do not. An open-economy NKPC expressed in terms of the real marginal cost is given by

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa \hat{\varphi}_t, \tag{4}$$

[8] See Chowdhury et al. (2006) for a detailed discussion of Equation (3).

where $\kappa = (1-\omega)(1-\omega\beta)/\omega$ and $\pi_{H,t}$ is producer price inflation.

The real marginal cost in an open economy is given as follows:

$$\hat{\varphi}_t = \hat{R}_t^L + (\sigma + \phi - \chi)y_t + \chi y_t^*, \tag{5}$$

As shown in Ravenna and Walsh (2006) and Chowdhury et al. (2006), real marginal cost depends on the lending rate in an economy with a cost channel. Moreover, the foreign output gap affects the real marginal cost through the terms of trade and consumption risk sharing in an open economy. As discussed in Clarida et al. (2002) and Pappa (2004), there exist externalities associated with an open economy as long as the parameter σa is not unity. If $\sigma a > 1$, domestic and foreign goods are substitutes in the Pareto-Edgeworth sense. In this case domestic inflation increases in response to an increase in the foreign output gap because a positive output gap in the foreign country induces an increase in the domestic real marginal cost. On the other hand, if $\sigma a < 1$, the two goods are complements. This implies that the domestic inflation rate declines because a positive foreign output gap reduces the domestic marginal cost. As mentioned earlier, these effects cancel each other out when the parameter σa takes the value of unity. Substituting Equation (5) into Equation (4), an open-economy NKPC expressed in terms of the output gap is derived as follows:

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa[\hat{R}_t^L + (\sigma + \phi - \chi)y_t + \chi y_t^*], \tag{6}$$

The dynamic investment-savings curve, which is derived from the representative household's Euler equation for optimal consumption, is given by:

$$y_t = E_t y_{t+1} + \frac{\sigma\vartheta}{\Omega}(E_t y_{t+1}^* - y_t^*) - \sigma_0^{-1}(\hat{R}_t - E_t\pi_{H,t+1} - \hat{R}_t^f), \tag{7}$$

where $\sigma_0 = \sigma(1+\vartheta)/\Omega$.

3.2 Flexible price equilibrium

The set of variables under flexible price equilibrium is given as follows:

$$\hat{R}_t^f = \sigma_0 \vartheta (E_t \hat{Y}_{t+1}^{f*} - \hat{Y}_t^{f*}) + \sigma_0 (E_t \hat{Y}_{t+1}^f - \hat{Y}_t^f), \tag{8}$$

$$\hat{Q}_t^f = (1-\beta)\hat{\Gamma}_t^f + \beta (E_t \hat{Q}_{t+1}^f - \hat{R}_t^f), \tag{9}$$

$$\hat{\Gamma}_t^f = \hat{Y}_t^f, \tag{10}$$

$$(\sigma + \phi - \chi)\hat{Y}_t^f + \chi \hat{Y}_t^{f*} + \hat{R}_t^f = (1+\phi) Z_t, \tag{11}$$

where the superscript f denotes the log-deviation of the natural level. Equation (8) represents the open economy natural rate of interest that holds the real interest rate under flexible-price equilibrium. Equations (9) and (10) are stock prices and dividends under flexible price equilibrium. Equation (11) describes the natural rate of output in an open economy model. In contrast to the natural rate of output shown in Clarida et al. (2002), the natural rate of output in the home country depends on the natural level of the lending rate.

3.3 Monetary policy rules

To close the model, we describe the monetary policy rules used in this study. This study employs the standard monetary policy rule suggested by Taylor (1993). In particular, we consider whether each central bank should react to its own asset prices in terms of equilibrium determinacy and macroeconomic volatility. More specifically, we specify a log-linearized home monetary policy rule as follows:

$$\hat{R}_t = \phi_\pi \pi_{H,t} + \phi_y y_t + \phi_q q_t + u_t, \tag{12}$$

where ϕ_π is the coefficient of the rate of inflation, and ϕ_y is the coefficient of the output gap. Similarly, the foreign monetary policy rule is given by

$$\hat{R}_t^* = \phi_\pi^* \pi_{F,t}^* + \phi_y^* y_t^* + \phi_q^* q_t^* + u_t^* \tag{13}$$

We can employ another specification of the monetary policy rule for asset price stabilization. Equations (12) and (13) state that each central bank responds to a deviation

in asset prices from their flexible-price equilibrium counterparts (Di Giorgio and Nistico, 2007; Nistico, 2012). In addition, the central bank may employ a monetary policy rule with the stabilization of asset price growth (e.g., Nistico, 2010). At this point, this paper explores the benchmark case in which each central bank responds to the deviation of asset prices from their flexible-price equilibrium counterparts.

4 Calibration

This section describes the parameters used in this study. The parameter values used in this paper is are calibrated based on Ida (2015). The degree of price rigidity, ω, is set to 0.75. Following previous studies in the NK literature, the discount factor, β, is set to 0.99. A value of 2.0 is used for the risk aversion coefficient, σ. The elasticity of household labor supply, ϕ, is set to 1.0. The elasticity of substitution between domestic and foreign consumption goods, a, is set to 1.5. With regard to the degree of openness, the value of γ is set to 0.2. The elasticity of substitution for individual goods, θ, is set to 5.0, based on the value calibrated in the existing literature. The calibrated parameters are summarized in Table 1.

[Table 1 around here]

Several studies have reported the value of the degree of financial market imperfection, ψ_r. According to Ravenna and Walsh (2006), the value of the parameter ψ_r is 0.276. Also, Chowdhury et al. (2006) estimated a value of financial market imperfection of 0.32 for the US. Castelnuovo (2007) used the values $\psi_r \in \{0.5, 1.7\}$.[9] Therefore, this paper uses the values $\psi_r \in \{0, 3\}$. This paper assumes a slightly larger value of ψ_r than do previous studies in order to examine how more severe financial imperfections change the international transmission mechanism of structural shocks in one country. In this paper, we mainly focus on how the degree of financial market imperfection in the foreign country affects the home country. Therefore, the degree of financial market imperfections

[9]Castelnuovo (2007) pointed out that a larger value of the parameter ψ_r is likely to generate the price puzzle that an increase in the policy rate increases inflation in the closed economy model.

in the home country is set to 0.2, based on the estimation value obtained in the study by Ravenna and Walsh (2006), whereas we set several values calibrated in the above studies to that of the foreign countries.

We now describe the parameters for the monetary policy rule. As a benchmark, we choose 2.0 and 0 for ϕ_π and ϕ_y for each country, respectively. Finally, with regard to the standard deviation of economic shocks, this paper assumes that σ_ν, σ_z, and σ_u are set to 0.01, respectively. Also, this paper assumes that the parameters ρ_ν, ρ_z, and ρ_u are set to 0.8, 0.8, and 0.5, respectively. Table 1 summarizes the deep parameters calibrated in this study.

5 Asset price stabilization in a two-country economy with the cost channel

This section examines incomplete loan rate pass-through and asset price stabilization in a two-country model. We explore how incomplete pass-through of the loan rate affects the determinacy of the worldwide equilibrium when each central bank stabilizes its own asset prices. In this paper, we define the worldwide equilibrium determinacy as the case in which the REE is achieved in both the home and foreign countries. Accordingly, the worldwide equilibrium is indeterminate if either country faces any indeterminacy problem.

As noted earlier, Bullard and Singh (2008) and Bullard and Schaling (2009) both investigated the determinacy condition in an open economy model. These papers abstracted the role of the cost channel. Di Giorgio and Nistico (2007) demonstrated how an asset price rule in the home country affects equilibrium determinacy in each country; we demonstrate how the case in which each central bank stabilizes its own asset prices changes worldwide equilibrium determinacy. Therefore, the contribution of this paper is in demonstrating how worldwide equilibrium determinacy is achieved when both central banks each care about a fluctuation in its own asset prices in the presence of financial market imperfections.

Section 5.1 investigates how incomplete pass-through of the loan rate affects the determinacy of the worldwide equilibrium when asset price stabilization is considered by home and foreign central banks. Section 5.2 considers how a stronger response to inflation in each central bank changes the results obtained in Section 5.1. Section 5.3 examines the role of output gap stabilization in this two-country economy. Section 5.4 explores worldwide determinacy when central banks employ a monetary policy rule with stabilization of asset price growth. Section 5.5 explores the effect of asset price stabilization on the international transmission mechanism of structural shocks.

5.1 World equilibrium determinacy and asset price stabilization

Figure 1 portrays how the degree of foreign loan rate pass-through changes the world equilibrium determinacy regions under several parameterizations of ϕ_q and ϕ_q^*. When financial market imperfections are present in the foreign country, the world equilibrium is uniquely determinate—as long as both the home and foreign central banks set asset price stabilization to less than 0.2. It follows from Figure 1 that the reaction of home asset prices ϕ_q is smaller than that of ϕ_q^*. When $\psi_r^* = 0.5$, given for the value of ϕ_q, a value of ϕ_q^* that takes 0.15 renders the world equilibrium indeterminate. In particular, when $\psi_r^* = 1.0$, a combination of a sufficiently smaller value of ϕ_q and ϕ_q^* renders the world equilibrium indeterminate. In the case in which the incomplete loan rate pass-through is very severe in the foreign country (i.e., $\psi_r^* = 1.5$), only a combination of a very narrow range of ϕ_q and ϕ_q^* can yield equilibrium determinacy. Thus, Figure 1 indicates that a larger value of ψ_r^* drastically shrinks the worldwide determinacy regions. These results are not observed in previous studies that focused on the role of asset price stabilization in an economy with financial market imperfections (e.g., Airaudo, 2013; Bernanke and Gertler, 2001; Nistico, 2010; Pfajfar and Santoro, 2014).

[Figure 1 around here]

The intuition from this result is as follows. Suppose that a sunspot shock that induces

a boom in both inflation and output occurs in the foreign country. In the case of severe incomplete loan rate pass-thorough, monetary tightening in reaction to a sunspot shock results in further inflation through the cost channel. As shown in Llosa and Tuesta (2009), a sunspot shock is likely to generate equilibrium indeterminacy in the presence of the cost channel. Moreover, in the foreign country, a rise in the inflation rate decreases asset prices via a decline in the dividend. Thus, the presence of the cost channel generates a trade-off between inflation and asset prices. Severe financial imperfections worsen this trade-off. In this case, a rule that puts a smaller weight on asset price stabilization might restrain this channel. However, the foreign country encounters equilibrium indeterminacy because a stronger response to asset prices dampens the rise in the policy rate, amplifying the cost channel induced by a larger value of ψ_r^*.

A sunspot equilibrium that occurred in the foreign country might be transmitted to the home country. A foreign sunspot shock generates downward pressure on domestic inflation and output through an appreciation in the exchange rate. Appreciation in the exchange rate in terms of the home currency leads to a decline in the domestic real marginal cost, reducing domestic inflation. A decline in home inflation increases home asset prices. Severe financial imperfections deteriorate this trade-off via the exchange rate channel. Therefore, while domestic inflation declines, the home central bank increases its policy rate in response to the increase in domestic asset prices. Accordingly, a foreign sunspot shock leads to world equilibrium indeterminacy when both the home and foreign each central banks employ a stronger response to asset price stabilization.

5.2 Stronger response of inflation and asset price stabilization

Figure 2 portrays the case in which both the home and foreign central banks employ a stronger response to inflation when considering the role of asset price stabilization. It turns out that compared to the case depicted in Figure 1, the worldwide determinacy regions expand if both the home and foreign central banks cooperatively employ a stronger response to inflation. Even in this case, depicted in the lower right panel of Figure 2, a unique worldwide REE can be attained if the home and foreign central banks place

a smaller weight on asset price stabilization in the monetary policy rule. This case is still observed when $\psi_r^* = 1.0$. Thus, the worldwide determinacy condition cannot be improved—even if both central banks each react strongly to their own inflation. The case of $\psi_r^* = 1.5$ is prone to generating world equilibrium indeterminacy. For the case of $\psi_r^* = 1.5$, while a stronger response to inflation by each central bank can enlarge the determinacy areas, worldwide equilibrium indeterminacy easily emerges unless each central bank puts a smaller weight on its asset price stabilization.

These results contrast with Bernanke and Gertler (1999) but are consistent with the assertions of Airaudo et al. (2013). However, this paper addresses that the worldwide determinacy condition can be restored when both central banks employ a milder response to its own asset prices in the case where a strong cost channel is present in each country.

[Figure 2 around here]

Next, given values for ϕ_π, consider how the worldwide equilibrium determinacy changes when the foreign central bank increases the value of ϕ_π^*. Figure 3 shows that larger values for ϕ_π^* can make the worldwide REE more determinate when the foreign central bank places a more aggressive weight on asset price stabilization.[10] However, irrespective of any combinations of ϕ_q^* and ϕ_π^*, the worldwide REE becomes indeterminate if the home central bank reacts more aggressively to domestic asset prices for any given value of ϕ_π. The world economy can escape the indeterminacy problem if the foreign central bank that strengthens its response to inflation reinforces the stabilization of its own asset prices. Even in such a case, unfortunately, the home central bank that employs a weaker response to home inflation makes the worldwide REE indeterminate if it reacts strongly to home asset prices.

As noted earlier, Ida (2011) argued that a stronger response to asset prices in the home country can enhance social welfare if the home central bank stabilizes not only domestic asset prices but also foreign asset prices.[11] Di Giorgio and Nistico (2007) showed the

[10]We set $\psi_r = \psi_r^* = 0.2$ in this simulation.

[11]Ida (2013) showed that a stronger response to asset prices increases welfare loss in a two-country model with local currency pricing.

gains achieved when the home central bank responds to foreign asset prices in a two-country economy with a wealth effect for consumption. However, this paper shows that worldwide equilibrium determinacy is not retained when both central banks each employ a larger weight on theirs own asset price stabilization.

[Figure 3 around here]

The intuition from Figures 2 and 3 is as follows. Consider, again, the case in which a sunspot shock occurs in the foreign country. Figure 3 implies that the foreign central bank can obtain additional gains from employing asset price stabilization by placing larger values on ϕ_π^*. This is because the foreign central bank can alleviate the trade-off between inflation and asset prices, which is generated by a severe cost channel as expressed by larger values of ψ_r^*. However, the alleviation of the policy trade-off in the foreign country induces an appreciation in the exchange rate in terms of the home currency. Therefore, given values for ϕ_π and ϕ_x, the home central bank must place a smaller weight on fluctuations in domestic asset prices in order to achieve a unique REE. In fact, the worldwide REE becomes indeterminate when ϕ_q is above 0.15, irrespective of any combinations of ϕ_q^* and ϕ_π^*. In other words, the foreign central bank that responds strongly to inflation can achieve the REE in its country, whereas the home central bank that aggressively stabilizes domestic asset prices fails to generate a unique home REE. As a consequence, a foreign sunspot shock renders the worldwide REE indeterminate whenever the home central bank responds aggressively to domestic asset prices.

5.3 Responses of the output gap and asset price stabilization

We consider the case in which given a value of ϕ_x, the foreign central bank reacts strongly to its output gap. As Figure 4 illustrates, if both central banks stabilize their own asset prices, the worldwide determinacy areas shrink when the foreign central bank puts a stronger weight on the stabilization of its output gap.

[Figure 4 around here]

As shown in Surico (2008) and Llosa and Tuesta (2009), a stronger policy response to the output gap is more prone to creating indeterminacy in the presence of the cost channel. Our result is different from these studies in that it shows that, even in the case in which an interest rate response to asset prices in each country is effective, the home and foreign central banks fail to achieve the worldwide equilibrium determinacy if either the home or foreign central bank employs a stronger policy reaction to its own output gap. In addition, Pfajfar and Santoro (2014) demonstrated the effectiveness of asset price stabilization in an NK model with a cost channel given a response to the output gap. On the other hand, we show that a larger weight on asset price stabilization in both countries easily renders the worldwide REE indeterminate when either central bank responds strongly to its own output gap in a two-country NK model.

5.4 The role of stabilization of the growth rate of asset prices

Finally, this paper considers the role of the stabilization of the asset price growth rate in the monetary policy rule. We assume that the home central bank employs the monetary policy rule (12), whereas the foreign central bank incorporates the stabilization of asset price growth into the monetary policy rule, namely:

$$\hat{R}_t^* = \phi_\pi^* \pi_{F,t}^* + \phi_y^* y_t^* + \phi_q^* (q_t^* - q_{t-1}^*) + u_t^* \tag{14}$$

As mentioned earlier, Nistico (2012) considered that the central bank might employ a monetary policy rule with the stabilization of asset price growth and showed that reacting to asset price growth can alleviate the indeterminacy problem. Di Giorgio and Nistico (2007) also investigated the role of a monetary policy rule that reacts to an asset price growth in a two-country NK model with wealth effects. Accordingly, this paper explores the asymmetrical monetary policy response in terms of asset price stabilization.[12]

Figure 5 plots the worldwide determinacy regions when the foreign central bank employs monetary policy rule (14). In contrast to the case depicted in Figure 1, for a

[12]We can also consider the case in which both central banks employ a monetary policy rule with an asset price growth. The result of this specification is available from the author upon request.

smaller value of ψ_r^*, a foreign asset price growth rule can expand the worldwide determinacy regions. In particular, compared to Figure 1, the case in which the values of ϕ_q^* are above 0.2 leads to a unique REE worldwide unless financial market imperfections are considerably severe in the foreign country. However, in the case of $\psi_r^* = 1.5$, some positive weight on asset price growth in a foreign monetary policy rule can attain the unique worldwide REE if the home central bank puts a smaller weight on asset price stabilization in its monetary policy rule.

[Figure 5 around here]

Nistico (2012) showed the effectiveness of reacting to asset price growth in a perpetual youth NK model, whereas Di Giorgio and Nistico (2007) argued that such a rule might lead to equilibrium instability in a two-country NK model with wealth effects. On the other hand, this paper shows that the gain from the foreign central bank stabilizing its asset price growth in that it can expand the worldwide determinacy regions. In contrast to Di Giorgio and Nistico (2007), our model notes that this gain may be derived from the situation in which stock markets are present in both countries, but they do not interact internationally.

5.5 Asset price stabilization and economic dynamics

This section examines the relationship between asset price stabilization and the international transmission of structural shocks. First, we investigate the impulse response analysis to check the role of asset price stabilization. We consider three cases. The first case assumes that the home and foreign central banks do not care about fluctuations in asset prices. The second case focuses on the case in which a stabilization weight on asset prices is considered only in the home country. The third case presumes that the home and foreign central banks jointly employ a stronger response to asset price stabilization in each country.

Figures 6 and 7 illustrate the impulse responses to both foreign productivity and loan rate shocks. A foreign productivity shock leads to a decline in inflation and an increase

in output in the foreign country. Since the Case III produces a huge decline in foreign inflation, the foreign central bank cuts its policy rate more aggressively. Overall, foreign stock prices seem to be unaffected by any combination of home and foreign asset price stabilization.

[Figure 6 around here]

[Figure 7 around here]

On the other hand, a foreign productivity shock induces a decline in both inflation and output in the home country. It turns out that when each central bank stabilizes asset prices in its own country (thus, Case III), as compared to Case II, a decline in both inflation and output in the home country is alleviated. This is the gain for the home country when each central bank stabilizes asset prices in its own country. This policy implication is also observed in the case of a foreign loan rate shock (e.g., Figure 7).

We also confirm the properties of standard deviations for the three cases. Table 2 shows that, in contrast to the case in which the central bank does not react to stock prices, volatility in both output and stock prices declines when each central bank stabilizes its own asset prices. On the other hand, in such a case, each central bank has to accept an increase in its own inflation. Thus, even when central banks employ asset price stabilization in a policy rule, they cannot overcome the policy trade-off between inflation and output stabilization.

[Table 2 around here]

Previous studies have argued that, for given foreign monetary policy rule, the home central bank that stabilizes its asset prices is able to reduce macroeconomic volatility (e.g., Di Giorgio and Nistico, 2007; Ida, 2011; Ida, 2013). This paper also shows that compared to making no response to asset prices, a monetary policy rule that contains asset price stabilization might achieve more preferable outcomes in terms of stabilization of the output gap, asset prices, and the exchange rate. Importantly, in contrast to previous studies, compared to the case in which the home central bank only stabilizes its

own asset prices, both central banks can obtain welfare gains when they stabilize their own asset prices. As shown in Table 3, this result is robust to the case in which financial market imperfections are severe in the foreign country (i.e., $\psi_r^* = 0.5$).

[Table 3 around here]

Finally, we confirm whether the foreign central bank that stabilizes its asset price growth can reduce volatility in worldwide macrovariables. Figure 8 plots the impulse responses to a foreign productivity shock when the foreign central bank employs different asset price rules. Case I indicates that no central bank responds to their asset prices. Case II assumes that while the home central bank follows a policy rule with no asset price response, the foreign central bank employs one with its asset price growth. Case III implies that the home central bank employs a monetary policy rule that includes stabilization of the asset price gap, whereas the foreign central bank incorporates the stabilization of its asset price growth into its monetary policy rule.

[Figure 8 around here]

Figure 8 illustrates that Case II can lead to preferable outcomes to the other cases because of it counteracts the volatility in worldwide macrovariables. This result can also be confirmed in Table 4. Compared to other regimes, Case II can reduce worldwide volatility in macrovariables. We reconfirm the findings of Di Giorgio and Nistico (2007) in a two-country NK model in which both countries have stock markets.[13]

[Table 4 around here]

6 Concluding remarks

A large number of studies have focused on the role of asset price stabilization in monetary policy analyses. The objective of this paper is to explore the role of asset price

[13]Note, again, that this gain may be derived from the fact that although stock markets are present in both countries, they do not interact internationally.

stabilization in a two-country NK model with incomplete pass-through of the loan rate. We focus on worldwide equilibrium determinacy when both the home and foreign central banks simultaneously react to their own asset prices in a two-country model with incomplete pass-through of the loan rate.

The results obtained in the paper are summarized as follows. When financial market imperfections are present in the foreign country, world equilibrium determinacy is achieved if home and foreign central banks set smaller weights on asset price stabilization. When the foreign central bank reacts more aggressively to inflation in its own country, it can cause the REE to become more determinate by placing a more aggressive weight on asset price stabilization. However, irrespective of any combinations of inflation and asset price stabilization in the foreign country, the worldwide REE becomes indeterminate if the home central bank reacts more aggressively to domestic asset prices.

There are possible future extensions of the work done in this study. We assumed that the exchange rate pass-through is perfectly complete. Thus, the law of one price holds in this model. However, as argued by Corsetti and Pesenti (2001), Monacelli (2005), and Engel (2009), exchange rate pass-through would be incomplete if firms set their export prices based on local currency pricing. It is interesting how financial market imperfection affects an open macroeconomic model in which incomplete exchange rate pass-through is present.

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A Appendix (Not for publication)

This appendix provides the detailed model description used in the paper. As noted earlier, this paper incorporates a simple financial market friction associated with a cost channel into a two-country framework. The model in this paper is based on Ida (2015).

A.1 Households

The consumption index for the domestic country, C_t, is given by

$$C_t = \left[(1-\gamma)^{1/a} C_{H,t}^{(a-1)/a} + \gamma^{1/a} C_{F,t}^{(a-1)/a}\right]^{a/(a-1)}, \tag{A.1}$$

where $C_{H,t}$ denotes consumption of domestic goods and $C_{F,t}$ denotes consumption of foreign goods. The parameter a denotes elasticity of substitution between domestic and foreign consumption goods, and the parameter γ represents the degree of trade openness.

First, households consider an intra-temporal cost minimization problem and derive the demand function for each good:

$$C_{H,t} = (1-\gamma)\left(\frac{P_{H,t}}{P_t}\right)^{-a} C_t, \tag{A.2}$$

$$C_{F,t} = \gamma\left(\frac{P_{F,t}}{P_t}\right)^{-a} C_t, \tag{A.3}$$

where the home country's price index is given by

$$P_t = \left[(1-\gamma) P_{H,t}^{1-a} + \gamma P_{F,t}^{1-a}\right]^{1/(1-a)}, \tag{A.4}$$

where $P_{H,t}$ is the price of domestic goods and $P_{F,t}$ is the price of foreign goods.

Next, we consider the household's dynamic optimization problem. The inter-temporal utility of an infinitely lived representative household is

$$U_t = E_t \sum_{j=0}^{\infty} \beta^j \left(\frac{C_{t+j}^{1-\sigma}}{1-\sigma} - \zeta \frac{N_{t+j}^{1+\phi}}{1+\phi}\right), \tag{A.5}$$

where N_t is the household's labor supply. The parameter β denotes the discount factor, and σ, ζ, and ϕ are positive parameters. The representative household faces the following

budget constraint:

$$P_tC_t + P_tQ_tA_t + M_{t+1} + E_t\mu_{t,t+1}B_{t+1} + D_t = M_t + B_t + R_t^D D_t + P_tA_t\Gamma_t + \Pi_t(B) + W_tN_t + P_tQ_tA_{t-1} + P_tT_t, \quad \text{(A.6)}$$

where R_t^D denotes the gross nominal interest rate on deposits, D_t is the deposit in financial intermediaries, B_t is the nominal bond, $\mu_{t,t+1}$ is the stochastic discount factor, which denotes the bond price of in terms of home currency. W_t and Γ_t are the nominal wage and the dividend from intermediate goods firms. $\Pi_t(B)$ denotes the dividend from financial intermediaries and A_t denotes shares of stock that sell at price Q_t. M_t is the nominal money stock and T_t denotes lump-sum transfers. In addition, the representative household faces the following cash-in-advance constraint:

$$P_tC_t \leq M_t - D_t + W_tN_t. \quad \text{(A.7)}$$

As in Ravenna and Walsh (2006), Equation (A.7) states that households enter period t with cash holdings of M_t. Before households enter goods and financial markets, they deposit the funds D_t with financial intermediaries. Hence, household's remaining cash balances are subject to a cash-in-advance constraint (A.7).

The household maximizes its own utility, subject to Eqs. (A.6) and (A.7). If the nominal interest rate is positive, the first-order conditions of this optimization problem are

$$C_t^{-\sigma} = \beta E_t\left(R_tC_{t+1}^{-\sigma}\frac{P_t}{P_{t+1}}\right), \quad \text{(A.8)}$$

$$\frac{\zeta N_t^{\phi}}{C_t^{-\sigma}} = \frac{W_t}{P_t}, \quad \text{(A.9)}$$

$$C_t^{-\sigma}(Q_t - \Gamma_t) = \beta E_tC_{t+1}^{-\sigma}Q_{t+1}, \quad \text{(A.10)}$$

where R_t denotes the nominal interest rate that is set by the home central bank. Equation (A.8) represents an Euler equation for consumption.[14] The left-hand side of Eq.

[14]In competitive bond and deposit markets, the nominal interest rate on bonds is equal to the deposit rate through the arbitrage condition between bond and deposit markets.

(A.8) is the marginal utility in period t, whereas the right-hand side of Eq. (A.8) is the discounted marginal utility of consumption in period $t+1$. The Euler equation requires that in equilibrium, the marginal utility of consumption will inter-temporally equalize through real interest rate adjustments. Equation (A.9) gives the marginal rate of substitution between consumption and a household's labor supply. Equations (A.10) represents the dynamics of share prices Q_t.

A.2 Firms

Each country has two production sectors. The first is the final goods sector, which produces final goods using intermediate goods and is characterized by perfect competition. The second is the intermediate goods sector, in which firms face monopolistic competition and Calvo pricing. In addition, intermediate goods firms have to borrow funds from only home financial intermediaries to pay employee wages. Following Pfajfar and Santoro (2014), it is assumed that domestic firms are completely rationed on the equity market located in the home country; this assumption allows the model to consider the case wherein firms borrow funds from home financial intermediaries due to the existence of financial gaps generated by firms facing a shortage of internal funds.[15] Therefore, in this model, intermediate firms borrow funds from financial intermediaries and also issue their own securities, which are held by domestic households.

A.2.1 The final goods sector

Each final goods firm employs the following constant elasticity of substitution (CES) technology:

$$Y_t = \left[\int_0^1 Y_t(i)^{(\theta-1)/\theta} di \right]^{\theta/(\theta-1)}, \tag{A.11}$$

where Y_t is aggregate output and $Y_t(i)$ denotes demand for intermediate goods produced by firm i. As in Clarida et al. (2002), both variables are normalized by population size

[15] See Pfajfar and Santoro (2014) for a detailed discussion of this problem.

$1-\gamma$. Parameter θ is the elasticity of substitution for individual goods, which parameter satisfies $\theta > 1$.

The demand for intermediate goods is

$$Y_t(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\theta} Y_t, \tag{A.12}$$

where $P_{H,t}(i)$ is the price for intermediate goods produced by firm i. The price index in this case is given by

$$P_{H,t} = \left[\int_0^1 P_{H,t}(i)^{1-\theta} di\right]^{1/(1-\theta)}. \tag{A.13}$$

A.2.2 The intermediate goods sector

The intermediate goods sector is characterized by monopolistic competition, and each firm produces a differentiated intermediate good. Firm i's production function is given by

$$Y_t(i) = Z_t N_t(i), \tag{A.14}$$

where Z_t denotes an aggregate productivity disturbance, which follows an AR (1) process given by $\log(Z_t) = \rho_z \log(Z_{t-1}) + \epsilon_t^z$ with $0 \leq \rho_z < 1$. ϵ_t^z is an i.i.d shock with constant variance σ_z^2.

Following Calvo (1983), price rigidity is assumed to exist in the intermediate goods sector. Thus, a fraction $1-\omega$ of all firms adjusts their prices, whereas the remaining fraction of firms ω do not. When revising their prices, these firms take into account uncertainty concerning their next potential opportunity to adjust prices. As such, the intermediate firm's optimization problem is given by

$$E_t \sum_{j=0}^{\infty} \omega^j \mu_{t,t+j} \left[\left(\frac{P_{H,t}^{opt}}{P_{H,t+j}}\right)^{1-\theta} - \varphi_{t+j}\left(\frac{P_{H,t}^{opt}}{P_{H,t+j}}\right)^{-\theta}\right] Y_{t+j}, \tag{A.15}$$

where $\mu_{t,t+j}$ is the stochastic discount factor, which is given by $\beta^j (C_{t+j}/C_t)^{-\sigma}$. φ_t denotes the real marginal cost and $P_{H,t}^{opt}$ is the optimal price index in period t. The first-order condition of this optimization problem is as follows:

$$E_t \sum_{j=0}^{\infty} (\omega\beta)^j \left[\frac{P_{H,t}^{opt}}{P_{H,t+j}} - \frac{\theta}{\theta-1}\varphi_{t+j}\right]\left(\frac{P_{H,t}^{opt}}{P_{H,t+j}}\right)^{-\theta} \frac{1}{P_{H,t}^{opt}} Y_{t+j} = 0. \tag{A.16}$$

This paper assumes that intermediate firms must borrow the funds $W_t N_t$ from domestic financial intermediaries at the gross lending rate R_t^L in order to pay employee wage. Intermediate firms face the following cost minimization problem:

$$R_t^L \frac{W_t}{P_{H,t}} N_t - \varphi_t (Z_t N_t - Y_t). \tag{A.17}$$

Cost minimization leads to

$$\varphi_t = \frac{1}{Z_t} \frac{W_t}{P_{H,t}} R_t^L. \tag{A.18}$$

In contrast to the standard new Keynesian analysis, because intermediate firms have to borrow funds from financial intermediaries under the assumption of the cost channel, their real marginal costs also depend on the lending rate. When the central bank raises the nominal interest rate, intermediate firm i's working capital increases because monetary tightening induces a rise in the lending rate. This indicates that a monetary tightening policy directly increases the real marginal cost.

Finally, as employed in the framework of Pfajfar and Santoro (2014), this paper assumes that firms fully transfer their profits through dividends to shareholders. In this case, dividends to shareholders are given as follows:

$$\Gamma_t = Y_t - R_t^L \frac{W_t}{P_{H,t}} N_t = (1 - \varphi_t) Y_t. \tag{A.19}$$

In contrast to the case of no cost channel, the lending rate affects the dividends to stockholders. Hence, it follows from Eq. (A.10) that the lending rate influences the dynamics of stock prices.

A.3 Financial intermediaries

Domestic financial intermediaries provide deposit services to domestic households. If a domestic household deposits the amount of D_t in period t, it will receive the amount of $R_t D_t$ at the end of the period. In turn, the financial intermediaries receive deposits from domestic households and lend these funds to domestic firms.[16]

[16] As noted earlier, we do not postulate that firms located in home country firms do not lend the funds from foreign financial intermediaries. Thus, this paper does not assume that financial intermediaries in one country lends their funds for firms only lend to firms located in the home country.

Following Chowdhury et al. (2006), financial intermediaries incurs a monitoring cost, $\Psi(R_t)$ when lending funds to intermediate goods producers. As mentioned earlier, this monitoring cost seems to serve as a shortcut to create incompleteness of loan rate pass-through. For the sake of strictly deriving the loan rate curve with a micro-foundation, this simplification makes the model description and model solution simple and intuitively understandable. To capture this argument in the model, following Chowdhury et al. (2006), it is here assumed that this monitoring cost is differentiable and satisfies the following properties: $\Psi^{'}(R_t) \geq 0$ and $\Psi^{''}(R_t) \geq 0$.

Financial intermediaries face the following profit maximization problem:

$$\Pi_t(B) = R_t^L(1 - \Psi(R_t)e^{\nu_t})L_t - R_t D_t - kL_t, \tag{A.20}$$

subject to $L_t = D_t$, where L_t denotes loans to a firm. The parameter k represents the management cost, which is constant. In addition, an exogenous loan rate shock ν_t is incorporated into the model. The financial market disturbance ν_t follows an AR (1) process given by $\nu_t = \rho_\nu \nu_{t-1} + \epsilon_t^\nu$ with $0 \leq \rho_\nu < 1$, where ϵ_t^ν is an i.i.d shock with constant variance σ_ν^2. One might consider the exogenous shock ν_t arised from a loan default rate. In addition to a simple introduction of financial frictions suggested by Chowdhury et al. (2006), this paper assumes that a simple introduction of an exogenous loan rate shock can capture structural shocks that tighten demand and supply in the loan market. Therefore, we assume that this shortcut of an exogenous loan rate shock might be just simply regarded as a reduced-form of a financial accelerator. The equilibrium for the lending market is $D_t = W_t N_t^d$, where N_t^d denotes the demand for labor.

A.4 Market clearing and international risk-sharing condition

We require market clearing conditions of goods market clearing in each country. Domestic producers sell their final goods to both domestic and foreign households. Since both Y_t and Y_t^* are defined in per capita terms, the clearing conditions for the goods market in

home and foreign countries are

$$(1-\gamma)Y_t = (1-\gamma)C_{H,t} + \gamma C^*_{H,t}, \tag{A.21}$$

$$\gamma Y^*_t = \gamma C_{F,t} + (1-\gamma)C^*_{F,t}, \tag{A.22}$$

where asterisks denote foreign variables. Substituting Equation (A.2) and the corresponding equation in the foreign country into Equation (A.21), we obtain

$$Y_t = \left(\frac{P_{H,t}}{P_t}\right)^{-a}\left[(1-\gamma)C_t + \gamma\left(\frac{\gamma}{1-\gamma}\right)S_t^a C_t^*\right], \tag{A.23}$$

where $S_t = \mathcal{E}_t P^*_t/P_t$ denotes the real exchange rate and $\mathcal{E}_t$ is the nominal exchange rate. The stock market clearing condition in each country is $(1-\gamma)A_t = 1$, and the clearing condition of the international bond market is given by $(1-\gamma)B_t + \gamma B^*_t = 0$.

Next, we consider a risk-sharing condition between countries. The Euler equation for foreign consumption denominated in domestic currency is

$$\frac{1}{R^*_t} = \beta E_t\left[\left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\sigma}\frac{P^*_t}{P^*_{t+1}}\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}\right]. \tag{A.24}$$

By assuming that there exist state-contingent bonds that allow both domestic and foreign households to trade internationally, combining Eq. (A.24) with the Euler equation for domestic consumption and the definition of the real exchange rate, the real exchange rate becomes

$$S_t = \tau\left(\frac{C^*_t}{C_t}\right)^{\sigma}, \tag{A.25}$$

where τ is a constant term. Equation (A.25) states that the real exchange rate adjusts for the difference between domestic and foreign consumption.

Table 1: Calibrated parameter values for a benchmark case

Parameter	Description	Value
ω	Degree of price stickiness	0.75
β	Discount factor	0.99
σ	Relative risk aversion coefficient	2.0
ϕ	Elasticity of labor supply	1.0
γ	Degree of openness	0.2
θ	Elasticity of substitution between individual goods	5.0
a	Elasticity of substitution between home and foreign goods	1.5
ϕ_π	Inflation stabilization in the Taylor rule	2.0
ϕ_y	Stabilization of the output gap in the Taylor rule	0
σ_z	Standard deviation of a productivity shock	0.01
σ_ν	Standard deviation of a loan rate shock	0.01
σ_u	Standard deviation of a monetary policy shock	0.01
ρ_z	Auto-regression coefficient for a productivity shock	0.8
ρ_ν	Auto-regression coefficient for a loan rate shock	0.8
ρ_u	Auto-regression coefficient for a monetary policy shock	0.5

Table 2: Standard deviations of key macrovariables in the case of $\psi_r = \psi_r^* = 0.25$

Variables	Case I	Case II	Case III
Home inflation	0.17	0.28	0.25
Foreign inflation	0.47	0.47	0.68
Home output gap	0.44	0.51	0.47
Foreign output gap	1.35	1.37	1.27
Home stock price gap	1.80	1.72	1.58
Foreign stock price gap	4.24	4.19	4.02
Real exchange rate	1.33	1.34	1.25

(Note) Case I: $\phi_q = \phi_q^* = 0$; Case II: $\phi_q = 0.1$ and $\phi_q^* = 0$; Case III: $\phi_q = \phi_q^* = 0.1$.

Table 3: Standard deviations of key macrovariables in the case of $\psi_r = 0.25$ and $\psi_r^* = 0.5$

Variables	Case I	Case II	Case III
Home inflation	0.18	0.29	0.26
Foreign inflation	0.48	0.48	0.70
Home output gap	0.46	0.53	0.48
Foreign output gap	1.41	1.43	1.31
Home stock price gap	1.84	1.77	1.64
Foreign stock price gap	4.38	4.31	4.18
Real exchange rate	1.39	1.45	1.31

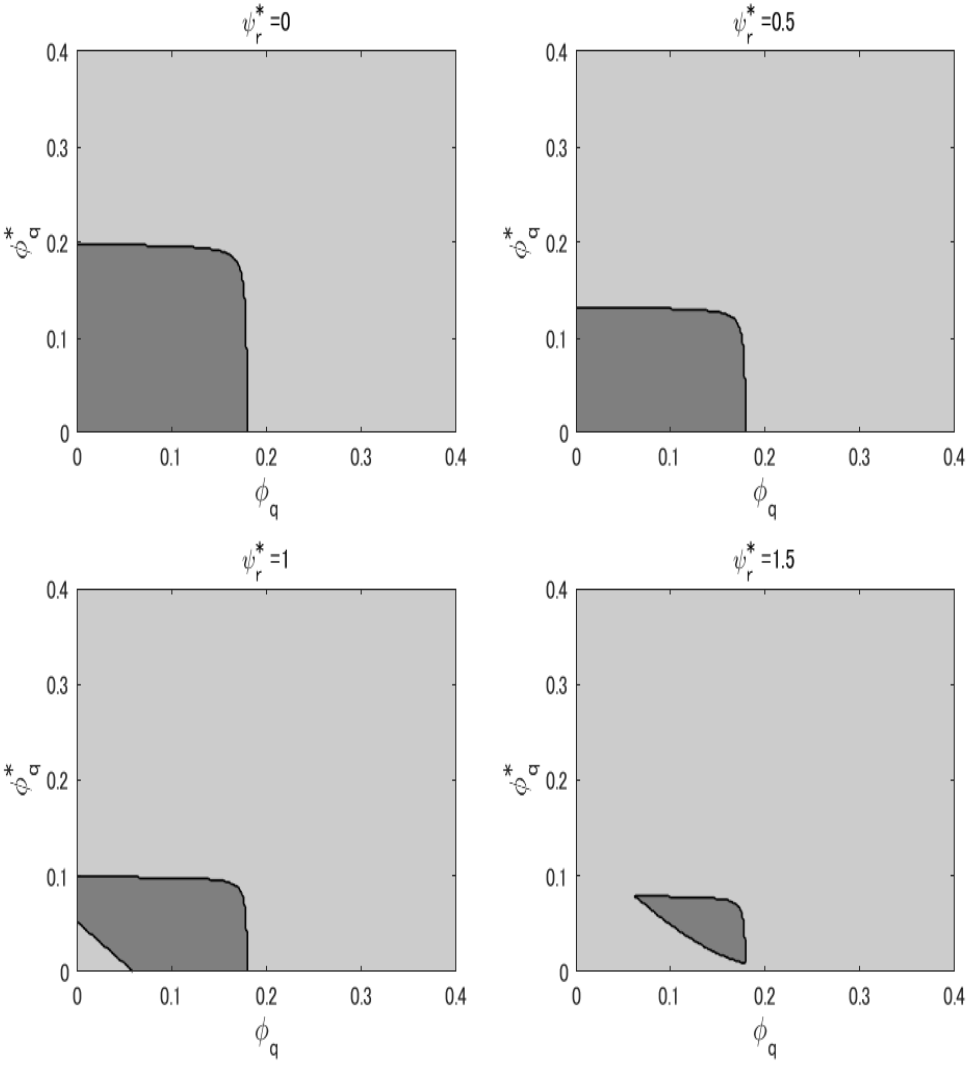
(Note) Case I: $\phi_q = \phi_q^* = 0$; Case II: $\phi_q = 0.1$ and $\phi_q^* = 0$; Case III: $\phi_q = \phi_q^* = 0.1$.

Table 4: Standard deviations of key macrovariables when foreign central bank stabilizes its asset price growth

Variables	Case I	Case II	Case III
Home inflation	0.18	0.17	0.28
Foreign inflation	0.48	0.45	0.44
Home output gap	0.46	0.44	0.50
Foreign output gap	1.41	1.37	1.39
Home stock price gap	1.84	1.82	1.74
Foreign stock price gap	4.38	4.27	4.20
Real exchange rate	1.39	1.30	1.36

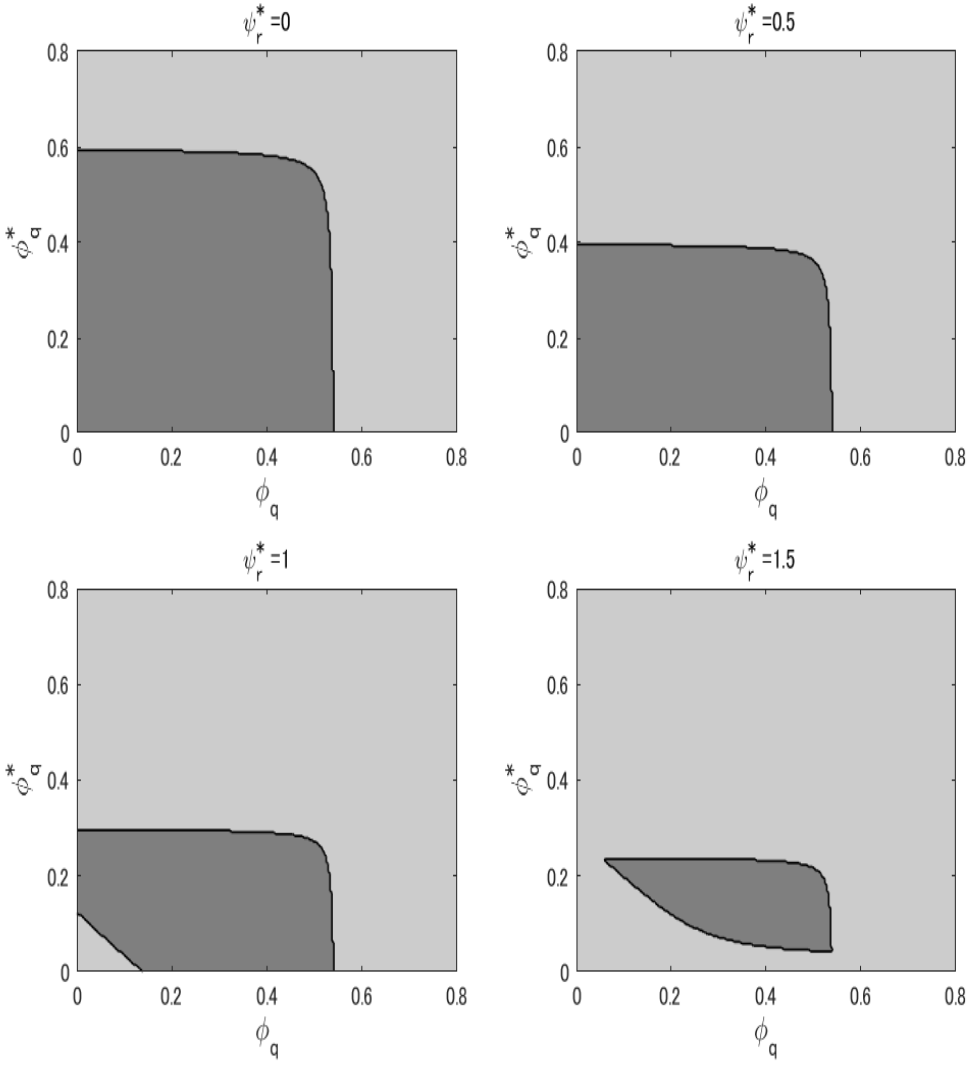
(Note) Case I (Solid line): no asset price responses in both country; Case II (Line with a diamond): no asset price response (home country) and asset price growth response (foreign country); Case III (Line with an asterisk): asset price gap response (home country) and asset price gap response (foreign country)

Figure 1: Worldwide equilibrium determinacy when ϕ_q and ϕ_q^* change under several values of ψ_r^*



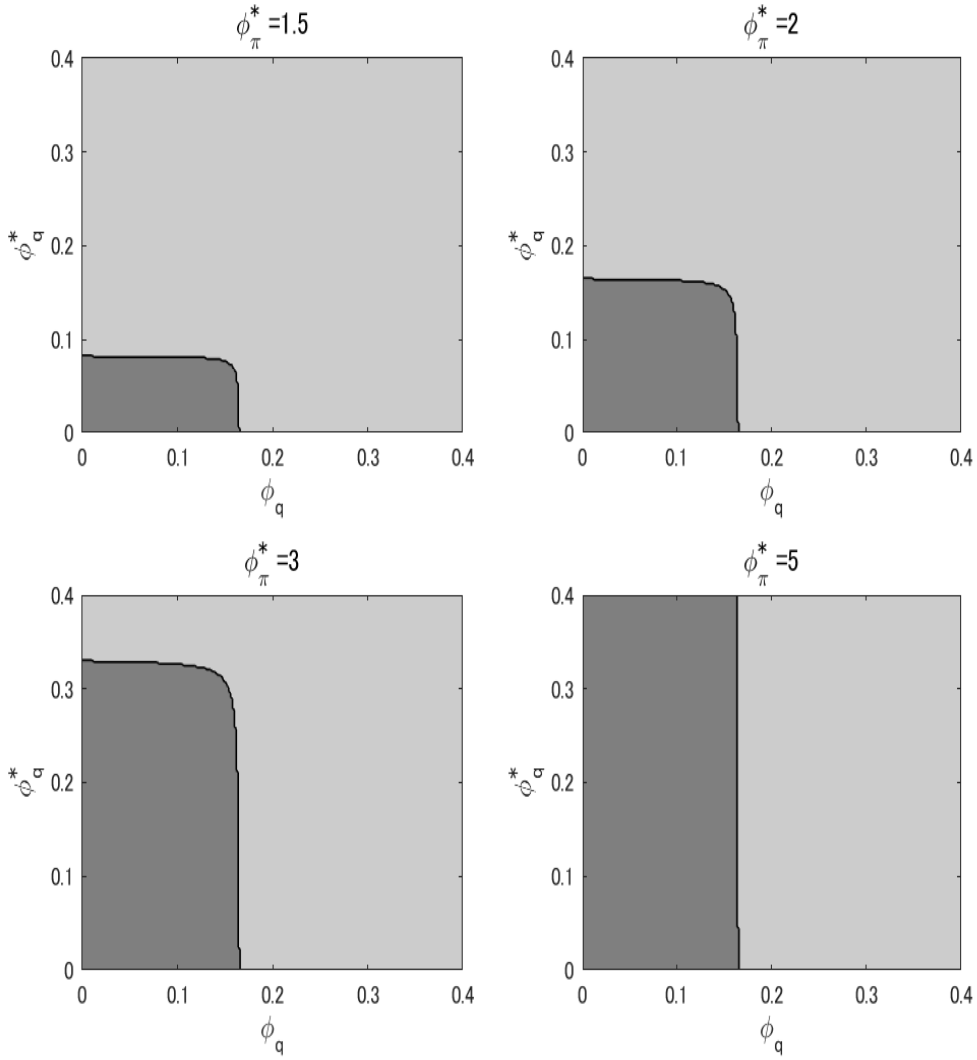
(Note) Dark-shaded areas: determinacy regions; Light-gray areas: indeterminacy regions

Figure 2: Worldwide equilibrium determinacy when ϕ_q and ϕ_q^* change under several values of ψ_r^*: The case of $\phi_\pi = \phi_\pi^* = 4.0$



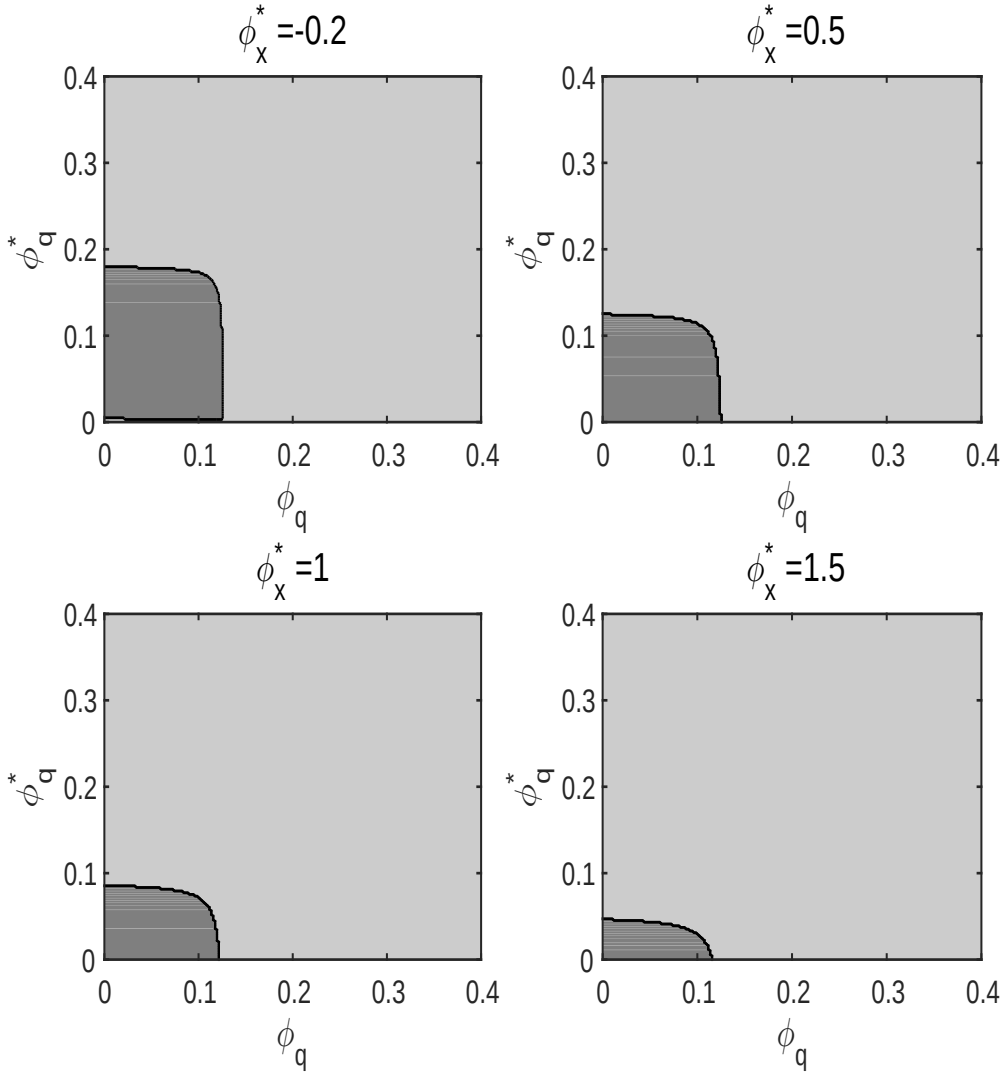
(Note) Dark-shaded areas: determinacy regions; Light-gray areas: indeterminacy regions

Figure 3: Worldwide equilibrium determinacy when ϕ_q and ϕ_q^* change under several values of ϕ_π



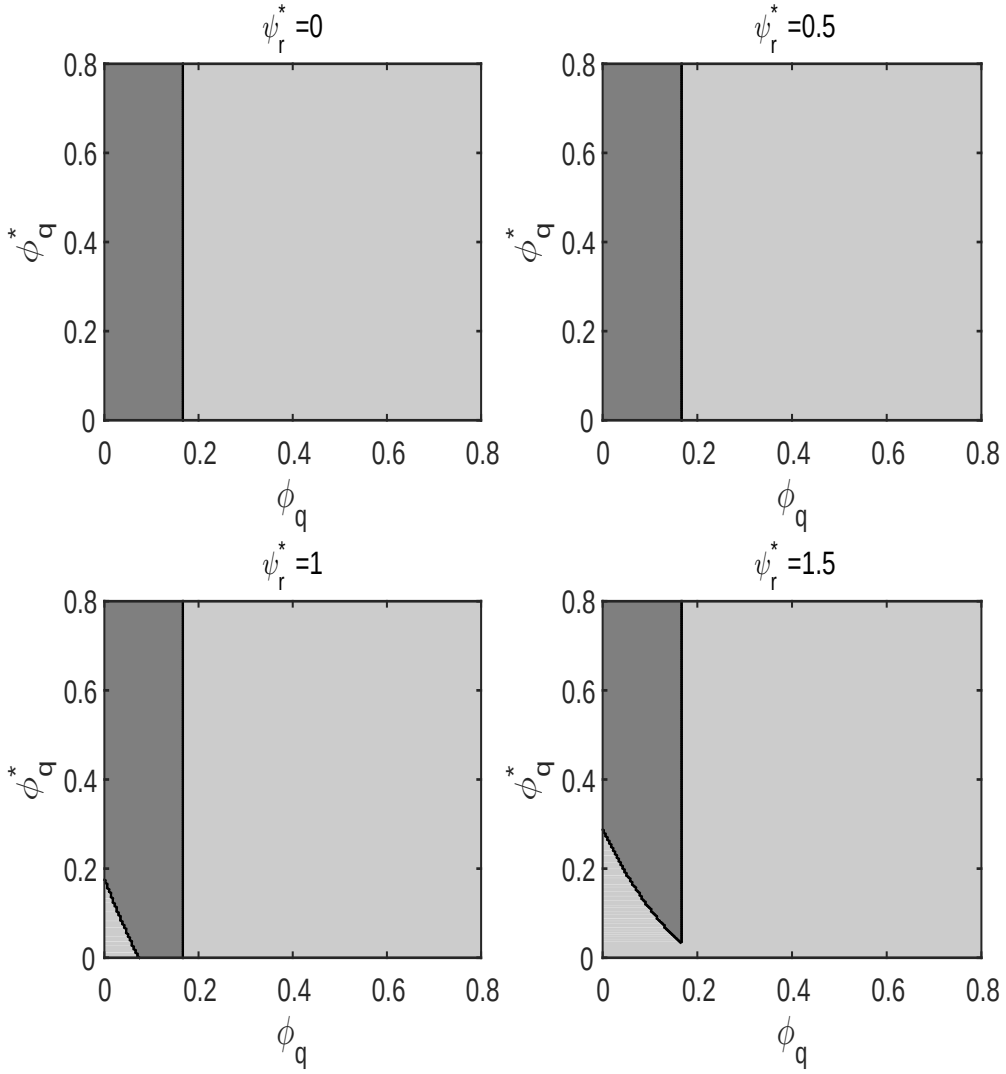
(Note) Dark-shaded areas: determinacy regions; Light-gray areas: indeterminacy regions

Figure 4: Worldwide equilibrium determinacy when ϕ_q and ϕ_q^* change under several values of ϕ_x^*



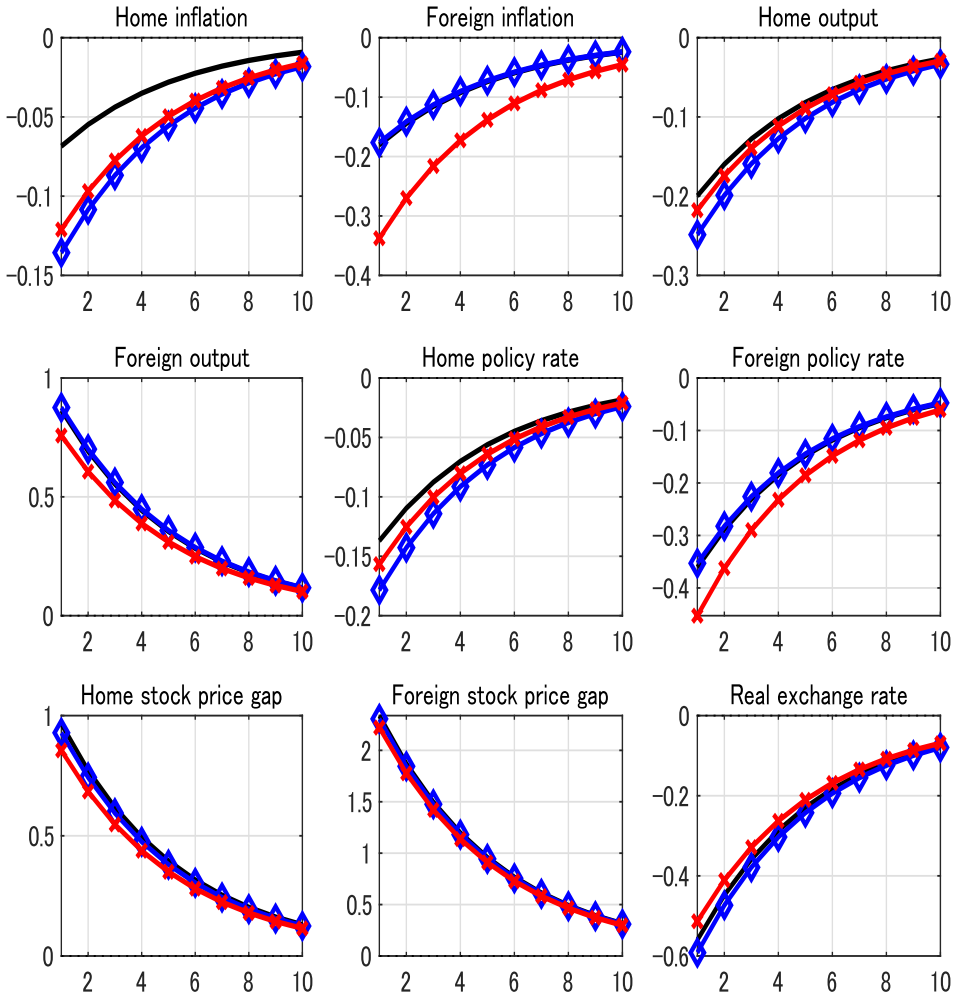
(Note) Dark-shaded areas: determinacy regions; Light-gray areas: indeterminacy regions

Figure 5: Worldwide equilibrium determinacy when ϕ_q and ϕ_q^* change when the foreign central bank stabilizes its asset price growth



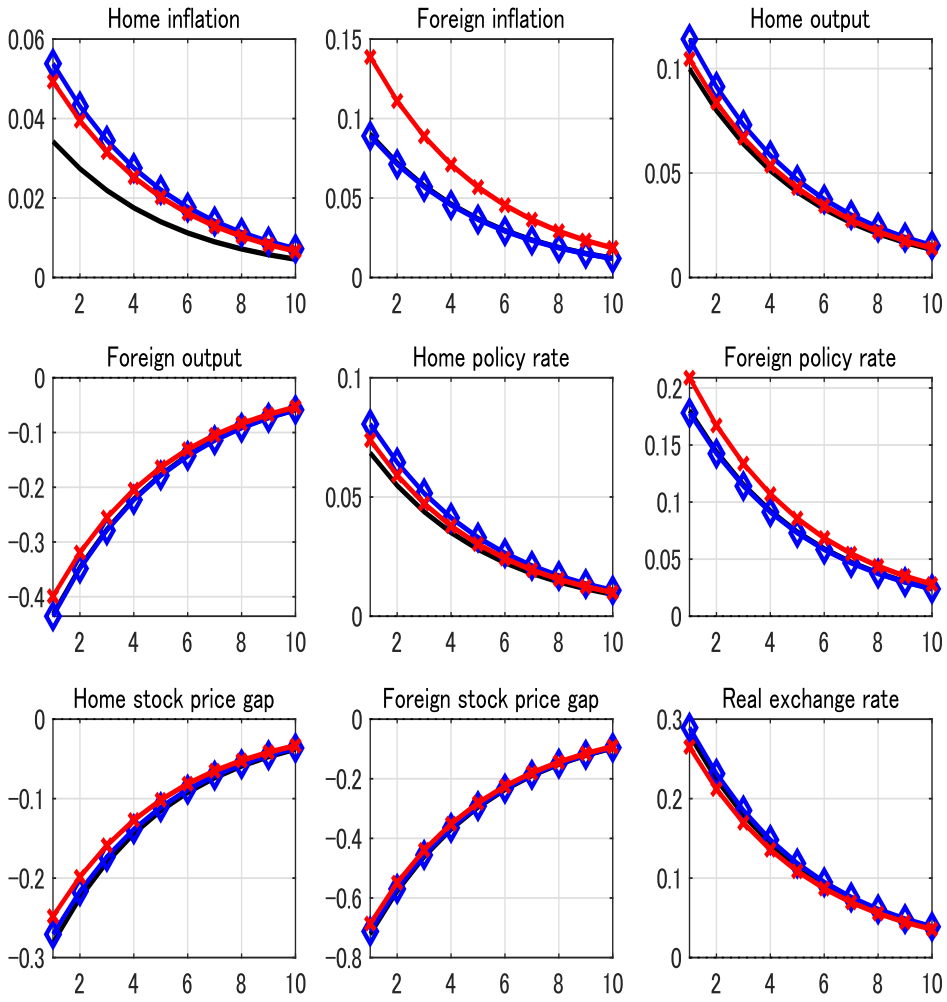
(Note) Dark-shaded areas: determinacy regions; Light-gray areas: indeterminacy regions

Figure 6: Impulse response to a foreign productivity shock in the case of $\psi_r = \psi_r^* = 0.2$



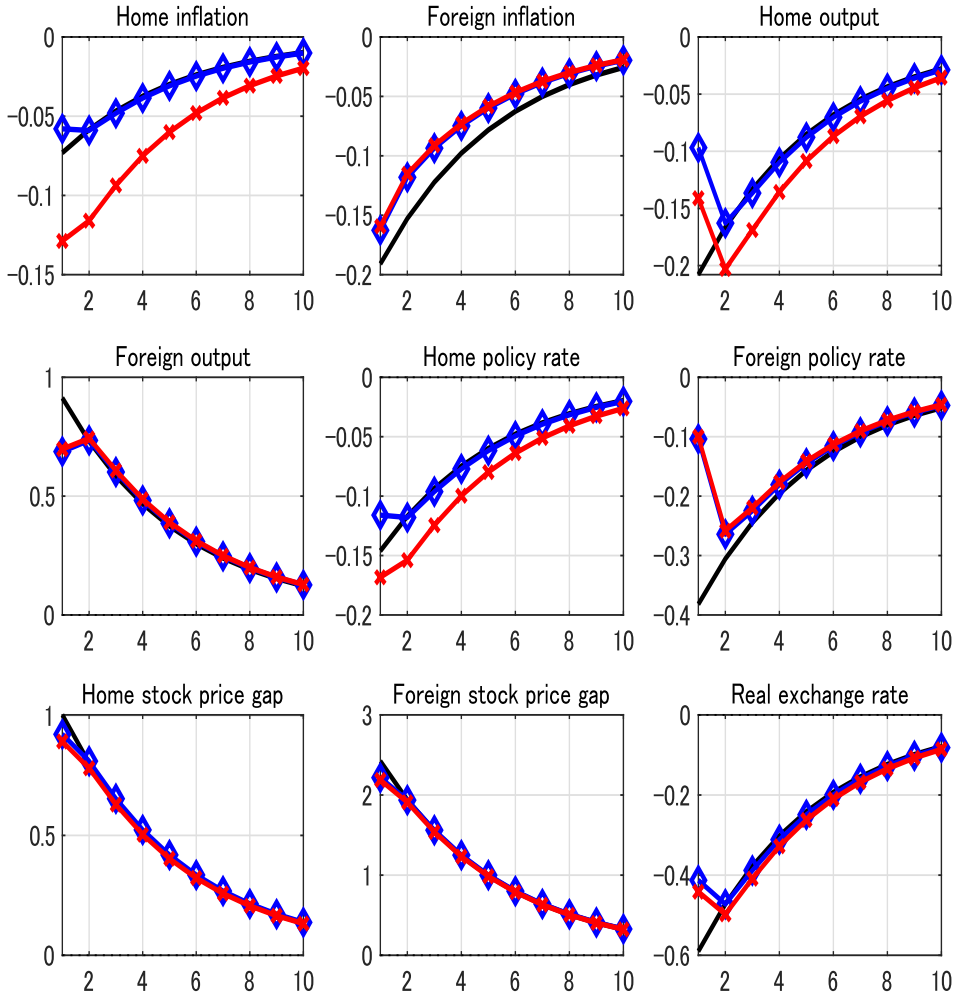
(Note) Case I (Solid line): $\phi_q = \phi_q^* = 0$. Case II (Line with a diamond): $\phi_q = 0.1$ and $\phi_q^* = 0$. Case III (Line with an asterisk): $\phi_q = \phi_q^* = 0.1$.

Figure 7: Impulse response to a foreign loan rate shock in the case of $\psi_r = \psi_r^* = 0.2$



(Note) Case I (Solid line): $\phi_q = \phi_q^* = 0$. Case II (Line with a diamond): $\phi_q = 0.1$ and $\phi_q^* = 0$. Case III (Line with an asterisk): $\phi_q = \phi_q^* = 0.1$.

Figure 8: Impulse response to a foreign productivity shock when foreign central bank employs different asset price rules



(Note) Case I (Solid line): no asset price responses in both country; Case II (Line with a diamond): no asset price response (home country) and asset price growth response (foreign country); Case III (Line with an asterisk): asset price gap response (home country) and asset price gap response (foreign country)