

International Interest Rate Shocks and Monetary Policy in a Small Open Economy*

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Considering that a significant part of business cycle fluctuations in small open economies could be explained by international interest rate shocks, this paper attempts to characterize the monetary policy rule that is optimal among simple and implementable rules for an economy where international interest rate shocks work as main sources of business cycles. For this purpose, the performances of various monetary policy rules are compared in terms of social welfare based on a standard small open economy model. The main findings of this paper are as follows. First, for a small open economy vulnerable to international interest rate shocks, domestic goods price inflation targeting is the optimal policy rule within a family of simple and implementable monetary policy rules. Second, it is found that exchange rate fluctuations implied by inflation targeting rule expose the monetary authority to a trade-off between total demand stabilization and increased volatility of inflation.

JEL Classification: F41, F44, E52

Keywords: Small Open Economy, International Interest Rate Shocks, Monetary Policy, Exchange Rate Regimes

I. Introduction

One of the most interesting observations from recent studies on business cycle fluctuations in small open economies is that a considerable portion of such fluctuations can be explained by international interest rate shocks. Specifically, Neumeyer and Perri (2005) report that international interest rate and country spread shocks can be accountable for almost half of the business cycle fluctuations

Received: Nov. 11, 2013. Revised: March 11, 2014. Accepted: June 10, 2014.

* The original version of this paper was circulated as a working paper at the Korea Development Institute (KDI). It was written in Korean and was substantially revised and translated into English for publication. The views expressed herein are those of the author and do not necessarily reflect the official views of the Bank of Korea and KDI.

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in some emerging economies. In a similar vein, Uribe and Yue (2006) and García-Cicco, Pancrazi and Uribe (2010) emphasize the role of feedback from each country's economic fundamentals to country spread as a magnifying mechanism of business cycle fluctuations.

Not only is the importance of international interest shocks recognized in the context of the regular business cycles of emerging economies. Some literature emphasizes the role of interest rates of major countries as one of the causes and transmission channels of economic crisis. Edwards (2010) argues that the sudden interest rates hikes in the U.S. contributed to some of the major currency crises in the emerging economies such as the Mexican Tequila crisis of 1994-1995 and the Argentine peso crisis of 2001-2002. In addition, Byrne and Fiess (2011) and IMF (2011) find that the U.S. interest rates have played a crucial role in the global capital flows to emerging economies, and Fratzscher, Duca, and Straub (2012) and Moore et al. (2013) report that the quantitative easing (LSAP) in the U.S. since the global financial crisis have exerted significant effects on net capital inflows to emerging economies, particularly on local currency long-term bond markets in emerging economies.

However, despite the importance of international interest rate shocks in business cycle fluctuations in small open economies, their implications on monetary policy in a small open economy have been rarely investigated in related literature. In most of the studies on monetary policy in a small open economy including Galí and Monacelli (2005), one of the seminal works in this area, only productivity shocks are considered to be the sources of business cycle fluctuations in a theoretical model while international prices including international interest rates are assumed not to affect cyclical fluctuations of the economy independently. Due to this analytic limitation, it is hard to find any relevant policy advice for a small open economy vulnerable to international interest rate shocks from the existing literature.

Given such limitations, this paper attempts to study the implications of international interest rate shocks on the monetary policy in a small open economy. Its particular focus is on characterizing the monetary policy rule that is optimal among simple and implementable rules for a small open economy where international interest rate shocks work as main sources of business cycle fluctuations. To be specific, three monetary policy rules are considered. Two of them are inflation targeting rules with inflation targets of different price indices. The first rule has the domestic central bank react to domestic goods price inflation while the second one to usual CPI inflation. The third rule is one that pegs the nominal exchange rate.

To this end, this paper first proposes a standard small open economy model with sticky prices, which has been widely used in previous studies, and imposes international interest rate shocks on the model. And then, based on the calibrated model, performances of monetary policy rules are compared in terms of social

welfare, which each policy rule can support. It is notable that an ordinary first order approximation method frequently used in the business cycle analysis is not appropriate for studying welfare implications of an economic model. To address the concern, a second-order approximation method proposed by Schmitt-Grohé and Uribe (2004) is employed for approximating the equilibrium conditions of the model up to the second order.

The main findings of this paper can be summarized as follows. First, for a small open economy where macroeconomic fluctuations are driven mainly by international interest rate shocks, domestic goods price inflation targeting is the optimal policy rule within a family of simple and implementable monetary policy rules considered in this paper. In addition, over a wide range of parameter values, both inflation targeting rules turn out to outperform exchange rate peg. Second, it is found that nominal exchange rate fluctuations implied by inflation targeting rule expose the monetary authority to a trade-off between the benefits of the total demand stabilization via foreign demand and the cost of increased volatility of inflation. Furthermore, the relative superiority of inflation targeting rules over exchange rate peg depends on the trade-off.

The remainder of the paper is organized as follows. The next section provides a detailed description of the theoretical model. Then, the parameterization and the solution method are discussed in section 3. Simulations and theoretical findings are presented and discussed in section 4. The final section concludes with a brief summary of the major findings and a discussion of the limitations of this paper.

II. Theoretical Model

In this section, a small open economy model with sticky prices is developed for analyzing the implications of international interest rate shocks for monetary policy in a small open economy. The main structure of the model is quite standard in the related literature, but a brief discussion will be helpful.

In the theoretical economy, there are three types of goods; one final good and two kinds of intermediate goods. One intermediate good is produced domestically and used domestically or exported while the other is imported from abroad by importing firms. A final good is assumed to be nontradable and domestically produced by combining these intermediate goods. In addition, each firm in the both intermediate good sectors is assumed to be a monopolistic competitor and indexed by its product in a continuum of varieties whereas a firm in the final good producing sector operates in a perfectly competitive market. Finally, it is notable that this paper takes an eclectic view regarding exchange rate pass-through. As is well known among international macroeconomists, the degree of exchange rate

pass-through is one of the key factors affecting the overall performances of international macroeconomic models including dynamics of real exchange rate. However, the degree of exchange rate pass-through on export or import prices is still under debate.¹ In this perspective, following Corsetti and Pesenti (2005) and Tille (2005), this paper assumes a functional form of exchange rate pass-through which can nest not only usual perfect pass-through (or PCP, producer currency pricing) and no pass-through (or LCP, local currency pricing) but also a hybrid case between them.

In the following subsection, optimization problems which households and firms face in the economy will be discussed in detail. Before describing them, I will make a brief remark on notation for readers' convenience. All foreign variables have an asterisk(*) to be distinguished from their home equivalents. H or F in subscripts of variables denotes their regional origin. In addition, s_t denotes a particular state of the world at time t and the history of events up to time t is represented by $s^t = (s_0, \dots, s_t)$. The probability of any particular history of s^t is $\pi(s^t)$.

2.1. Household

Households are assumed to own all the capital and firms in the economy and to supply labor and capital services to the firms.² Also, only uncontractible bonds are allowed for households to share their risks with foreign counterparts. A representative household determines consumption, labor, investment, and new domestic and foreign bond holdings, $C(s^t)$, $N(s^t)$, $I(s^t)$, $B_H(s^t)$ and $B_F(s^t)$, given real wage and rental fee rate, capital stock and bond holdings, $W(s^t)$, $Z(s^t)$, $K(s^{t-1})$, $B_H(s^{t-1})$ and $B_F(s^{t-1})$, to maximize the sum of discounted expected utilities

$$\sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} \beta^{\tau} \pi(s^{t+\tau}) U(C(s^{t+\tau}), N(s^{t+\tau})) \quad (1)$$

subject to sequence of budget constraints

$$\begin{aligned} & P(s^t)C(s^t) + B_H(s^t) + S(s^t)B_F(s^t) \\ & + P(s^t)I(s^t) + P(s^t)\frac{1}{2}\phi_K\left(\frac{I(s^t)}{K(s^{t-1})} - \delta\right)^2 K(s^{t-1}) \end{aligned}$$

¹ For details of the issue, see Obstfeld and Rogoff (2000), Betts and Devereux (2000), Corsetti and Pesenti (2005) and others.

² The labor and capital services supplied by households are homogenous and the labor and capital service markets are assumed as perfectly competitive.

$$\begin{aligned} &\leq P(s^t)W(s^t)N(s^t) + P(s^t)Z(s^t)K(s^{t-1}) \\ &\quad + \Pi(s^t) + (1 + ir(s^{t-1}))B_H(s^{t-1}) + S(s^t)(1 + ir^*(s^{t-1}))B_F(s^{t-1}) \end{aligned} \quad (2)$$

and the law of motion for capital

$$K(s^t) = (1 - \delta)K(s^{t-1}) + I(s^t) \quad (3)$$

where $U(\cdot)$ denotes the household's instantaneous utility function over consumption and leisure and $P(s^t)$ and $S(s^t)$ represent overall price index (CPI) and nominal exchange rate respectively.³ Note that the exchange rate $S(s^t)$ is defined as the price of a foreign currency in units of domestic currency. $\Pi(s^t)$ represents total dividend from the firms and $ir(s^t)$ and $ir^*(s^t)$ denote nominal interest rates applied for domestic and foreign bonds at time $t+1$. Finally, β , δ and ϕ_K are the time discount factor, the depreciation rate of capital, and the scaling factor of capital adjustment cost. The household's utility maximization problem leads to standard first-order conditions and two first-order conditions with respect to bond holdings can be combined to derive the uncovered interest rate parity (hereinafter UIP) condition given as

$$\sum_{s^{t+1}} \Gamma(s^t, s^{t+1}) \left[(1 + ir(s^t)) - \frac{S(s^{t+1})}{S(s^t)} (1 + ir^*(s^t)) \right] = 0 \quad (4)$$

where $\Gamma(s^t, s^{t+1})$ is a stochastic discounting factor which is derived from the household optimization problem and it is given as

$$\Gamma(s^t, s^{t+1}) = \beta \frac{\pi(s^{t+1})}{\pi(s^t)} \frac{U_C(C(s^{t+1}), N(s^{t+1}))}{U_C(C(s^t), N(s^t))} \frac{P(s^t)}{P(s^{t+1})}. \quad (5)$$

2.2. Final Goods Producing Sector

Final goods used for domestic consumption and investment are assumed to be produced by combining domestic and imported tradable intermediate goods according to the following production function.

³ As Schmitt-Grohé and Uribe (2003) points out, a small open economy model with incomplete market can have an infinite number of steady state equilibria. To close the model with the unique steady state equilibrium, I assume small costs of bond holdings for both bonds. But, for expositional convenience, the terms of costs of bond holdings are omitted in the related equations including the UIP condition. For alternative ways of addressing this issue, see Schmitt-Grohé and Uribe (2003).

$$Y(s') = [aY_H(s')^\rho + (1-a)Y_F(s')^\rho]^\frac{1}{\rho} \quad (6)$$

where $Y(s')$, $Y_H(s')$, and $Y_F(s')$ represent the quantity of the final good and the quantities of the aggregate domestic and imported intermediate goods. ρ measures the elasticity of substitution between domestic and imported intermediate goods and a determines the degree of home bias in the demand of tradable intermediate goods. In addition, the aggregate domestic and imported intermediate goods, $Y_H(s')$ and $Y_F(s')$, respectively, represent the aggregations of a continuum of differentiated domestic and imported intermediate goods according to the following technology given by

$$Y_H(s') = \left(\int_0^1 Y_H(i, s')^\theta di \right)^\frac{1}{\theta} \quad (7)$$

and

$$Y_F(s') = \left(\int_0^1 Y_F(j, s')^\theta dj \right)^\frac{1}{\theta} \quad (8)$$

where $Y_H(i, s')$ and $Y_F(j, s')$ are the quantities of differentiated domestic and imported intermediate goods and $i \in [0, 1]$ and $j \in [0, 1]$ are respectively indices for each variety of intermediate goods.

Finally, the final goods producing sector is assumed to be perfectly competitive. From a simple profit maximization problem of a representative final goods producing firm, given the prices of each intermediate goods, $P_H(i, s')$ for $i \in [0, 1]$ and $P_F(j, s')$ for $j \in [0, 1]$, the demand for each intermediate goods is easily derived as follows:

$$Y_H(i, s') = \left(\frac{P_H(i, s')}{P_H(s')} \right)^\frac{1}{\theta-1} Y_H(s') \quad \text{for } i \in [0, 1] \quad (9)$$

$$Y_F(j, s') = \left(\frac{P_F(j, s')}{P_F(s')} \right)^\frac{1}{\theta-1} Y_F(s') \quad \text{for } j \in [0, 1] \quad (10)$$

where $P_H(s')$ and $P_F(s')$ are domestic and imported intermediate good price indices and they are obtained as

$$P_H(s') = \left(\int_0^1 P_H(i, s')^\frac{\theta}{\theta-1} di \right)^\frac{\theta-1}{\theta} \quad (11)$$

$$P_F(s') = \left(\int_0^1 P_F(j, s')^\frac{\theta}{\theta-1} dj \right)^\frac{\theta-1}{\theta}. \quad (12)$$

Simultaneously, from the same profit maximization problem, the demands for the aggregate domestic and imported intermediate goods, $Y_H(s')$ and $Y_F(s')$, are derived as

$$Y_H(s') = a^{\frac{1}{1-\rho}} \left(\frac{P_H(s')}{P(s')} \right)^{\frac{1}{\rho-1}} Y(s') \quad (13)$$

$$Y_F(s') = (1-a)^{\frac{1}{1-\rho}} \left(\frac{P_F(s')}{P(s')} \right)^{\frac{1}{\rho-1}} Y(s') \quad (14)$$

where $P(s')$ represents the price of the final good and is obtained as

$$P(s') = \left[a^{\frac{1}{1-\rho}} P_H(s')^{\frac{\rho}{\rho-1}} + (1-a)^{\frac{1}{1-\rho}} P_F(s')^{\frac{\rho}{\rho-1}} \right]^{\frac{\rho-1}{\rho}}. \quad (15)$$

2.3. Domestic Intermediate Goods Producing Sector

Each firm in domestic intermediate goods producing sector is assumed to be a monopolistic competitor and faces nominal rigidity as in standard international monetary models. The nominal rigidity is introduced following Calvo (1983). Each intermediate goods producing firm faces an opportunity of re-optimizing its price with a constant probability of ϕ_x at each period. Meanwhile, as discussed above, no empirical consensus on the degree of exchange rate pass-through on export price has been established so far despite its theoretical importance.⁴ Addressing the concern, similarly in Corsetti and Pesenti (2005) and Tille (2005), this paper parameterizes the degree of exchange rate pass-through in the form of a functional relationship given by

$$P_H^*(i, s') = \overline{P}_H^*(i, s') S(s')^{-\mu} \quad (16)$$

where $\overline{P}_H^*(i, s')$ denotes prices determined by the firm while $P_H^*(i, s')$ does actual price in the foreign market and μ represents the degree of exchange rate pass-through. Note that in the case of $\mu=1$, the relationship implies a perfect pass-through (or PCP) while in the case of $\mu=0$, it implies no pass-through (or LCP).

⁴ The related literature has linked the degree of pass-through to the invoicing currency with nominal rigidities. If exports are invoiced in the producer's currency, the whole exchange rate movements can pass through the foreign price of the goods and as a result, the law of one price can hold. Instead, if exports are invoiced in the importer's currency, foreign price of the goods is sticky regardless of exchange rate movements. Consequently, the pass-through does not happen and the law of one price breaks down.

With these assumptions, a representative domestic intermediate goods producing firm (i)'s profit maximization problem can be formulated as follows. When the opportunity to re-optimize its prices arrives, a representative domestic intermediate goods producing firm chooses its reset prices, $P_H(i, s^t)$ and $P_H^*(i, s^t)$, for the home and foreign markets and the inputs of labor and capital, $N(i, s^t)$ and $K(i, s^t)$, to solve the following profit maximization problem:

$$\max \sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} \Gamma(s^t, s^{t+\tau}) (\varphi_X)^\tau [P_H(i, s^t) Y_H(i, s^{t+\tau}) + S(s^{t+\tau}) P_H^*(i, s^t) Y_H^*(i, s^{t+\tau}) - P(s^{t+\tau}) W(s^{t+\tau}) N(i, s^{t+\tau}) - P(s^{t+\tau}) Z(s^{t+\tau}) K(i, s^{t+\tau})] \quad (17)$$

subject to its demand functions in the home and foreign markets

$$Y_H(i, s^{t+\tau}) = \left(\frac{P_H(i, s^t)}{P_H(s^{t+\tau})} \right)^{\frac{1}{\theta-1}} Y_H(s^{t+\tau}) \quad \text{for } i \in [0, 1] \quad (18)$$

$$Y_H^*(i, s^{t+\tau}) = \left(\frac{P_H^*(i, s^t)}{P_H^*(s^{t+\tau})} \right)^{\frac{1}{\theta-1}} Y_H^*(s^{t+\tau}) \quad \text{for } i \in [0, 1] \quad (19)$$

and the following constraints

$$Y_H(i, s^{t+\tau}) + Y_H^*(i, s^{t+\tau}) = F(A(s^{t+\tau}), N(i, s^{t+\tau}), K(i, s^{t+\tau})) \quad (20)$$

$$P_H^*(i, s^{t+\tau}) = \bar{P}_H^*(i, s^t) S(s^{t+\tau})^{-\mu} \quad (21)$$

where $\Gamma(s^t, s^{t+\tau})$ is the stochastic discounting factor obtained from the household's optimization problem and φ_X is the probability of not re-optimizing its prices at each period in the domestic intermediate goods producing sector.⁵ Also, $F(\cdot)$ denotes a production function and $A(s^{t+\tau})$ represents the overall productivity in the economy. Note that the foreign price of domestic intermediate goods is sticky in terms of $P_H^*(i, \cdot)$ in (21).

From the optimization problem, optimal reset prices for the home and foreign markets, $P_H^\#(i, s^t)$ and $P_H^{\#*}(i, s^t)$, are given by

$$P_H^\#(i, s^t) = \frac{1}{\theta} \frac{\sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} \Lambda_X(s^{t+\tau}) MC^n(s^{t+\tau}) P_H(s^{t+\tau})^{\frac{1}{1-\theta}} Y_H(s^{t+\tau})}{\sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} \Lambda_X(s^{t+\tau}) P_H(s^{t+\tau})^{\frac{1}{1-\theta}} Y_H(s^{t+\tau})} \quad (22)$$

⁵ Since all the firms in the economy are assumed to be owned by households, the stochastic discounting factors are obtained from the first-order conditions of households' optimization problem.

$$\overline{P_H^*}^\#(i, s^t) = \frac{1}{\theta} \frac{\sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} \Lambda_X(s^{t+\tau}) MC^n(s^{t+\tau}) S(s^{t+\tau})^{-\mu \frac{1}{\theta-1}} P_H^*(s^{t+\tau})^{\frac{1}{1-\theta}} Y_H^*(s^{t+\tau})}{\sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} \Lambda_X(s^{t+\tau}) S(s^{t+\tau})^{1-\mu-\mu \frac{1}{\theta-1}} P_H^*(s^{t+\tau})^{\frac{1}{1-\theta}} Y_H^*(s^{t+\tau})} \quad (23)$$

where $\Lambda_X(s^{t+\tau}) \equiv (\varphi_X)^t \Gamma(s^t, s^{t+\tau})$ and $MC^n(s^{t+\tau})$ is the nominal marginal cost in the domestic intermediate goods producing sector.⁶ $P_H^*(s^{t+\tau})$ is the price index of tradable intermediate goods exported to the foreign country, denominated in the foreign currency.

Finally, the foreign demand of domestic intermediate goods is assumed to be dependent on its relative price to foreign intermediate goods and the foreign output and simply given as

$$Y_H^*(s^t) = \kappa \left(\frac{P_H^*(s^t)}{P_F^*(s^t)} \right)^{\omega_1} (Y^W(s^t))^{\omega_2}$$

where $P_F^*(s^t)$ and $Y^W(s^t)$ denote the price of foreign intermediate goods denominated in foreign currency in the foreign market and the foreign output while ω_1 and ω_2 are the elasticities of foreign demand to its relative price to foreign intermediate goods and the foreign output.

2.4. Foreign Intermediate Goods Importing Firm

As discussed, the foreign intermediate goods importing sector consists of an infinite number of firms competing against each other monopolistically. Each firm in the sector imports intermediate goods from abroad, transforms them into differentiated goods, and then supplies them to the final goods producing firms. In addition, the importing firms are also assumed to face nominal rigidity similarly to domestic intermediate good producing firms. Hence, a representative foreign intermediate goods importing firm chooses its price, $P_F(j, s^t)$, to maximize the current and future profits

$$\max \sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} (\varphi_M)^t \Gamma(s^t, s^{t+\tau}) [P_F(j, s^t) Y_F(j, s^{t+\tau}) - S(s^{t+\tau}) P_F^*(s^{t+\tau}) Y_F(j, s^{t+\tau})] \quad (24)$$

subject to its demand given as

⁶ From the assumption that all domestic intermediate goods producing firms share the same production technology and that production factor markets are perfectly competitive, it is straightforward that the nominal marginal costs are the same across the firms.

$$Y_F(j, s^{t+\tau}) = \left(\frac{P_F(j, s^t)}{P_F(s^{t+\tau})} \right)^{\frac{1}{\theta-1}} Y_F(s^{t+\tau}) \quad (25)$$

where φ_M is the probability of not re-optimizing its price at each period in the foreign intermediate goods importing sector. The optimization problem leads to the following optimal reset price for the representative foreign intermediate goods importing firm

$$P_F^\#(j, s^t) = \frac{1}{\theta} \frac{\sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} \Lambda_M(s^{t+\tau}) S(s^{t+\tau}) P_F^*(s^{t+\tau}) P_F(s^{t+\tau})^{\frac{1}{1-\theta}} Y_F(s^{t+\tau})}{\sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} \Lambda_M(s^{t+\tau}) P_F(s^{t+\tau})^{\frac{1}{1-\theta}} Y_F(s^{t+\tau})} \quad (26)$$

where $\Lambda_M(s^{t+\tau}) \equiv (\varphi_M)^\tau \Gamma(s^t, s^{t+\tau})$.

2.5. Implementable Monetary Policy and Equilibrium

In the previous subsections, the optimization problems of individual agents and accompanying optimality conditions have been discussed in detail. However, for the model to be completed, a monetary policy rule needs to be specified to determine domestic nominal interest rate. As discussed in the introduction, this paper limits its attention to a family of implementable and simple policy rules and attempts to characterize the monetary policy rule that is optimal within the family of rules for a small open economy where international interest rate shocks work as main sources of business cycle fluctuations. Among simple and implementable monetary policy rules, the three most popular rules in the related literature and policy circle are selected and investigated. Two of them are inflation targeting rules with inflation targets of different price indices. The first rule (CPIT) makes the domestic central bank react to ordinary CPI inflation while the second one (DPIT) has it to domestic goods price inflation, and they are given respectively by

$$\left(\frac{1 + \dot{i}r(s^t)}{1 + \bar{i}r} \right) = \left(\frac{P(s^t) / P(s^{t-1})}{\bar{\Pi}} \right)^{\psi_\pi} \quad (27)$$

and

$$\left(\frac{1 + \dot{i}r(s^t)}{1 + \bar{i}r} \right) = \left(\frac{P_H(s^t) / P_H(s^{t-1})}{\bar{\Pi}_H} \right)^{\psi_\pi} \quad (28)$$

where $\bar{i}r$ denotes the nominal interest rate at the steady state and $\bar{\Pi}$ and $\bar{\Pi}_H$

are the inflation rates of ordinary CPI and domestic goods price index at the steady state.⁷ Meanwhile, the third rule (FIX) has the central bank peg nominal exchange rate as given by

$$S(s^t) = \bar{S}. \quad (29)$$

Combining it with the UIP condition leads to the following relationship between domestic and foreign nominal interest rates,

$$1 + ir(s^t) = 1 + ir^*(s^t). \quad (30)$$

Given that a small open economy cannot affect foreign interest rate, the relationship implicates that the domestic interest rate is simply determined by the foreign interest rate.⁸

Depending on the specifications of monetary policy rule, the equilibrium of the model is constituted differently. If the monetary authority is assumed to employ exchange rate peg, in addition to ordinary equilibrium conditions such as the first-order conditions obtained from individual agents' optimization problems and market clearing conditions, the equations (29) and (30) are included in the equilibrium conditions. On the other hand, when the inflation targeting rules are employed, one of the equations describing inflation targeting rules and the UIP condition are included in the equilibrium conditions.

2.6. Welfare Measure and Computation

To conduct policy evaluations by comparing social welfare level supported by each policy rule, a proper welfare metric is first needed. It is defined by using lifetime utility of the representative household as usual in the literature. More specifically, in this paper, both conditional and unconditional welfare levels are calculated for policy comparison. The former is defined as the expected lifetime utility of household at a certain state and is given by

$$W(s^t) \equiv \sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} \beta^{\tau} \pi(s^{t+\tau}) U(C(s^{t+\tau}), N(s^{t+\tau})) \quad (31)$$

⁷ Following Galí and Monacelli (2005), interest rate smoothing is abstract from monetary policy rules.

⁸ In the literature, the relationship is called the *trilemma* in the international macroeconomics. According to the trilemma, in the case of free capital mobility, the independence of domestic monetary policy cannot stand together with exchange rate peg.

and the latter is defined as a simple average of conditional welfare at each period.⁹

Even after social welfare levels are precisely calculated based on the metrics, it is still hard to compare the performances of policy rules because differences in welfare levels are not easy to interpret. In this regard, for a better comparison of policy rules, this paper also presents welfare differences among policy rules in terms of consumption units in a similar fashion in Schmitt-Grohé and Uribe (2006).¹⁰ Let's suppose that there are two policy rules A and R and $\lambda(s_0)$ represents the difference between welfare levels $W^A(s_0)$ and $W^R(s_0)$ supported respectively by policy rule A and R conditional on a particular state at period zero. $\lambda(s_0)$ is defined as the fraction of policy rule R 's consumption process which makes both welfare levels equal and is formally formulated as

$$W^A(s_0) = \sum_{\tau=0}^{\infty} \sum_{s^\tau} \beta^\tau \pi(s^\tau) U((1-\lambda(s_0))C^R(s^\tau), N^R(s^\tau)) \quad (32)$$

where $C^R(s^\tau)$ and $N^R(s^\tau)$ denote the processes of consumption and labor supply under policy rule R . Then, as Schmitt-Grohé and Uribe (2006) show, if a specific functional form is assumed for the period utility function in equation (31), the above expression can be rewritten as

$$\lambda(s_0) = \left[1 - \left(\frac{(1-\sigma)W^A(s_0) + (1-\beta)^{-1}}{(1-\sigma)W^R(s_0) + (1-\beta)^{-1}} \right)^{1/(1-\sigma)} \right]. \quad (33)$$

Note that DPIT will be considered to be the reference policy rule in the later analysis. Hence, in the equations (32) and (33), policy rule R corresponds to DPIT while the policy rule A to either CPIT or FIX and if $\lambda(s_0)$ is a positive (negative) number, then choosing CPIT or FIX over DPIT gives a welfare loss (gain).

Meanwhile, as Kim and Kim (2003) point out, an ordinary first-order approximation method which has been widely used in the business cycle studies is not appropriate for studying welfare or asset pricing implications of an economic model. To deal with the issue, this paper approximates the equilibrium conditions of the model up to the second order.¹¹ However, some of the equilibrium conditions need to be modified for the second-order approximation because they contain infinite sums that standard second-order approximation algorithms are

⁹ The conditional welfare will be calculated at the nonstochastic steady state and be reported.

¹⁰ For details of derivation and second-order approximation of $\lambda(s_0)$, see Schmitt-Grohé and Uribe (2006).

¹¹ The second order approximation is implemented using the algorithm proposed by Schmitt-Grohé and Uribe (2004).

unable to handle. For example, there are two infinite sums in the equation (34) denoting the optimal reset price of domestic intermediate good producing firms

$$P_H^\#(s^t) = \frac{1}{\theta} \frac{\sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} \Lambda_X(s^{t+\tau}) MC^n(s^{t+\tau}) P_H(s^{t+\tau})^{\frac{1}{1-\theta}} Y_H(s^{t+\tau})}{\sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} \Lambda_X(s^{t+\tau}) P_H(s^{t+\tau})^{\frac{1}{1-\theta}} Y_H(s^{t+\tau})} \quad (34)$$

and it can be rewritten in a recursive fashion that does away with the use of infinite sums.¹² To this end, two new variables $P_H^\#(n; s^t)$ and $P_H^\#(d; s^t)$ are defined and rewritten in a recursive way as follows:

$$\begin{aligned} P_H^\#(n; s^t) &\equiv \sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} (\varphi_X)^\tau \Gamma(s^t, s^{t+\tau}) MC^n(s^{t+\tau}) P_H(s^{t+\tau})^{\frac{1}{1-\theta}} Y_H(s^{t+\tau}) \\ &= MC^n(s^t) P_H(s^t)^{\frac{1}{1-\theta}} Y_H(s^t) + \varphi_X \sum_{s^{t+1}} \Gamma(s^t, s^{t+1}) P_H^\#(n; s^{t+1}) \end{aligned} \quad (35)$$

$$\begin{aligned} P_H^\#(d; s^t) &\equiv \sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} (\varphi_X)^\tau \Gamma(s^t, s^{t+\tau}) P_H(s^{t+\tau})^{\frac{1}{1-\theta}} Y_H(s^{t+\tau}) \\ &= P_H(s^t)^{\frac{1}{1-\theta}} Y_H(s^t) + \varphi_X \sum_{s^{t+1}} \Gamma(s^t, s^{t+1}) P_H^\#(d; s^{t+1}). \end{aligned} \quad (36)$$

Using these auxiliary variables, the equation (34) can be rewritten simply as

$$P_H^\#(s^t) = \frac{1}{\theta} \frac{P_H^\#(n; s^t)}{P_H^\#(d; s^t)} \quad (37)$$

and now the second-order approximation method can be applied for the equation (37). Other equations associated with optimal reset prices can also be modified in the same way.

III. Parameterization

This section discusses how functional forms for technology and preferences are chosen and how parameter values are calibrated in simulations.

¹² Note that index i has been dropped in the equation (34). Because the optimal reset price of all domestic intermediate goods producing firms with an opportunity to change their price will be the same due to the symmetricity of the firms.

3.1. Preference and Technology

The preference of households is given by the instantaneous utility function

$$U(C, N) = \frac{(C(1 - a_n N)^\gamma)^{1-\sigma} - 1}{1-\sigma}$$

where C and N represent consumption and labor supply in each period and σ and γ determine risk aversion and the elasticity of labor supply.¹³

Turning to the production function, the technology of domestic intermediate goods producing firms is given by a standard Cobb-Douglas production function

$$F(A, K, N) = AN^\alpha K^{1-\alpha}$$

where A , N , and K represent the productivity level, labor, and capital respectively. The labor share is represented by α .

3.2. Parameter values

Most of the parameters in the model are calibrated using standard values from the existing literature. Table 1 summarizes the benchmark calibration of the parameters in the model. However, some parameters merit a brief discussion.

First of all, consider parameters related to aggregating technologies at various levels. Following Chari *et al.* (2002), I use an elasticity of substitution between domestic and imported intermediate goods of 1.5 which implies $\rho = 1/3$ and calibrate θ to be 0.83 such that the markup rate is 20% at the steady state. The weighting parameter a between domestic and imported intermediate goods in the final good production is calibrated such that a ratio of import to GDP is equal to 40% at the steady state.

With regard to price stickiness, domestic intermediate goods producing firms and importing firms are assumed to face the same degree of nominal rigidity. Both ϕ_X and ϕ_M are calibrated as 2/3 such that their prices are fixed for 3 quarters on average.

Meanwhile, the parameters related to foreign demand of domestic intermediate goods are calibrated as follows. Reflecting the fact that there is no consensus on the degree of exchange rate pass-through among international economists, the usual perfect pass-through and no pass-through cases and an eclectic case are all

¹³ a_n is a weighting parameter between consumption and leisure in the utility function. Also note that the specification of instantaneous utility function is compatible with the derivation of welfare difference measure $\lambda(s_0)$.

considered in the benchmark calibration. Hence, μ is set as 0.5, 1.0, and 0.0 corresponding respectively to the eclectic, perfect pass-through and no pass-through case. In addition, ω_1 and ω_2 are simply set as -1.0 and 1.0 implying that the foreign demand of domestic intermediate goods is unit elastic both to its relative price and to the foreign output.

[Table 1] Benchmark Parameters

Preference	intertemporal elasticity of consumption=2	$\sigma = 2$
	elasticity of labor supply=1	$\gamma = 1$
Technology I	labor share=2/3	$\alpha = 2 / 3$
	depreciation rate=0.021	$\delta = 0.021$
Technology II	elasticity of substitution between domestic and imported goods=1.5	$\rho = 1 / 3$
	elasticity of substitution among differentiated goods=6	$\theta = 0.83$
Others	frequency of price change: prob. of not reoptimizing price=0.66	$\phi_X = \phi_M = 0.66$
	time discount factor=0.99	$\beta = 0.99$
	degree of exchange rate pass-through	$\mu = 0.5; 0.0; 1.0$
	unit elasticity of foreign demand of domestic goods to terms of trade	$\omega_1 = -1.0$
	unit elasticity of foreign demand of domestic goods to foreign output	$\omega_2 = 1.0$
	sensitivity to policy rate to inflation	$\psi_\pi = 1.5$

Note: α is calibrated such that the ratio of exports (or imports) to GDP is 40% at the steady state. ϕ_K is calibrated such that the ratio of the standard deviation of investment to that of GDP is around 3.

Finally, based on a simple empirical analysis, the international interest rate shocks which serve as the only source of business cycle fluctuations in the theoretical model are specified to follow a stochastic process given by

$$(ir^*(s^{t+1}) - \overline{ir^*}) = 0.94(ir^*(s^t) - \overline{ir^*}) + e^{ir^*}(s^{t+1}) \quad (38)$$

where $\overline{ir^*}$ denotes the international nominal interest rate at the steady state.¹⁴ $e^{ir^*}(\cdot)$ represents an international interest rate shock and is normally distributed

¹⁴ Except for international interest rate, domestic aggregate productivity ($A(s^t)$), foreign output ($Y^*(s^t)$), and foreign price of imported goods ($P_F^*(s^t)$) are exogenous variables that can potentially provide economic shocks to the model through a specific stochastic process. However, since this paper does not consider any other shocks except for international interest rate shocks, they are all assumed to be constants.

with the mean of 0 and the variance of 0.0013.¹⁵ The parameter ψ_π , representing the sensitivity of nominal interest rate to inflation, is set as 1.5 following Galí and Monacelli (2005).

IV. Findings

In this section, the findings from the simulations are discussed. First of all, the welfare levels under various monetary policy rules are compared quantitatively to characterize the optimal monetary policy rule for a small open economy where international interest rate shocks work as main sources of business cycle fluctuations. To this end, international interest rate shocks are imposed on the theoretical model and it is simulated with the benchmark set of parameters. Also, for sensitivity analyses, it will be simulated with different sets of parameters.

4.1. Benchmark case

Table 2 reports main business cycle properties of several key variables including social welfare levels and their differences in units of consumptions under alternative monetary policy rules when the eclectic view on the exchange rate pass-through ($\mu=0.5$) is taken. The most noticeable observation from the table is that both inflation targeting rules outperform exchange rate peg. Particularly, the domestic goods price inflation targeting rule (DPIT) turns out to constitute an optimal monetary policy rule among the alternatives. Under DPIT, the conditional and unconditional welfare are -372.59 and -372.58 respectively. Meanwhile, conditional and unconditional welfare under FIX turn out to be lowest and they are only -372.66 and -372.65. The relative conditional and unconditional welfare losses of FIX compared to DPIT are equivalent, respectively, to 0.007% and to 0.006% of consumption flows under DPIT.¹⁶

The ordering of welfare among the policy rules can be confirmed as well by examining the volatility of real marginal cost. As the New Keynesian macroeconomic literature points out, for an economy where inefficiency arises from

¹⁵ To specify a stochastic process of foreign interest rate shocks, a simple regression analysis is implemented using the LIBO, the Eurodollar and the federal funds rate over the period of 1990 Q1 and 2008 Q4 after verifying using a standard unit-root test that they are stationary in usual significance level. The period since the global financial crisis is excluded, as those international interest rates have hit virtually the zero lower bound since the crisis.

¹⁶ Overall welfare differences among monetary policy rules are quite small even after considering that small welfare differences are not unusual in the related literature. The small welfare differences can be attributed to the failure of the model in generating enough volatility. As Table 2 reports, output volatilities are less than 1% in all cases, which is too low compared to its empirical counterparts reported in some empirical studies such as Neumeyer and Perri (2005) and Guajardo (2008).

[Table 2] Simulation Result of Imperfect Pass-Through ($\mu = 0.5$)

	DPIT	CPIT	FIX
Social Welfare level			
Conditional	-372.59	-372.63 (0.004)	-372.66 (0.007)
Unconditional	-372.58	-372.62 (0.004)	-372.65 (0.006)
Standard Deviations			
Output	0.57	0.63	0.83
Consumption	0.31	0.36	0.50
Investment	1.85	1.96	2.43
Labor	0.13	0.15	0.33
Real Marginal Cost	0.20	0.37	0.76
Trade Balance	3.14	3.14	3.47
Domestic Nominal Interest Rate	0.17	0.29	0.20
Real Exchange Rate	0.58	0.48	0.22
Nominal Exchange Rate	1.73	2.60	0.00
CPI Inflation	0.13	0.19	0.08
Domestic Goods Price Inflation	0.11	0.19	0.16

Note: The statistics on the table are computed as average of 1000 simulations of 100 quarters except for conditional social welfare level which is calculated at the nonstochastic steady state. The numbers in parentheses in the panel of social welfare level are the values of $\lambda(\cdot)$ in simulations denoting welfare differences (%) in units of consumption. All variables except for conditional social welfare and unconditional social welfare are defined as % deviations from their steady state level and the trade balance is defined as a ratio (%) to GDP.

nominal rigidity, the welfare improving effect of a monetary policy works through the stabilization of real marginal cost.¹⁷ So, a monetary policy rule which generates the least volatility of real marginal cost will be an optimal monetary policy among the alternative rules. As reported in Table 2, the ordering of the volatility of real marginal cost is in exact opposition to that of welfare. While the standard deviation of real marginal cost is only 0.20% under DPIT, it amounts to 0.37% and 0.76% under CPIT and FIX respectively.

On the other hand, as mentioned above, considering that the degree of exchange rate pass-through is still controversial among international economists, similar simulations are run additionally for two extreme cases of a perfect pass-through ($\mu = 1$) and no pass-through ($\mu = 0$), and the results from the simulations are summarized in Tables 3 and 4 respectively. The key finding from these simulations is that the major results in the benchmark case do not depend heavily on the degree of exchange rate pass-through. Especially, the ordering of welfare among alternative policy rules in the hybrid case is preserved in these extreme cases only with minor

¹⁷ For details, see Galí (2008) and others.

quantitative variations. As Table 3 reports, in the case of a perfect pass-through, the conditional welfare of DPIT and FIX are -372.59 and -372.66 respectively and their difference becomes a bit larger than in the eclectic case. However, as shown in Table 4, in the case of no pass-through, the welfare difference between two policy rules shrinks slightly although the ordering of welfare is kept the same.

The main findings from the benchmark simulations can be related to the existing literature as follows.

The findings suggest that the recent literature on the optimal monetary policy rule in a small open economy can be revisited with a different perspective. As well known among international macroeconomists, the literature has studied the optimal monetary policy in a small open economy with particular attention to potential factors making it deviate from its counterpart in a closed economy.¹⁸ For example, Galí and Monacelli (2005) and Faia and Monacelli (2008) show that only in the special case of the same elasticity of intertemporal and intratemporal substitutions,

[Table 3] Simulation Result of Perfect Pass-Through ($\mu = 1.0$)

	DPIT	CPIT	FIX
Social Welfare level			
Conditional	-372.59	-372.62 (0.004)	-372.66 (0.008)
Unconditional	-372.58	-372.61 (0.003)	-372.64 (0.007)
Standard Deviations			
Output	0.58	0.65	0.83
Consumption	0.31	0.36	0.50
Investment	1.92	2.03	2.42
Labor	0.20	0.15	0.33
Real Marginal Cost	0.15	0.31	0.76
Trade Balance	3.10	3.20	3.47
Domestic Nominal Interest Rate	0.20	0.30	0.20
Real Exchange Rate	0.55	0.47	0.22
Nominal Exchange Rate	1.83	2.65	0.00
CPI Inflation	0.15	0.20	0.08
Domestic Goods Price Inflation	0.13	0.20	0.16

Note: The statistics on the table are computed as average of 1000 simulations of 100 quarters except for conditional social welfare level which is calculated at the nonstochastic steady state. The numbers in parentheses in the panel of social welfare level are the values of $\lambda(\cdot)$ in simulations denoting welfare differences (%) in units of consumption. All variables except for conditional social welfare and unconditional social welfare are defined as % deviations from their steady state level and the trade balance is defined as a ratio (%) to GDP.

¹⁸ For optimal monetary policy in a more general open-economy context including a two-country model, see Corsetti, Dedola, and Leduc (2011).

[Table 4] Simulation Result of No Pass-Through ($\mu = 0.0$)

	DPIT	CPIT	FIX
Social Welfare level			
Conditional	-372.61	-372.64 (0.004)	-372.66 (0.006)
Unconditional	-372.60	-372.63 (0.003)	-372.65 (0.005)
Standard Deviations			
Output	0.57	0.63	0.83
Consumption	0.31	0.36	0.50
Investment	1.79	1.92	2.42
Labor	0.10	0.18	0.33
Real Marginal Cost	0.27	0.43	0.76
Trade Balance	3.20	3.24	3.48
Domestic Nominal Interest Rate	0.15	0.28	0.20
Real Exchange Rate	0.60	0.50	0.21
Nominal Exchange Rate	1.65	2.60	0.00
CPI Inflation	0.11	0.18	0.08
Domestic Goods Price Inflation	0.10	0.19	0.16

Note: The statistics on the table are computed as average of 1000 simulations of 100 quarters except for conditional social welfare level which is calculated at the nonstochastic steady state. The numbers in parentheses in the panel of social welfare level are the values of $\lambda(\cdot)$ in simulations denoting welfare differences (%) in units of consumption. All variables except for conditional social welfare and unconditional social welfare are defined as % deviations from their steady state level and the trade balance is defined as a ratio (%) to GDP.

the stabilization of the domestic goods price inflation constitutes an optimal monetary policy rule in a small open economy as in a closed economy. However, except for the case, the simple stabilization of domestic goods price inflation is not enough to achieve the efficient allocation in general and some degree of exchange rate stabilization is also needed. In a similar vein, De Paoli (2009) and Monacelli (2005) point out a high elasticity of intratemporal substitution between domestic and imported goods and incomplete pass-through of exchange rate as another factors making the difference.

However, despite their valuable contributions to the literature, they share the same limitation that they do not pay enough attention to sources of economic fluctuations of a small open economy but consider productivity shocks only.¹⁹ To the contrary, motivated by recent studies emphasizing international interest rate

¹⁹ There are noteworthy exceptions. Some studies such as Schmitt-Grohé and Uribe (2001), Kollman (2002) and Batini et al. (2003) consider other internal and external shocks including international interest rate shocks as well as productivity shocks. But, even in those cases, all shocks are considered together, and as a result, it is hard to investigate, in isolation, the implications of international interest rate shocks for the optimal monetary policy in a small open economy.

shocks as main sources of business cycles of small open economies, this paper takes them into serious account and investigates their implications for the optimal monetary policy in a small open economy. By presenting the result that the domestic good price inflation targeting rule outperforms other monetary policy rules in a small open economy severely exposed to international interest rate shocks, it suggests that the optimal monetary policy rule might also be dependent on the source of business cycle fluctuations. In addition, based on the result, this paper can deliver more practical policy recommendations to a small open economy heavily exposed to fluctuations of international interest rates, which have not been available from the existing literature due to the limitation.

In addition, it is also notable that the outperformance of both inflation targeting rules over exchange rate peg is consistent with recent empirical studies. According to them, a country with an exchange rate peg is affected more by international interest rate shocks than a country with a free floating exchange rate. For example, De Giovanni and Shambaugh (2008) report that for a 1%p hike in international interest rate, a country with an exchange rate peg tends to experience a severer slow-down of GDP growth by 0.1%~0.2%p on average than a country with a free floating exchange rate.

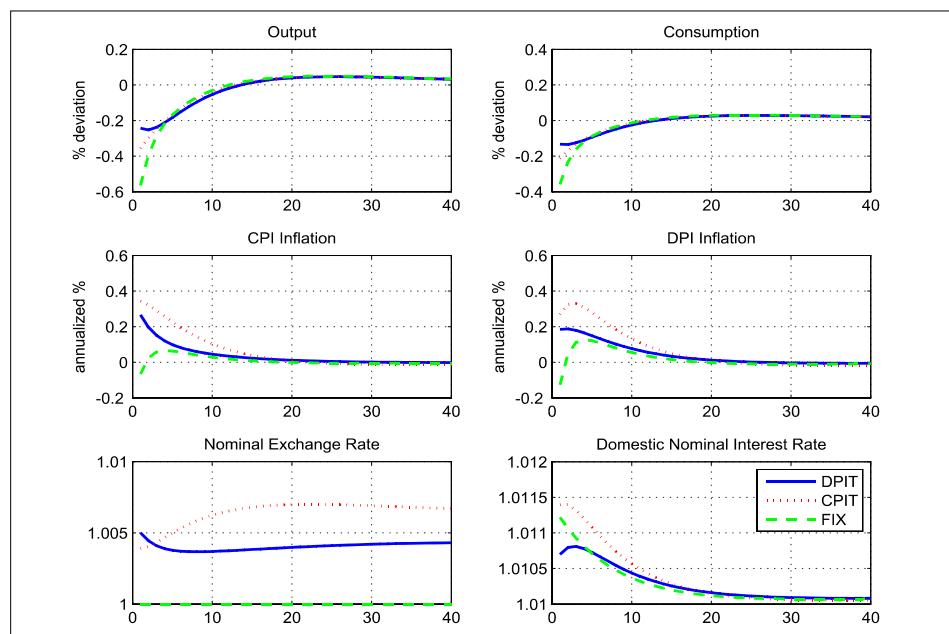
To better understand the simulation results, it will be helpful to examine how differently an international interest rate shock affects the theoretical economy depending on exchange rate regimes. Again, it can be easily exhibited by revisiting the UIP condition.

$$\sum_{s^{t+1}} \Gamma(s^t, s^{t+1}) \left[(1 + ir(s^t)) - \frac{S(s^{t+1})}{S(s^t)} (1 + ir^*(s^t)) \right] = 0. \quad (39)$$

If the exchange rate is pegged, an international interest rate shock affects the economy only through the domestic nominal interest rate. According to the UIP condition, in the case of an exchange rate peg, the domestic and foreign nominal interest rates must have a one-to-one relationship. As a result, a positive international interest rate shock has the same effect as a domestic contractionary monetary policy shock. Hence, a sudden hike in international interest rate is expected to cause the contraction of domestic demand and output.

Meanwhile, if the exchange rate is allowed to float freely, as the UIP condition indicates, the shock can be absorbed both by the adjustment of nominal exchange rate and by the adjustment of domestic nominal interest rate. This additional channel of adjustment through the movement of nominal exchange rate presents pros and cons of inflation targeting rules with a flexible exchange rate over exchange rate peg. The benefit comes from the stabilization of total demand. Given an international interest rate shock, with the help of adjustment of exchange rate, a

[Figure 1] Impulse Response Function of Major Variables to an International Interest Rate Shock



Note: While the impulse response functions of GDP and consumption denote % deviations from their steady state, those of other variables denote levels. The nominal exchange rate is normalized as 1 at the steady state.

smaller adjustment of domestic nominal interest rate is required to absorb the shock in the case of flexible exchange rate. As a result, the domestic demand is expected to fluctuate less. Furthermore, the adjustment of nominal exchange rate contributes to the stabilization of total demand through the movement of foreign demand. For example, when a positive international interest rate shock hits a small open economy, according to the UIP condition, it is likely that the domestic nominal interest rate jumps up while the home currency depreciates. Then, the domestic demand of the economy will shrink due to the rise of domestic interest rate but its foreign demand will expand due to the depreciation of the domestic currency. On the other hand, the disadvantage of inflation targeting rules with a flexible exchange rate is connected to the instability of inflation. The fluctuation of nominal exchange rate may influence the domestic prices of imported goods, and the volatility of inflation can be magnified as a result.

The difference between inflation targeting rules and exchange rate peg elaborated above is clearly visualized in Figure 1, which plots the impulse response functions of key variables responding to an international interest rate shock of one standard error under the different monetary policy rules. From the figure, it is observed that the fluctuation of output is smaller in the case of CPIT and DPIT than in the case

of FIX. On the impact of the shock, the output falls only 0.24% from the steady state value under DPIT while it does more than 0.56% under FIX. On the contrary, on the impact moment, the CPI inflation jumps up by 0.34% and 0.27% from the steady state rate under CPIT and DPIT respectively but it rather falls by 0.06% under FIX. DPI inflation under DPIT and CPIT exhibits a similar pattern but with a hump-shape and smaller magnitude compared with CPI inflation. It jumps up at the impact moment by 0.18% and 0.27% respectively under DPIT and CPIT and the difference between DPI inflations under the two policy rules increases to 0.15%p up to 3 quarters in a hump-shaped fashion. Meanwhile, the difference between CPIT and DPIT is mainly due to the higher inflation of imported goods prices induced by the depreciation of exchange rate. As the figure shows, the nominal exchange rate jumps up immediately on the impact of the shock in both cases of inflation targeting rule but its volatility is a little greater under CPIT than under DPIT.

4.2. Sensitivity Analysis

The discussion on benchmark simulation results also provides useful perspectives for sensitivity analysis. As discussed above, for an international interest rate shock, inflation targeting rules with a flexible exchange rate face a trade-off between the benefit of stabilization of total demand and the cost of destabilization of inflation via fluctuations of nominal exchange rates compared to exchange rate peg. On the benefit side, the main result from the benchmark simulations can be changed significantly depending on how exports are affected by nominal exchange rate fluctuations. To address such concern, sensitivity analyses need to be implemented with parameters determining the behavior of exports such as the degree of trade openness and the elasticity of foreign demand of domestic goods. Meanwhile, as for the cost side, the degree of pass-through of exchange rates to imported goods price or the degree of aggressiveness of monetary authority to inflation can be pointed out as another important factors affecting the dynamics of domestic inflation. In this regard, sensitivity analyses will be implemented with respect to those factors.

The results of sensitivity analyses are summarized in Table 5 and 6 and for the expositional convenience, only conditional welfare and corresponding welfare differences are reported in those tables. At first, the panel (a) of Table 5 shows how simulation results change when the degree of trade openness is calibrated differently from that in the benchmark case. For the purpose, the ratio of exports (or imports) to GDP at the steady state is calibrated as 30% and 50%, which are 10%p lower and higher than the benchmark case respectively.²⁰

²⁰ As in the benchmark calibration, the parameter of home bias α in the equation (5) is calibrated such that the ratio of exports (or imports) to GDP is 30% and 50% at the steady state in turn.

[Table 5] Sensitivity Analysis: Trade Openness and Elasticity of Foreign Demand to Terms of Trade

	DPIT	CPIT	FIX
(a) Trade Openness			
Lower trade openness ($Export/GDP=0.3$)	-366.95	-366.98 (0.003)	-367.05 (0.011)
Benchmark ($Export/GDP=0.4$)	-372.59	-372.63 (0.004)	-372.66 (0.007)
Higher trade openness ($Export/GDP=0.5$)	-350.56	-350.59 (0.003)	-350.59 (0.003)
(b) Elasticity of Foreign Demand to Terms of Trade			
No Pass-Through ($\mu = 0.0$)			
Inelastic ($\omega_1 = 0$)	-371.26	-371.60 (0.036)	-371.83 (0.060)
Benchmark ($\omega_1 = -1.0$)	-372.61	-372.64 (0.004)	-372.66 (0.006)
Highly elastic ($\omega_1 = -2.0$)	-372.70	-372.70 (0.001)	-372.75 (0.001)
Partial Pass-Through ($\mu = 0.5$)			
Inelastic ($\omega_1 = 0$)	-371.64	-371.76 (0.013)	-371.83 (0.021)
Benchmark ($\omega_1 = -1.0$)	-372.59	-372.63 (0.004)	-372.66 (0.007)
Highly elastic ($\omega_1 = -2.0$)	-372.63	-372.66 (0.002)	-372.75 (0.012)
Perfect Pass-Through ($\mu = 1.0$)			
Inelastic ($\omega_1 = 0$)	-371.79	-371.87 (0.009)	-371.83 (0.004)
Benchmark ($\omega_1 = -1.0$)	-372.59	-372.62 (0.004)	-372.66 (0.008)
Highly elastic ($\omega_1 = -2.0$)	-372.60	-372.64 (0.004)	-372.75 (0.015)

Note: All numbers are conditional social welfare levels for corresponding set of parameter values and the numbers in parentheses are the values of $\lambda(\cdot)$ in simulations denoting welfare differences (%) in units of consumption.

In the case of lower trade openness, the conditional social welfare of DPIT and FIX are -366.95 and -367.05 respectively and the welfare difference in units of consumption between those monetary policy rules increases to 0.011% while it is only 0.007% in the benchmark case. Meanwhile, in the case of higher trade openness, the conditional welfare levels of DPIT, CPIT, and FIX are -350.56, -350.59 and -350.59 respectively and the welfare difference between DPIT and FIX is merely 0.003%. In sum, the social welfare is highest under DPIT while lowest under FIX irrespective of size of trade openness and the welfare difference between

inflation targeting rules and exchange rate peg increases as the degree of openness is lower.

The sensitivity analysis presented in the panel (a) of Table 5 shows that the main result in the benchmark is robust for the reasonable range of trade exposure. Also, it suggests that trade openness can be an important factor in determining the relative superiority of inflation targeting rules over exchange rate peg responding to international interest rate shocks. More specifically, with lower trade openness, inflation targeting rules are more likely to outperform exchange rate peg.

Considering the importance of the degree of nominal exchange rate pass-through and the price elasticity of foreign demand of domestic goods in dynamics of trade, it is also investigated how the main results in the benchmark case are sensitive to the changes of related parameters, μ and ω_1 . For this purpose, similar simulations are repeated with various pairs of different values of those parameters and the simulation results are summarized in the panel (b) of Table 5. Most notable observation from the table is that the overall ordering of welfare among alternative monetary policy rules in the benchmark case is still preserved even with different values of those parameters. In most cases, DPIT outperforms the other monetary policy rules in terms of social welfare and exchange rate peg is outperformed by the others. For example, in the case of no pass-through and inelastic foreign demand ($\mu=0$ and $\omega_1=0$), the conditional welfare under DPIT, CPIT and FIX are -371.26, -371.60, and -371.83 respectively and the welfare difference in units of consumption between DPIT and FIX amounts to 0.060%. Only in the case of perfect pass-through and inelastic foreign demand ($\mu=1.0$ and $\omega_1=0$), FIX provides a higher social welfare than CPIT. However, even in the case, the differences are quite small.

So far the results of the sensitivity analysis regarding the benefit side of inflation targeting rules over exchange rate peg have been presented and discussed. Now let's turn to the sensitivity analyses related with the cost side of inflation targeting rules. As discussed above, particular attention will be paid to the degree of pass-through of exchange rate to imported goods price and the sensitivity of policy rate to inflation.

Before discussing the result of the sensitivity analysis regarding the degree of pass-through to imported goods price, it is notable that this paper assumes the local currency pricing in contrast to some early contributions in this area such as Galí and Monacelli (2005) and Faia and Monacelli (2008) that assume the producer currency pricing and then analyze the case of perfect pass-through.²¹ Hence, for a better comparison with the existing literature, it is also helpful to consider the case of perfect pass-through as a sensitivity analysis. However, since all foreign sectors are

²¹ As described in detail in the previous section, this paper assumes that the imported goods are assumed to be priced in local currency by monopolistically competitive local importers facing a nominal rigidity and consequently, the fluctuations of nominal exchange rate are passed through local prices of the imported goods only partially. Similar modeling can be found in Monacelli (2005).

modeled simply as exogenous stochastic processes rather than as rational economic agents, it is hard to formulate fluctuations of foreign prices of imported goods with micro-foundations. Instead, this paper attempts to approximate the case of perfect pass-through by assuming that importers do not face any nominal rigidity ($\varphi_M = 0$). The basic idea of the approximation can be easily understood by revisiting the importing firm's optimization problem. Without nominal rigidity, the problem is converted into a simple static one and its first-order condition is obtained as

$$P_F(s') = \frac{1}{\theta} S(s') P_F^*(s'). \quad (40)$$

Considering that the foreign price of imported goods are assumed to follow an exogenous stochastic process, it is easy to see that the exchange rate passes through domestic price of imported goods perfectly. In addition, after adjusting the importer's markup $1/\theta$, the law of one price holds good as well.

The sensitivity analysis of the degree of pass-through to imported goods price is implemented by calibrating the Calvo parameter φ_M denoting the degree of nominal rigidity in the importing sector as 0 and simulating the model. As discussed above, the benchmark case of $\varphi_M = 0.66$ represents the local currency pricing and the imperfect pass-through while the case of $\varphi_M = 0$ does the producer currency pricing and the perfect pass-through. The results summarized in the panel (a) of Table 6 suggest that the main findings of the benchmark calibration is robust for the degree of pass-through to imported goods prices. DPIT outperforms CPIT and FIX irrespective of the degree of pass-through and the welfare differences of DPIT with CPIT and FIX expand to 0.008% and 0.016% from 0.004% and 0.007%, respectively, when the degree of pass-through increases.

The final sensitivity analysis presented in this section is related to how aggressively the monetary authority tries to stabilize domestic inflation. For this purpose, the model is simulated with different values of ψ_π from the benchmark one. In the case of less aggressive, ψ_π is calibrated as 1.1 while in the case of more aggressive, calibrated as 2.0. The results from the simulations are summarized in the panel (b) of Table 6.

The most notable observation from the table is that the ordering of welfare is reversed when the sensitivity of policy rate to inflation is quite low. In that case, FIX provides the highest welfare level of -372.66 and the welfare levels under two inflation targeting rules are virtually the same but smaller than FIX. Furthermore, the size of welfare difference between DPIT and FIX measured in units of consumption is quite big compared to that in the benchmark case. Its absolute value is 0.046%, which is much bigger than 0.007% in the benchmark case. On the other hand, when the monetary authority is quite aggressive in stabilizing inflation, the welfare ordering of the benchmark calibration is preserved and the welfare

difference between DPIT and FIX increases from 0.007% to 0.012%.

[Table 6] Sensitivity Analysis: Degree of Exchange Rate Pass-Through to Imported Goods Prices and Sensitivity of Policy Rate to Inflation

	DPIT	CPIT	FIX
(a) Degree of Pass-Through to Imported Goods Price			
Benchmark ($\varphi_M = 0.66$)	-372.59	-372.63 (0.004)	-372.66 (0.007)
Perfect pass-through ($\varphi_M = 0$)	-372.52	-372.60 (0.008)	-372.67 (0.016)
(b) Sensitivity of Policy Rate to Inflation			
Less sensitive ($\psi_\pi = 1.1$)	-373.10	-373.09 (-0.000)	-372.66 (-0.046)
Benchmark ($\psi_\pi = 1.5$)	-372.59	-372.63 (0.004)	-372.66 (0.007)
Highly sensitive ($\psi_\pi = 2.0$)	-372.54	-372.56 (0.001)	-372.66 (0.012)

Note: All numbers are conditional social welfare levels for corresponding set of parameter values and the numbers in parentheses are the values of $\lambda(\cdot)$ in simulations denoting welfare differences (%) in units of consumption.

In sum, from the sensitivity analyses presented above, it can be concluded that the main result of the benchmark simulations that domestic goods price inflation targeting is the optimal policy rule for a small open economy vulnerable to international interest rate shocks is quite robust for the reasonable range of key parameter values. But, to exploit the welfare gain from adopting inflation targeting rules over exchange rate peg, it is necessary that the monetary authority attempt to stabilize domestic inflation aggressively enough.

V. Conclusions

Despite the recent empirical evidence that a considerable part of business cycle fluctuations in small open economies could be explained by international interest rate shocks, their implications on monetary policy in a small open economy have rarely been investigated in the related literature. Considering the limits of the existing literature, this paper attempts to study the implications of international interest rate shocks for monetary policy in a small open economy. Particularly, it focuses on characterizing the monetary policy rule that is optimal among simple and implementable rules for a small open economy where international interest rate shocks work as main sources of business cycle fluctuations.

For this purpose, this paper introduces international interest rate shocks into a

standard small open economy model with sticky prices and the performances of various monetary policy rules are compared in terms of social welfare. To be specific, two inflation targeting rules with inflation targets of different prices and exchange rate peg are considered to be simple and implementable monetary policy rules. The main findings of this paper can be summarized as follows. First, for a small open economy vulnerable to international interest rate shocks, domestic goods price inflation targeting is the optimal policy rule within a family of simple and implementable monetary policy rules. Second, it is found that nominal exchange rate fluctuations implicated by inflation targeting rule expose the monetary authority to a trade-off between the benefits of the total demand stabilization via foreign demand and the cost of increased volatility of inflation. Furthermore, the relative superiority of inflation targeting rules over exchange rate peg depends on the trade-off.

Admittedly, there are several analytic limitations of this paper which are to be reserved for future research. However, two of them are particularly mentionable. First, although existing empirical studies, such as Neumeyer and Perri (2005), emphasize the importance of the country spread and its relationship with each country's economic fundamentals as a magnifying mechanism, they are not properly reflected in the model. This unwilling negligence of the country spread is largely due to the lack of guidance for modeling and calibration from the existing literature. Arguably, the relationship between the country spread and each country's fundamentals has not been explored enough to be formulated into a theoretical model to the present. Second, there is a possibility that the world economy and the international interest rate have a systematic relationship on a worldwide scale similar to the Taylor rule at an individual country level. But this paper does not take that possibility into serious account because of the lack of solid empirical evidence. Should such relationship between the world economy and the international interest rate exist, then the main conclusion of this paper should be revisited.

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