Journal of Development Economics 111 (2014) 246–260

Contents lists available at ScienceDirect

Journal of Development Economics

journal homepage: www.elsevier.com/locate/devec

Oil price stabilization and global welfare☆

Qing Liu [a,*], Kang Shi [b,1], Zhouheng Wu [d], Juanyi Xu [c,2]

[a] School of Economics and Management, Tsinghua University, Beijing, China
[b] Department of Economics, Chinese University of Hong Kong, Hong Kong
[c] Department of Economics, Hong Kong University of Science and Technology, Hong Kong
[d] Department of Economics, Chinese University of Hong Kong, Hong Kong

ARTICLE INFO

Article history:
Received 15 January 2013
Received in revised form 30 September 2013
Accepted 8 October 2013
Available online 23 October 2013

JEL Classification:
F3
F4

Keywords:
Oil price stabilization
Dollar currency pricing
Monetary policy
Welfare

ABSTRACT

Oil price stabilization polices are adopted extensively in developing countries. Some argue that developed economies, especially the US, may gain from these policies through trade. This paper studies this issue in a two-country model with dollar currency pricing. We find that the optimal level of oil price stabilization chosen by developing countries and its implications for global welfare depend critically on whether monetary policy can effectively respond to oil shocks. In an environment without monetary shocks, when optimal monetary policies are considered, there is no role for oil price stabilization in developing countries. However, to make the oil price stabilization policy redundant, optimal monetary policy is not necessary. Some non-optimal endogenous monetary policies satisfying certain conditions can also make the developing countries choose zero oil price stabilization. The results change when there are monetary shocks. Even with optimal monetary policies, the developing countries will choose a positive level of oil price stabilization. However, due to dollar currency pricing, the US actually loses from the stabilization policy. Our results are well supported by the quantitative analysis in a full-fledged dynamic stochastic general equilibrium model.

1. Introduction

During the past half century, various oil price stabilization policies have been adopted in many developing countries to insulate their economies from highly volatile oil prices. For example, in some economies, such as Argentina, Cameron, Chile, and Thailand, the governments will set a targeted domestic price, which is supposed to be equal to the long run equilibrium price. When the world oil price goes up, government funds subsidize oil importing firms; when the world price goes down, the oil importing firms are taxed and the revenues are returned to government funds. As reported in Economist (2008-05-29): "half of the world's population enjoys oil subsidies." The World Bank (2009) reported that the average oil subsidies of a selected sample of countries in the recent period of high oil prices (2007–2008) are approximately 2% of their GDP. Without fiscal difficulties, the economies may benefit from these polices. However, a natural question arises; to what extent the government should stabilize the domestic oil price? Also, many commentators argue that large amounts of subsidies will be embodied in the export good prices and indirectly benefit developed economies, especially the US, the largest export market for most developing countries. Does the US really gain from the oil price stabilization in developing countries through trade? If so, how much is the gain?

This paper studies these issues in an asymmetric world economy, where the US dollar is the central reference currency for international trade pricing and primary commodities invoicing. In the model, we assume that oil is an input of production and the export good prices for both home and foreign firms are set in the US dollar.[3] We assume that only the foreign country (developing countries) directly uses subsidies to stabilize oil prices such that the pass-through of oil prices to the foreign economy depends on the degree of intervention.

We first consider a simple two-country model with one-period price setting to show some analytical results. In this baseline model, we treat the oil price as an exogenous shock. We find that the optimal level of oil price stabilization chosen by developing countries and its welfare consequences depend critically on monetary policies. In an environment without monetary shocks, when monetary authorities

☆ We thank the editor, Nina Pavcnik, the two anonymous referees, David Cook, Michael Devereux, and Shang-jin Wei for their useful comments and discussions, as well as conference participants at Tsinghua International Macroeconomics meeting. All errors are our own responsibilities.

* Corresponding author.
E-mail addresses: liuqing@sem.tsinghua.edu.cn (Q. Liu), kangshi@cuhk.edu.hk (K. Shi), wuzhouheng@cuhk.edu.hk (Z. Wu), jennyxu@ust.hk (J. Xu).
[1] Tel.: +852 3943 8194.
[2] Tel.: +852 2358 7604.

[3] This model setting is consistent with the findings in Goldberg and Tille (2008) and Gopinath and Rigibon (2008). The former found that the dollar is overwhelmingly used for invoicing both export and import prices for the US economy, while the latter showed that the exchange rate pass-through into US dollar prices of export and import goods is very low.

0304-3878/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jdeveco.2013.10.006

can optimally respond to the oil price shock, oil price stabilization becomes unnecessary even for developing countries. This is because, without monetary shocks, the responses of money supply to oil price shocks can fully offset the impact of oil price changes on marginal cost and thus stabilize price level. In this sense, the monetary policy is a substitute for the oil price stabilization policy. In particular, when monetary policies can stabilize firms' marginal cost, if the foreign country still imposes the oil price stabilization policy, the stabilization effect of monetary policies will be mitigated. This may lead to a less efficient equilibrium compared to the case with optimal monetary policy and zero oil price stabilization policy. Therefore, with optimal monetary policy, oil price stabilization is redundant. The US is also better off with zero oil price stabilization. Is optimal monetary policy necessary for zero oil price stabilization? Our answer is no. We find that, without monetary shocks, some endogenous but non-optimal monetary policy rules satisfying certain conditions can also replace the oil price stabilization.

When there are uncontrollable errors (or shocks) in the conduct of optimal monetary policies, the developing countries will choose to stabilize oil prices. However, this may be at the expense of the US welfare. That is, instead of gaining from the stabilization of oil prices in developing countries, the US may *lose* in terms of welfare. Why do developing countries gain from oil price stabilization whereas the US loses from such policies? The intuition is simple. Due to the presence of monetary shocks, the exchange rate risk is unavoidable. When developing countries intervene in their domestic oil market, it not only eliminates the uncertainty of world oil price, but also reduces the exchange rate risk of importing oil. For developing countries, this helps to lower firms' expected marginal cost and then expected price level, and thus leads to an increase in the welfare of households. However, introducing oil price stabilization policy reduces the stabilization effect of monetary policies on oil prices. Therefore, there exists a trade-off and non-zero oil price stabilization policies are optimal for developing countries.

For the US, oil price stabilization policy can stabilize oil price, but it cannot reduce the exchange rate risk in the price of import goods. Instead, it amplifies the exchange rate risk in the price of imported goods. This is because firms in developing countries set export good price in the US dollar, and they will take the exchange rate risk into consideration and embody a risk premium in the price. Without oil price stabilization policies, the exchange rate risk can be offset partially by the exchange rate risk of importing oil. However, when there is oil price stabilization, this effect is reduced. As a result, oil price stabilization leads to more exchange rate risks. Hence, in an environment without monetary shocks, the combination of optimal monetary policy and zero oil price stabilization is optimal for both the US and the developing countries. In the presence of monetary shocks, zero oil price stabilization is still preferred by the US, though it may not be the optimal choice for developing countries. This implies that when there exist optimal monetary policies, oil price stabilization policy in developing countries does not have any positive spill-over effect on the US.

There is an exceptional case where the US can indeed gain from oil price stabilization in developing countries. This occurs when monetary policies are fully random. For developing countries, oil price stabilization can reduce uncertainties from both oil prices and exchange rate movements, so full oil price stabilization is optimal. However, for the US, there is a trade-off between stabilizing oil price and stabilizing exchange rates. The US will, therefore, prefer partial stabilization or zero stabilization depending on the size of shocks. If the developing countries impose a full price stabilization policy, compared with zero oil price stabilization, the US may gain from this policy when oil price shocks are sufficiently large.

For quantitative assessments, we extend our analytical model to a full-fledged general equilibrium model. To make the model more realistic, we introduce four features: dynamic price setting, endogenous oil prices, Taylor-type interest rate rule and alternative financial market structure. In the quantitative analysis, we first report the impulse responses of home and foreign economic variables to a negative oil supply shock, and then use numerical methods to study the optimal degree of oil price stabilization and its welfare consequences. We find that with Taylor interest rate rules, the developing countries may choose positive level of oil price stabilization if the monetary shocks are large. Nevertheless, given reasonable parameter values, the US always loses from oil price stabilization policies. However, if the monetary policies are well conducted, there is no role for oil price stabilization in the foreign country. The sensitivity analysis shows that our results are robust to changes in financial structure and Taylor rules, introduction of technology shocks, and variation in some parameter values such as home country size, price elasticity of oil supply, and the share of oil in production. Thus, our analytical results are well supported by quantitative analysis.

This paper builds on Devereux et al. (2007, 2010). Devereux et al. (2007) study the optimal monetary policy in an asymmetric environment where all the export goods are priced in the US dollar. Devereux et al. (2010) examine how the role of the US dollar as invoicing currency for oil affects the currency choice of export pricing and households' welfare. In the current paper, we take the dollar currency pricing as given and investigate how oil price stabilization policies in developing countries affect the US welfare. Bouakez et al. (2008) are the first to study the issue of optimal oil price pass-through. They find that, in a two-sector small open economy model with nominal rigidities, when the monetary policy is capable of stabilizing the economy, the government intervention in the oil market should be avoided; otherwise, the government should limit the degree of pass-through of oil prices. We obtain similar results in our two-country model. Our paper is complementary to their work. We show that the optimal level of oil price stabilization depends critically on whether endogenous monetary policy can respond to oil shocks effectively. Another major difference of our paper is that we also focus on the global spill-over effects of oil price stabilization policies in developing countries. We show that the US may not gain from huge oil subsidies in developing countries through trade, contrary to common conjecture. This is because given dollar currency pricing, oil price stabilization actually leads to higher export price to the US.

We organize the rest of the paper as follows. Section 2 documents some stylized facts about oil price stabilization in developing countries. Section 3 presents a simple model based on Devereux et al. (2007, 2010). Section 4 studies the optimal oil price stabilization policy and its welfare consequences. Section 5 extends the analytical model to a quantitative model. Section 6 provides quantitative results. Section 7 concludes.

2. Stylized facts

To our knowledge, Bouakez et al. (2008) are the first to formally study the issue of optimal oil price pass-through in the dynamic stochastic general equilibrium model (DSGE) framework. Based on the studies of World Bank (2006) and Baig et al. (2007), they document that roughly half of the developing and emerging market economies surveyed have not passed through the increases in the world oil prices into domestic oil prices. In particular, in one-third of these countries, the degree of oil price pass-through was less than 50 percent.

To show clearly how the governments respond to oil price changes, we summarize some facts from a recently released report by World Bank (2009). The report examines the policy responses of 49 countries to world oil price movement from January 2007 to July 2008. The countries listed in Table 1 are those that use direct price control.

Many governments also use subsidies and tax reductions to mitigate price changes on the world oil market. Table 2 reports the countries with large subsidies in recent years. We observe that the subsidies during the period 2007–2008 were substantially large. For the selected sample countries, the subsidies account for roughly 1 percent of their

Table 1
Price control in selected developing countries in 2007–2008.

Country	Price control
Bolivarina de Venezuela, Yemen	No adjustment
Ethiopia, Ghana, Honduras, Malawi, Morocco, Mozambique, Pakistan, Sri Lanka	Frozen price for several months
Mexico	Adjust oil price with inflation
Brazil	Maintain producer's price stable
Egypt, Indonesia, Bangladesh, China, Malaysia	Ad hoc pricing

GDP. If we exclude China, however, the number rises to 2 percent of GDP. In Egypt, the subsidy in 2008 is about 6.76 percent of its GDP. For most countries, these subsidies are supported by oil price stabilization funds. To finance the subsidies in 2007 and early 2008, oil prices in some countries such as Morocco, Brazil, and Mexico, did not go down at all in the last four months of 2008 despite a sharp fall in world oil prices.

3. A simple analytical model

The world economy consists of two countries, which are referred to as the home country (the United States) and the foreign country (developing countries). There is a continuum of home goods (home population) and foreign goods (foreign population) of measures n and $1-n$ respectively. Each good is produced by a monopolistic competitive firm using oil (or more generally, primary commodities) and labor. The economy is exposed to two types of shocks: money supply shocks and oil price shocks.

In this section, we abstract from any dynamics by considering a single-period model with uncertainty.[4] The timing of events within the period unfolds as follows: Before the period begins, households can trade in a full set of nominal state-contingent bonds; and the foreign government sets a rule to stabilize the domestic oil market. [5] Then, firms set prices in advance; After the realization of stochastic shocks, households work and choose their optimal consumption baskets; production and consumption then take place, and the exchange rate is determined.

Our model is asymmetric, in that the dollar is the reference currency for international goods pricing and commodities invoicing. The detailed structure is described below. Where appropriate, foreign variables are indicated with an asterisk.

3.1. Households

The preference of the representative household is given by

$$U=E\left(\frac{C^{1-\rho}}{1-\rho}+\chi\ln\frac{M}{P}-\eta L\right),\tag{3.1}$$

where $C=\frac{C_h^n C_f^{1-n}}{n^n(1-n)^{1-n}}$, $C_h=\left[\int_0^n n^{-\frac{1}{\lambda}}C_h(i)^{\frac{\lambda-1}{\lambda}}di\right]^{\frac{\lambda}{\lambda-1}}$, $\lambda>1$. C is the home aggregate consumption, which is composed of home goods and foreign goods with weights of n and $1-n$, respectively. C_h is the home sub-aggregate consumption of a continuum of home goods indexed by $[0,n]$, and λ is the elasticity of substitution across home individual goods. ρ is the parameter of risk aversion and $\rho\geq 1$.[6] $\frac{M}{P}$ is real money balance. L represents the costly labor effort. η and χ are positive constant scale parameters. E is the expectation operator defined across all possible states of nature. From the consumption structure, we may derive the consumption-based price index, $P=P_{hh}^n P_{fh}^{1-n}$, where P_{hh} and P_{fh} represent the prices for home goods and foreign goods sold in the home country, respectively.

In the model, we assume a complete financial market where home and foreign households can trade ex-ante a full set of nominal state-contingent bonds. The household earns wage income, gets the payoff of state-contingent securities, and receives the profit from the ownership of home goods firms as well as the revenue from the share of world oil endowment, initial money balances, and lump-sum transfers from the government. The government is assumed to repay seigniorage revenue through a lump-sum transfer.

Following recent literature such as Chari et al. (2002) and Devereux and Engel (2003), we show that the trade in state-contingent nominal assets across countries leads to the following risk-sharing condition:

$$\frac{C^{-\rho}}{P}=\Gamma\frac{C^{*-\rho}}{SP^*},\tag{3.2}$$

where S is the nominal exchange rate and Γ is the state-invariant weight.[7] As in Devereux and Engel (2003), we show that equilibrium in the ex-ante securities market implies that $\Gamma=\frac{EC^{(1-\rho)}}{EC^{*(1-\rho)}}$. In addition, the home household's optimization gives rise to the money demand function, $M=\chi PC^{\rho}$, and the implicit labor supply schedule, $W=\eta PC^{\rho}$. Therefore, the nominal wage is given by $W=\frac{\eta}{\chi}M$. Combining the money market equilibrium for the home and foreign countries with cross-country risk-sharing condition (3.2), we can derive the exchange rate as

$$S=\Gamma\frac{M}{M^*}.\tag{3.3}$$

3.2. Oil market

We model oil as a direct input in the production process suggested by Mork and Hall (1980) and Leduc and Sill (2003). Oil endowment is assumed to be owned by a third party such as OPEC. Both home and foreign firms import oil from OPEC and take the oil price as given. The oil price Q is quoted in the home currency (the US dollar) and follows a log normal distribution,

$$\ln Q=q,\quad q\sim N\left(0,\sigma_q\right).\tag{3.4}$$

Table 2
Subsidies in selected developing countries in 2008.

Country	Subsidies (billion US dollar)	Share of GDP (%)
China	7.5	0.17
India	6.7	0.58
Mexico	25	2.79
Iran	6.5	1.68
Indonesia	13	2.87
Egypt	11	6.76
Malaysia	2.7	1.26
Columbia	3	1.37
Pakistan	2.8	2.16
Bangladesh	1.5	1.89
Nepal	0.1	0.79
Total	79.8	0.985

[4] This assumption is innocuous because we assume asset markets are complete. The results extend to an infinite horizon model without change.

[5] In most economies, oil price stabilization policies are conducted by the fiscal authority, and the legislative process of oil price stabilization is long. In the literature, the fiscal authority is usually assumed to move before the monetary authority, so we also assume that the level of oil price stabilization is determined before the monetary policy rule is announced.

[6] Note that $\rho\geq 1$ is a standard assumption in new Keynesian open economy macroeconomics literature, since empirical estimates of ρ and quantitative calibration of ρ for business cycle and asset pricing literature are almost always above unity.

[7] Γ represents the ratio of the Lagrange multiplier on the home households' budget constraint to the Lagrange multiplier on the foreign households' budget constraint. In equilibrium, the budget constraints for both home and foreign countries are not needed, as they are replaced by the risk-sharing condition. Therefore, for simplicity, we do not specify the budget constraint here.

It is assumed that the foreign government sets its domestic oil price according to the following rule

$$Q^* = \overline{Q}^v \left(\frac{Q}{S}\right)^{1-v}, \tag{3.5}$$

where $\overline{Q}$ is the targeted oil price set by the foreign government. When $v = 0$, the domestic oil price faced by foreign firms in terms of foreign currency is $\frac{Q}{S}$. This implies a full pass-through of world oil price into the foreign economy or zero oil price stabilization. When $v = 1$, the domestic oil price faced by foreign firms is simply $\overline{Q}$, which implies a zero pass-through of world oil price into the foreign economy or full oil price stabilization. Given the intervention rule, the subsidy or tax that the foreign government imposes on firms is $(\frac{Q}{S} - Q^*)O^*$, which is financed through a lump-sum transfer from households.[8]

3.3. Production

Each firm i in the home country has the following production function, $Y(i) = A(L(i))^{1-\alpha}O(i)^{\alpha}$, where O represents the amount of oil used in production, $A = \frac{1}{\alpha^{\alpha}}\frac{1}{(1-\alpha)^{1-\alpha}}$ is a constant parameter. Therefore, marginal costs for home and foreign firms in terms of their own currency, respectively, are

$$MC = W^{1-\alpha}Q^{\alpha}, \tag{3.6}$$

$$MC^* = W^{*1-\alpha}Q^{*\alpha} = W^{*1-\alpha}\overline{Q}^{\alpha v}\left(\frac{Q}{S}\right)^{\alpha(1-v)}. \tag{3.7}$$

Eqs. (3.6) and (3.7) imply that the oil price shock has a direct impact on the firm's production cost. However, home and foreign firms are affected asymmetrically since foreign firms' marginal cost depends on the domestic oil price, which is subject to not only exchange rate changes but also government intervention.

In the model, the home currency (the US dollar) is the reference currency for international goods pricing and firms in both home and foreign countries set export prices in the US dollar. This implies that all firms in the home country choose producer currency pricing (PCP) and all firms in the foreign country choose local currency pricing (LCP).[9] From the firms' optimization problem, we can derive the optimal pricing policy for home and foreign goods sold in home and foreign markets, respectively.

$$P_{hh} = \hat{\lambda}\frac{E\left[(MC)C^{1-\rho}\right]}{E\left[C^{1-\rho}\right]}, \quad P_{hf} = \hat{\lambda}\frac{E\left[(MC)C^{*1-\rho}\right]}{E\left[C^{*1-\rho}\right]}, \tag{3.8}$$

$$P^*_{ff} = \hat{\lambda}\frac{E\left[(MC^*)C^{*1-\rho}\right]}{E\left[C^{*1-\rho}\right]}, \quad P_{fh} = \hat{\lambda}\frac{E\left[(MC^*)SC^{1-\rho}\right]}{E\left[C^{1-\rho}\right]}, \tag{3.9}$$

where $\hat{\lambda} = \frac{\lambda}{\lambda-1}$ represents the markup. An asterisk over the price implies that the price is denominated in the foreign currency. Given these prices, the price index for each country can be derived as follows:

$$P = P^n_{hh}P^{1-n}_{fh}, \quad P^* = \left[\frac{P_{hf}}{S}\right]^n P^{*\,1-n}_{ff}. \tag{3.10}$$

Note that the home CPI is completely predetermined while there is positive exchange rate pass-through into the foreign CPI.

These pricing equations show that the effects of oil price stabilization on the economies are mainly through P^*_{ff} and P_{fh}. Due to dollar currency pricing, the law of one price does not hold between them. We find that oil price stabilization can stabilize marginal cost and lower P^*_{ff}, but not necessarily decrease P_{fh}. This is because when a foreign firm presets the export price, it will take the exchange rate risk into consideration and embody a risk premium in the export price. Without oil price stabilization, the exchange rate risk can be offset partially by the exchange rate risk of importing oil. However, when there is oil price stabilization, this effect is reduced. As a result, the firm may include a higher exchange rate risk premium in the export price. This implies that oil price stabilization may reduce the oil price risk but increase the exchange rate risk in the price. This is the reason the export price of foreign goods, P_{fh}, is not necessarily lower under oil price stabilization.

3.4. Monetary rules

We assume that monetary authorities commit to the following form of contingent monetary rules[10]:

$$m = aq + u, \quad m^* = bq + u^*, \tag{3.11}$$

where m and m^* are the log of money supply; {a, b} are policy parameters determined by solving international monetary game; and the terms u and u^* represent uncontrollable disturbances to money supplies. We assume that $u \sim N(0,\sigma^2_u)$, $u^* \sim N\left(0,\sigma^2_{u^*}\right)$, and $\sigma^2_u = \sigma^2_{u^*}$.

3.5. Equilibrium

In equilibrium, good market, labor market, money market, and asset market clear. The goods market clearing conditions for home and foreign goods are given below, respectively,

$$Y = n\frac{PC}{P_{hh}} + (1-n)\frac{P^*C^*}{P_{hf}/S}, \tag{3.12}$$

$$Y^* = n\frac{PC}{P_{fh}} + (1-n)\frac{P^*C^*}{P^*_{ff}}. \tag{3.13}$$

4. Results

To derive the solution to the baseline model, we solve for the endogenous variables contingent on the realizations of external shocks given the optimal pricing policies. Then, we calculate the expected welfare for the home and foreign consumers.

It is assumed that the welfare of the home household is measured as[11]

$$E\left(\frac{C^{1-\rho}}{1-\rho} - \eta L\right)$$

[8] With a complete financial market, the ownership of world oil endowment does not affect our results. This is because the equilibrium of the model depends on the risk-sharing condition across countries, which is not affected by oil revenue and expenditure flow.

[9] In one-period price setting model, if we allow for endogenous currency choice of export pricing, with optimal monetary policy, both symmetric producer currency pricing and local currency pricing can be an equilibrium. However, whether this result holds for a dynamic price setting model seems unexplored in the literature. For the asymmetric dollar currency pricing, Devereux et al. (2010) show that this can be a natural outcome in an economy where the US dollar is the oil currency.

[10] Since the model solution is log-linear and shocks are log-normal, our monetary rules are quite general representations of the choices available to monetary authorities. See Devereux et al. (2005). Since $E(m) = E(m^*) = 0$, this rule actually captures the response of money growth rate to the shock.

[11] Obstfeld and Rogoff (1998, 2002) argue that the utility of real balance is small enough to be neglected.

The expected utility of the household in a stochastic environment is a function of variances and covariance terms of log consumption and log exchange rate. Thus, given the solution to consumption and the exchange rate, we may rewrite welfare in terms of the variance of external shocks and monetary policy parameters. For details, please refer to the Appendix A. For simplicity, we focus on a special case where $\rho = 1$. Nevertheless, our analysis extends in a straightforward manner to the case $\rho > 1$ and the results still hold.

Home (foreign) monetary authority chooses policy parameter $a(b)$ to solve the following international monetary game:

$$\max_a EU(a,b) \quad \max_b EU^*(a,b) \tag{4.1}$$

We solve the monetary game in the Appendix A and give the solution to game in the following proposition.

Proposition 1. *The solution to the international monetary Nash game is*

$$a = -\frac{\alpha}{1-\alpha}\left[1-\frac{(1-n)(1-\alpha+\alpha v)v}{\phi}\right], b = -\frac{(1-v)\alpha(1-\alpha+\alpha v-\alpha n v)}{(1-\alpha)\phi}, \tag{4.2}$$

where $\phi = \alpha n v(\alpha-2) + (1-\alpha+\alpha v) > 0$.

The solution implies that optimal monetary policies for both countries require money supply to respond negatively to the oil price shock. When $v = 0$, home and foreign monetary authorities respond to the oil price shock in the same manner, $a = b = -\frac{\alpha}{1-\alpha}$. In this case, the firm's marginal cost in both countries can be stabilized since the rise of oil price is completely offset by the decrease of wages, which changes proportionally with money supply. However, when $v = 1$, as the oil price shock is fully stabilized in the foreign country, we have $a < 0$ and $b = 0$. That is, foreign monetary policy does not respond to the oil price shock while home monetary policy still responds negatively to the oil price shock with a smaller magnitude. For any $v > 0$, we have $a \neq b$.

It should be noted that both monetary policy and oil price stabilization policy can stabilize firms' marginal cost, but they work through different channels. Monetary policies stabilize both home and foreign firms' marginal cost through wage adjustment, so the impact of oil price shocks on both home and foreign economies can be completely eliminated. The oil price stabilization policy, however, only can stabilize foreign firms' marginal cost through direct oil price intervention. Since the home firms' marginal cost will be affected by oil price shocks, the foreign country will still be subject to these shocks through goods trade. Therefore, relatively speaking, monetary policies are more efficient than oil price stabilization policy in mitigating the impact of oil price shocks on real economy.

Given the solutions to the monetary game, we calculate the expected utility of the home household and the foreign household as functions of v. From the Appendix A, we have

$$EU = \Lambda - \left\{\frac{(1-n)n\left[(1-n)(1-\alpha+\alpha v)^2 + n(1-\alpha)^2\right]v^2\alpha^2}{2\phi^2}\sigma_q^2 + \left[\frac{(1-\alpha)^2}{2} + (1-n)(1-\alpha+\alpha v)\alpha v\right]\sigma_u^2\right\} \tag{4.3}$$

$$EU^* = \Lambda - \left\{\frac{n(1-n)^2(1-\alpha+\alpha v)^2 v^2\alpha^2}{2\phi^2}\sigma_q^2 + \left[\frac{(1-\alpha)^2}{2} + (1-n)\alpha(1-v)(1-\alpha v)\right]\sigma_u^2\right\} \tag{4.4}$$

where Λ is a constant function of parameters and represents the steady-state welfare. From Eqs. (4.3) and (4.4), we establish the following proposition.

Proposition 2. *In an environment without monetary shocks* $(\sigma_u^2 = \sigma_{u^*}^2 = 0)$, *the optimal level of oil price stabilization chosen by the foreign country is* $v = 0$, *i.e., zero oil price stabilization. For the home country, zero oil price stabilization is also optimal.*

The proof is straightforward. Proposition 2 shows that when monetary authorities can optimally respond to the oil price shock, oil price stabilization becomes unnecessary for the foreign country. This is because, without implementation errors, the optimal monetary policy can completely offset the impact of oil price on marginal cost and price level. So in this case, oil price stabilization policy can be replaced by optimal monetary policy. Furthermore, since optimal monetary policies can fully stabilize the firms' marginal cost in both countries, if the foreign country still use oil price stabilization policy, the stabilization effect of optimal monetary policies will be reduced, which result in a less efficient outcome compared to the case with optimal monetary policy and zero oil price stabilization. Therefore, when there exists optimal monetary policy without implementation errors, oil price stabilization is redundant.[12] Both home and foreign economies can achieve the steady-state welfare level (Λ), which implies that optimal monetary policies fully eliminate the welfare loss caused by oil price shocks (σ_q^2).

Proposition 3. *If there are monetary shocks in the conduct of optimal monetary policies, the oil price stabilization policy will be welfare-improving for the foreign country, and the optimal level of oil price stabilization is given by* $v = \arg\max\{EU^*\} > 0$.

The proof is given in the Appendix A. Now let us consider the case in which monetary authorities can respond optimally to oil price shocks, but there exist implementation errors or monetary shocks. These shocks will lead to inefficient exchange rate movements. Thus, the foreign country has incentives to stabilize the oil price so as to reduce the welfare loss caused by exchange rate risks in setting price. However, this oil price stabilization will reduce the stabilization effect of monetary policy on oil price shocks. Given optimal monetary policies, Eq. (4.4) shows that $v = 0$ is required to eliminate the welfare loss caused by the oil price shock. However, to reduce the welfare loss caused by monetary shocks, a positive level of oil price stabilization should be chosen. Therefore, for the foreign country, the choice of v depends on a trade-off between removing the welfare loss caused by the oil price shock and reducing the welfare loss caused by monetary shocks (exchange rate risks).

How does oil price stabilization affect the welfare in the home and foreign countries? We express the gain from oil price stabilization as ξ, which is defined as the fraction of initial consumption (without stabilization, $v = 0$) that the household would be willing to forgo in order to have oil price stabilization in the foreign country. In the baseline case, we still take $\rho = 1$. That is, ξ is defined by the following equation:

$$E\left\{\ln\left[\widetilde{C}(1+\xi)\right] - \eta\widetilde{L}\right\} = EU(v) \tag{4.5}$$

where $\widetilde{C}$ and $\widetilde{L}$ are the consumption and employment in the case with zero stabilization ($v = 0$), respectively. Since $\rho = 1$, Eq. (4.5) implies that $\xi = EU(v) - EU(v = 0)$.Hence, we can obtain a measure of welfare gain from oil price stabilization for both home and foreign countries in real terms as follows:

$$\xi = -\frac{(1-n)n\left[(1-n)(1-\alpha+\alpha v)^2 + n(1-\alpha)^2\right]v^2\alpha^2}{2\phi^2}\sigma_q^2 - (1-n)(1-\alpha+\alpha v)\alpha v\sigma_u^2 < 0 \tag{4.6}$$

[12] In this case, the exchange rate is fixed since the responses of home and foreign money supply to the oil shock are the same. In a sense, this case is equivalent to a case where the home country conducts monetary policy perfectly while the foreign country pegs the exchange rate unilaterally.

$$\xi^* = -\frac{n(1-n)^2(1-\alpha+\alpha v)^2 v^2 \alpha^2}{2\phi^2}\sigma_q^2 + (1-n)(1-\alpha+\alpha v)\alpha v \sigma_u^2 \quad (4.7)$$

We can establish the following proposition from Eqs. (4.6) and (4.7).

Proposition 4. *In an environment with monetary shocks, even if monetary policies are optimally chosen, the home country always loses from a positive level of oil price stabilization, and the foreign country may gain from this policy only when monetary shocks are sufficiently large.*

The proof is trivial. For the foreign country, oil price stabilization can stabilize the exchange rate risk in importing oil. This lowers firms' expected marginal cost and expected price level, implying a higher welfare. But this policy also reduces the stabilization effect of monetary policy, thus reducing welfare. The former effect will be stronger when monetary shocks are sufficiently large. For the home country, however, oil price stabilization implies higher exchange rate risk will be embedded in the imported good price and thus the home country is worse off. This is because of the dollar currency pricing foreign firms used when setting export prices. They will embed exchange rate risks into price setting. With zero oil price stabilization, the exchange rate risk can be offset partially by the exchange rate risks associated with oil import. But positive level of oil price stabilization mitigates this effect and thus leads to more exchange rate risks.

As shown in Proposition 2, when monetary authorities can optimally respond to the oil price shock without implementation errors, the combination of optimal monetary policy and zero oil price stabilization can fully eliminate the welfare loss caused by oil price shocks. With monetary shocks, zero oil price stabilization may not be the optimal choice for the foreign country, but it is still preferred by the home country. This proposition has important welfare implications; when there are optimal monetary policies, oil price stabilization policy *does not* have any *positive* spill-over effect on the home country.[13]

In the above analysis, we show that, without monetary shocks or implementation errors in the conduct of monetary policy, optimal monetary policy can substitute for oil price stabilization policy. Therefore, an interesting question arises, is the optimal monetary policy necessary to replace oil price stabilization policy? In other words, are there any other monetary arrangements under which the foreign country will choose a zero oil price stabilization policy? We answer these questions in the following proposition.

Proposition 5. *In an environment without monetary shocks, if monetary policy rules satisfy* $a-1<b\le\alpha(a-1)$ *and* $a\le\frac{-\alpha}{1-\alpha}$*, then* $v=0$ *is the optimal choice for the foreign country; and the home country also prefers zero oil price stabilization policy.*

See the Appendix A for proof.

From the Appendix A, we can find that, even when a and b are not optimally chosen, as long as the above conditions for a and b are satisfied, we still have $\frac{\partial EU}{\partial v}\le 0$ and $\frac{\partial EU^*}{\partial v}\le 0$.To achieve price stability, endogenous monetary policies will respond negatively to the oil price shock, which implies that $a<0$ and $b<0$.In our model, the welfare in both home and foreign country depends on expected price level, which is a function of variance and covariance terms of money, the exchange rate, and the oil price.

From Eq. (8.9) in the Appendix A, if there are no monetary shocks ($\sigma_u^2=\sigma_{u^*}^2=0$), for the foreign country, the oil price stabilization policy v affects the foreign expected price level through the variance of domestic oil price, $(1-v)^2 var\left[\log\left(\frac{Q_t}{S_t}\right)\right]$, and the covariance of

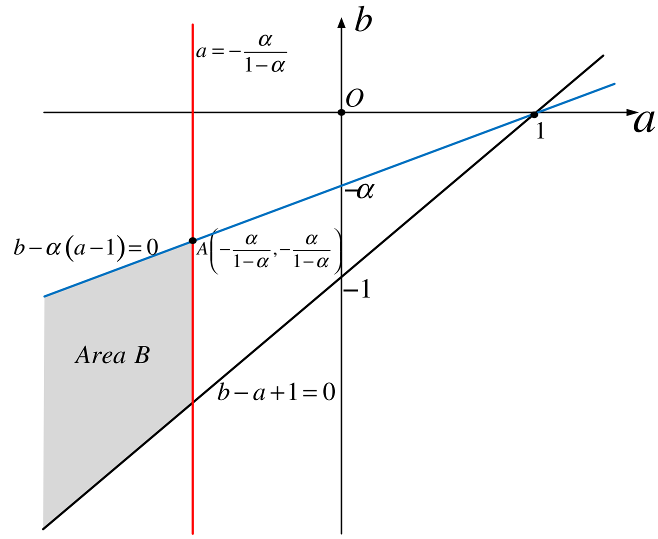

Fig. 1. Feasible monetary policies for $v=0$.

money with domestic oil price, $(1-v)cov\left[\log\left(\frac{Q_t}{S_t}\right),\log(M^*)\right]$.[14] If the covariance term is positive, the foreign country will choose full oil price stabilization because the oil price stabilization policy can reduce both the variance of domestic oil price and the covariance term and then increase welfare. Therefore, the foreign country may choose zero oil price stabilization only when the covariance term is negative.

Since the money supply responds negatively to the world oil price, if the $\frac{Q_t}{S_t}$ comoves positively with the world oil price Q_t, then the covariance terms between $\frac{Q_t}{S_t}$ and money will be negative. In our model, the exchange rate is determined by the relative money supply, so the log of $\frac{Q_t}{S_t}$ can be simplified as $(1-a+b)q$.If $a-b<1$, that is, if the rise of exchange rate (the depreciation of home currency against foreign currency) is less than the rise of world oil price, then $\frac{Q_t}{S_t}$ comoves positively with Q_t. This implies that $cov\left[\log\left(\frac{Q_t}{S_t}\right),\log(M^*)\right]<0$.

However, this condition is not sufficient to make the foreign country choose $v=0$. This is because the foreign country still have incentive to reduce $var\left[\log\left(\frac{Q_t}{S_t}\right)\right]$ through oil price stabilization. We can show that when $b\le\alpha(a-1)$, the negative covariance term is large enough to offset the variance of $\log\left(\frac{Q_t}{S_t}\right)$. In this case, the oil price stabilization will become unnecessary.

Given $a-1<b\le\alpha(a-1)$, zero oil price stabilization may not be optimal for the home country because the monetary policies (a,b) are not optimally chosen. However, there still exists a set of policy parameters that make the home country also prefer $v=0$. For the home country, since the export price is preset in the home currency, the exchange rate risk will also be embodied in the export price. This introduces a new term in the home price level and welfare, as shown in Eq. (8.6) in the Appendix A. The new term is $(1-v)cov\left[\log(S),\log\left(\frac{Q_t}{S_t}\right)\right]$, the covariance between the exchange rate and the foreign oil price, which will also be affected by the oil price stabilization policy v. This covariance can be either negative or positive. To make the home country prefer $v=0$, the home money supply must respond more negatively to the world oil price. This requires that the home monetary policy satisfies $a\le\frac{-\alpha}{1-\alpha}$.

The Area B in Fig. 1 is the feasible monetary policy set under which the foreign country will choose zero oil price stabilization $v=0$, and the home country will also prefer $v=0$. It should be noted that different combinations of a and b in this area deliver different welfare levels. As shown in Proposition 1, Point A with $a=b=\frac{-\alpha}{1-\alpha}$ is the optimal

[13] In such a case, there is a scope for policy coordination between home and foreign countries. Since the global welfare itself is a sum of home and foreign welfare weighted by country sizes, the optimal level of oil price stabilization that maximizes the global welfare will depend critically on the country size (n).

[14] The covariance term actually represents the covariance between nominal wage and domestic oil price. Money is equivalent to nominal wage in the model ($W^*=\frac{\eta}{\chi}M^*$), so we use money to replace nominal wage in the marginal cost.

monetary policy, which delivers the highest welfare level. Fig. 1 also show that the combination $a = b = 0$ is outside Area B. $a = b = 0$ represents an exogenous money policy rule (constant money supply). When $a = b = 0$, the foreign country will always choose a positive level of oil price stabilization. From Eq. (8.10) in the Appendix A, we can easily find that $v = 1$ is optimal in this case.

Proposition 5 shows that without monetary shocks, some endogenous monetary policies can also replace oil price stabilization policy, so optimal monetary policy is not necessary for monetary policy to substitute for oil price stabilization policy. This finding implies that developing countries may use endogenous monetary policy to stabilize oil price and do not need to rely on oil price stabilization policy which may lead to fiscal burden. In reality, central banks may not be able to figure out or implement the optimal monetary policy, but endogenous monetary rules are often used.

From the above analysis, both endogenous monetary policy and the existence of monetary shocks are critical for the desirability of oil price stabilization. Intuitively, if monetary policies can respond the oil price shock effectively, then they can replace oil price stabilization policy. However, if they are far away from optimal monetary policy or are subject to large implementation errors, they will not be able to stabilize the impact of oil shocks on the real economy, then oil price stabilization policies are needed.

If there are no endogenous monetary policies and monetary policies are fully random, how will our results be affected? If we assume that neither home nor foreign country responds to oil price shock, that is, $a = 0$ and $b = 0$, but money supply is stochastic ($\sigma_u^2 = \sigma_{u^*}^2 > 0$), then the expected utility for home and foreign countries are given by:

$$EU = \Lambda - \left\{ \frac{\alpha^2}{2} \left[n + (1-n)(1-v)^2 \right] \sigma_q^2 + \left[\frac{(1-\alpha)^2}{2} + (1-n)(1-\alpha+\alpha v)\alpha v \right] \sigma_u^2 \right\} \tag{4.8}$$

$$EU^* = \Lambda - \left\{ \frac{\alpha^2}{2} \left[n + (1-n)(1-v)^2 \right] \sigma_q^2 + \left[\frac{(1-\alpha)^2}{2} + (1-n)\alpha(1-v)(1-\alpha v) \right] \sigma_u^2 \right\} \tag{4.9}$$

Thus it is straightforward to have the following proposition.

Proposition 6. *If monetary policies are fully random, it is optimal for the foreign country to choose full oil price stabilization ($v = 1$), but this is not the preferred level of oil price stabilization for the home country. The home country will gain from the full oil price stabilization if and only if $\alpha\sigma_q^2 - 2\sigma_u^2 > 0$.*

See the Appendix A for proof. For the foreign economy, if monetary policies are fully random, full oil price stabilization is optimal. However, for the home country, we can see from Eq. (4.8) that an increase of v will reduce the first term in the bracket, but increase the second term in the bracket. So there is a trade-off in the choice of oil price stabilization. Intuitively, for the home country, on the one hand, higher degree of oil price stabilization reduces the welfare loss due to oil price shock (σ_q^2); on the other hand, it implies that more exchange rate risks will be incorporated into their imported goods prices. The home country will, therefore, prefer partial stabilization or even zero stabilization depending on the size of shocks. If the foreign country chooses a full oil price stabilization policy, will the home country gain from this policy? The answer is yes if the oil price shock is sufficiently large or monetary shocks are sufficiently small.

To summarize, our analytical results show that in most cases, the home country will not gain from the oil price stabilization policy in developing countries. In the following sections, we will use quantitative analysis to assess welfare implications of oil price stabilization policy in a more general and realistic DSGE model setting.

5. A quantitative model with dynamic pricing and endogenous oil price

To check if our analytical results hold in more general setup, we extend our analytical model to a full-fledged dynamic stochastic general equilibrium model. First, our analytical model is a static model with one-period price setting, so the currency choice of export pricing has very extreme implications on exchange rate pass-through. Now we consider a dynamic price setting where exchange rate pass-through is incomplete. Second, we assume that the oil price is exogenous and stochastic in previous sections. Although this assumption is standard in the literature, it has its own limitations. That is, the oil price is not affected by monetary policies and oil price stabilization policies. To make the model more realistic, we consider a stochastic oil supply function so that the oil price is endogenously determined by the oil market clearing of demand and supply. By doing so, the oil price can interact with monetary policies.[15] Third, in our one-period model, inflation dynamics are not important and we do not take it into consideration. Nevertheless, in a dynamic setting, the inflation is crucial for monetary policy, so we consider endogenous monetary policy rules that target inflation in the dynamic model. In the real world, more and more countries adopt interest rate rules in the conduct of monetary policy. Meanwhile, in recent literature, the analysis of monetary policy in a dynamic price setting is mostly based on Taylor-type interest rate rules. Therefore, we also introduce a Taylor interest rate rule in both countries in the dynamic model.[16] Finally, in our analytical model, we assume a complete financial market to avoid complexity. For quantitative assessment, we consider an alternative financial structure, namely, balanced trade or financial autarky, so as to investigate if our results are sensitive to financial structure change. The extended model is presented in the following subsection.

5.1. Household

In this section, the representative household maximizes life time utility, $U = E_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\rho}}{1-\rho} - \eta \frac{L_t^{1+\psi}}{1+\psi} \right)$, where ψ is the inverse of elasticity of labor supply.[17] We consider two financial structures, complete financial market and financial autarky. The budget constraint under complete market is given by

$$P_t C_t + B_{ht+1} + \sum_{\zeta^{t+1} \in Z_{t+1}} B\left(\zeta^{t+1} | \zeta^t\right) D\left(\zeta^{t+1}\right) = W_t L_t + R_{t-1} B_{ht} + \Pi_t + T_t + D\left(\zeta^t\right), \tag{5.1}$$

where $D(\zeta^t)$ represents the household's payoff on state-contingent claims on state ζ^t. $B(\zeta^{t+1}|\zeta^t)$ is the price of a claim that pays one dollar in state ζ^{t+1}, conditional on state of ζ^t occurring at time t. B_h is the holding of domestic bond, and R_t is the domestic gross interest rate between period t and $t + 1$. In addition to optimal conditions in the

[15] In the static model, to have analytical results, we assume financial market is complete and the shocks are log normal. If we consider endogenous oil price determination in the analytical model, due to the presence of world oil market clearing condition, even with complete market, the model cannot be log-linear any more. So there will be no close-form solutions.

[16] It should be noted that the Taylor rule is not the optimal monetary policy, but an endogenous monetary policy. To our knowledge, there are still difficulties in solving non-cooperative optimal monetary policies in a two-country general equilibrium model with dynamic pricing and endogenous oil price determination. Actually this topic itself deserves investigation a separate paper. Furthermore, as shown in the analytical model, optimal monetary policy is not necessary for monetary policy to replace oil price stabilization. Hence, in the dynamic model we only consider some endogenous monetary policy rules and check if they can substitute for oil price stabilization policy. Intuitively, the optimal monetary policy should be more effective in stabilizing economic fluctuations than these sub-optimal policies.

[17] Interest rates are used as monetary policy instruments so money will be endogenously determined and becomes redundant in the model. Therefore, we drop the real money balance in the utility function.

analytical model, we have a new Euler equation for holding domestic bond,

$$\frac{1}{R_t} = \beta \frac{C_t^{\rho} P_t}{C_{t+1}^{\rho} P_{t+1}}, \tag{5.2}$$

where R_t is also used as monetary policy instrument by home monetary authority.

We also consider an alternative financial structure, namely, balanced trade or financial autarky. The budget constraint under financial autarky is given by

$$P_t C_t + B_{ht+1} = W_t L_t + R_{t-1} B_{ht} + \Pi_t + T_t. \tag{5.3}$$

For simplicity, we assume that the oil producer rebates the revenue of oil sold to the home country as a lump-sum transfer to the home country, and similarly for oil sales to the foreign country.[18] Under financial autarky, we also have the Euler Eq. (5.2).

5.2. World Oil Supply and Oil Price Stabilization

We assume that the oil is supplied by a third party such as OPEC. The oil price is quoted in the home currency and is endogenously determined in the world market. The world oil supply function is assumed to follow,

$$O_t^s = \Theta \left(\frac{Q_t / P_t}{\overline{Q}} \right)^{\varphi} exp(x_t), \tag{5.4}$$

where Q_t is the nominal world oil price quoted in US dollars, so Q_t/P_t is the real price of oil; and x is an oil supply shock that captures all the uncertainties related to the oil supply, including oil productivity shocks, geopolitical risk, and other factors that may affect oil supply; and Θ and $\overline{Q}$ are the world oil supply and real oil price in the steady state, respectively. $\varphi > 0$ is the price elasticity of world oil supply. x is assumed to follow a stochastic AR(1) process $x_t = \rho_x x_{t-1} + \varepsilon_{xt}$ with persistence $\rho_x \in (0,1)$ and variance ε_x^2.

There is no market intervention in the home country, so the oil price faced by home firms is Q_t.The foreign government sets its domestic oil price according to the following rule,

$$Q_t^* = \overline{Q}_f^{v} \left(\frac{Q_t}{S_t} \right)^{1-v}, \tag{5.5}$$

where $\overline{Q}_f$ is the targeted oil price (inflation adjusted) set by the foreign government and v, as in previous analysis, denotes the degree of oil price stabilization.

5.3. Production

In this model, firms' production and marginal cost are the same as those in the analytical model; and firms in both home and foreign countries set export prices in the US dollar. Following Clarida et al. (2002) and Engel (2011), we adopt the standard Calvo price-setting technology, which allows for asynchronized price setting.

Now we present home and foreign firms' optimization problems. In the home country, a given firm may reset its prices with probability $1 - \kappa$ each period. When the firm resets prices, it will be able to reset a single price in home currency for sales in both home and foreign markets.

[18] Note that under complete financial market, we do not need the assumption about the oil sale revenue rebate since the transfer does not affect the risk-sharing condition.

The home firm that can reset its price at time t chooses price $P_{hh}^o(i)$, to maximize the following objective function,

$$E_t \sum_{j=0}^{\infty} \kappa^j \beta_{t,t+j} \left[\left(P_{hht}^o(i) - MC_{t+j}(i) \right) Y_{t+j}(i) \right], \tag{5.6}$$

where $Y_{ht}(i) = C_{ht}(i) + C_{ht}^*(i)$ is the demand for home good i from home and foreign markets, and $\beta_{t,t+j} = \beta^j \left(\frac{C_{t+j}}{C_t} \right)^{-\rho} \left(\frac{P_t}{P_{t+j}} \right)$ is the stochastic discount factor. The optimal price for home good i is given by

$$P_{hht}^o(i) = \frac{\lambda}{\lambda - 1} \frac{E_t \sum_{j=0}^{\infty} \kappa^j \beta_{t,t+j} P_{hht+j}^{\lambda} MC_{t+j} Y_{t+j}}{E_t \sum_{j=0}^{\infty} \kappa^j \beta_{t,t+j} P_{hht+j}^{\lambda} Y_{t+j}}. \tag{5.7}$$

Since a fraction κ of goods prices remain unchanged from the previous period, the price index for home goods sold in the home and foreign markets can be written as follows, respectively,

$$P_{hht} = \left[\kappa P_{hht-1}^{1-\lambda} + (1-\kappa) \left(P_{hht}^o \right)^{1-\lambda} \right]^{\frac{1}{1-\lambda}}, \tag{5.8}$$

$$P_{hft}^* = \left[\kappa P_{hft-1}^{*1-\lambda} + (1-\kappa) \left(P_{hft}^{*o} \right)^{1-\lambda} \right]^{\frac{1}{1-\lambda}}, \tag{5.9}$$

where $P_{hft}^{*o} = \frac{P_{hht}^o}{S_t}$.

In the foreign country, when a firm is able to reset prices at time t, it chooses to reset two prices, P_{ff}^{*o}, in terms of foreign currency for sales in its own country and P_{fh}^o, in terms of home currency for exports to the home country, to maximize the following objective function,

$$E_t \sum_{j=0}^{\infty} \kappa^j \beta_{j,t+j}^* \left[\left(\frac{P_{fht}^o(i)}{S_{t+j}} - MC_{t+j}^*(i) \right) C_{ft+j}(i) + \left(P_{fft}^{*o}(i) - MC_{t+j}^*(i) \right) C_{ft+j}^*(i) \right], \tag{5.10}$$

where $C_{ft}(i)$ and $C_{ft}^*(i)$ denote the demand for foreign good i from the home and foreign markets, respectively. The optimal prices for the foreign good i are given by,

$$P_{fht}^o(i) = \frac{\lambda}{\lambda - 1} \frac{E_t \sum_{j=0}^{\infty} \kappa^j \beta_{t,t+j}^* P_{fht+j}^{\lambda} MC_{t+j}^* C_{ft+j}}{E_t \sum_{j=0}^{\infty} \kappa^j S_{t+j}^{-1} \beta_{t,t+j}^* P_{fht+j}^{\lambda} C_{ft+j}}, \tag{5.11}$$

$$P_{fft}^{o*}(i) = \frac{\lambda}{\lambda - 1} \frac{E_t \sum_{j=0}^{\infty} \kappa^j \beta_{t,t+j}^* P_{fft+j}^{\lambda} MC_{t+j}^* C_{ft+j}^*}{E_t \sum_{j=0}^{\infty} \kappa^j \beta_{t,t+j}^* P_{fft+j}^{\lambda} C_{ft+j}^*}. \tag{5.12}$$

Similarly, the price index of foreign goods in the home and foreign markets can be written as,

$$P_{fht} = \left[\kappa P_{fht-1}^{1-\lambda} + (1-\kappa) \left(P_{fht}^o \right)^{1-\lambda} \right]^{\frac{1}{1-\lambda}}, \tag{5.13}$$

$$P_{fft}^* = \left[\kappa P_{fft-1}^{*1-\lambda} + (1-\kappa) \left(P_{fft}^{*0} \right)^{1-\lambda} \right]^{\frac{1}{1-\lambda}}. \tag{5.14}$$

Given these prices, we derive the price index for each country as follows:

$$P_t = P_{hht}^n P_{fht}^{1-n}, \quad P_t^* = P_{hft}^{*\,n} P_{fft}^{*\,1-n}. \tag{5.15}$$

5.4. Monetary Rules

Monetary authority in each country is assumed to commit to a Taylor-type interest rate rule:

$$\log(R_t/\bar{R}) = (1-\rho_r)\log(R_{t-1}/\bar{R}) + \rho_r\left[\alpha_\pi \log(\pi_t/\bar{\pi}) + \alpha_y \log(Y_t/\bar{Y})\right] + \varepsilon_{rt}, \quad (5.16)$$

$$\log(R_t^*/\bar{R}) = (1-\rho_r^*)\log(R_{t-1}^*/\bar{R}) + \rho_r^*\left[\alpha_\pi^* \log(\pi_t^*/\bar{\pi}) + \alpha_y^* \log(Y_t^*/\bar{Y})\right] + \varepsilon_{rt}^*, \quad (5.17)$$

where R_t (R_t^*) is the gross domestic interest rates, π_t (π_t^*) is the CPI inflation; Y_t (Y_t^*) is the domestic output. The variables with bar are targets for monetary authorities. $\rho_r(\rho_r^*)$ is the parameter that governs the interest rate smoothing. Following Chari et al. (2002), we introduce two monetary shocks ε_{rt} and ε_{rt}^*, which represent uncontrollable disturbances to the interest rate rule. These shocks capture the imperfect conduct of monetary policy. We assume that $\varepsilon_{rt} \sim N(0,\sigma_r^2)$, and $\varepsilon_{rt}^* \sim N\left(0,\sigma_{r^*}^2\right)$.

5.5. Equilibrium

The goods market clearing conditions for home and foreign goods can be written as, respectively,

$$Y_t = n\frac{P_tC_t}{P_{hht}} + (1-n)\frac{P_t^*C_t^*}{P_{hft}^*}, \quad Y_t^* = n\frac{P_tC_t}{P_{fht}} + (1-n)\frac{P_t^*C_t^*}{P_{fft}^*}. \quad (5.18)$$

In equilibrium, the world oil market clears, such that

$$O_t + O_t^* = O_t^s, \quad (5.19)$$

where $O_t = \alpha\frac{MC_tY_t}{Q_t}$ and $O_t^* = \alpha\frac{MC_t^*Y_t^*}{Q_t^*}$.The employment in each country is determined by the following conditions,

$$L_t = (1-\alpha)\frac{MC_tY_t}{W_t}, \quad L_t^* = (1-\alpha)\frac{MC_t^*Y_t^*}{W_t^*}.$$

Finally, in the case with complete financial market, two domestic bond markets clear ($B_h = 0$ and $B_f^* = 0$) and the state-contingent bond market clears.

In the case with alternative financial structure (financial autarky), two domestic bond markets clear (B_h and $B_f^* = 0$). Hence, in equilibrium, the budget constraint for the home country can be simplified as $S_tP_{hft}^*C_h^* = P_{fht}C_{ft}$, which implies that

$$(1-n)S_tP_t^*C_t^* = nP_tC_t \quad (5.20)$$

Eq. (5.20) is the balanced trade condition, which is analogous to the risk-sharing condition (3.2) under complete market.

6. Quantitative analysis

In this section, we conduct quantitative analysis of oil price stabilization policy. To solve the stationary problem in the two-country model, all the home nominal prices will be detrended by the home CPI whereas the foreign prices will be detrended by the foreign CPI.[19]

6.1. Calibration

The model is calibrated at quarterly frequency. The parameter values for the benchmark model are reported in Table 3. Most values are those commonly used in recent literature, for example, Benigno (2009) and Chari et al. (2002). We set $\beta = 0.99$, which implies that the steady-state annual real interest rate is 4%. The risk coefficient, ρ, is set to 2 so that the elasticity of intertemporal substitution is 0.5. We set $\psi = 1$ so that the inverse of the elasticity of labor supply is 1. Following recent empirical studies on the estimation of price rigidities, we set $\kappa = 0.75$ so that all the prices will be fully adjusted in four quarters. We assume $\lambda = 11$ so that average markup is 10%.

Table 3
Major parameter values in the calibrations (benchmark model).

β	Discount factor	0.99
ρ	Inverse of the elasticity of intertemporal substitution	2
ψ	Inverse of the elasticity of labor supply	1
κ	Degree of price stickiness	0.75
λ	Elasticity of substitution across individual goods	11
α	Share of oil/commodity goods in production	0.08
n	Home country size	0.5
$\rho_r(\rho_r^*)$	Interest rate smoothing coefficient in taylor rules	0.79
$\alpha_\pi(\alpha_\pi^*)$	Inflation coefficient in taylor rules	2.15
$\alpha_y(\alpha_y^*)$	Output coefficient in taylor rules	0.23
$\sigma_r(\sigma_r^*)$	Standard deviation of interest rate shock	0.0025
φ	Price elasticity of oil supply	0.04
ρ_x	Persistence of oil supply shocks	0.74
σ_x	Standard deviation of oil supply shock	0.0156

As before, the home country is assumed to be the US while the foreign country is a group of developing countries. In the benchmark case, we assume that they are of equal size, $n = 0.5$. In the data, the share of oil in the production, α, differs substantially across countries. Bouakez et al. (2008) show that, on average, α is close to 4−5% in developing counties while in the US it is approximately 3−4%. However, when we interpret α as the share of primary commodities generally, rather than oil in particular, α could be relatively larger. Following Devereux et al. (2010), we set $\alpha = 0.08$.Since the country size and the share of oil in production are critical for welfare evaluation, we will discuss how changes in n and α affect our results in the sensitive analysis.

We consider a standard Taylor rule with interest rate smoothing in both countries. Following Clarida et al. (2000), we set $\rho_r = \rho_r^* = 0.79$, $\alpha_\pi = \alpha_\pi^* = 2.15$, and $\alpha_y = \alpha_y^* = 0.23$.In the benchmark model, we choose $\sigma_r = \sigma_r^* = 0.0025$ (0.25 percentage point), which is within the range of recent estimates in Lubik and Schorfheide (2003) and Dong (2012).[20] We estimate the oil supply function using quarterly data of real oil price and production from 2003 to 2012. From the estimation, the price elasticity of oil supply, φ, is set to 0.04; and the shock to oil supply, x_t, is assumed to follow a stochastic process

$$x_t = 0.74x_{t-1} + \varepsilon_{xt},$$

where ε_x is a white-noise process with standard deviation $\sigma_x = 0.0156$.[21]

6.2. Impulse responses to oil supply shock

In this subsection we investigate how the oil price stabilization policy affects dynamic responses of the home and foreign economies

[19] The Dynare software is used for quantitative analysis such as impulse response function analysis and welfare comparison.

[20] Gali (2011) also considers a disturbance to the interest rate, which raises interest rate by 0.25%. Although there is no interest rate smoothing, shocks to interest rate rule follows an AR(1) process with an AR coefficient of 0.5. In the absence of an endogenous component in the rule, such an experiment would be associated with a one percentage-point increase in the (annualized) interest rate. Our choice of σ_r has a similar implication on the interest rate.

[21] Structural analysis of the oil market (eg., Bodenstein and Guerrieri, 2011) typically considers a perfectly inelastic oil supply. However, recent empirical studies by Krichene (2002) and Baumeister and Peersman (2011) suggest the existence of small but significantly positive oil supply elasticity. Our estimation is close to the value (0.025) used in their work. We also consider alternative values of φ from 0 to 0.1 and find that our results are not very sensitive to the value of φ.Details of our estimation can be found in the Technical Appendix A, which is not for publication, but available upon request.

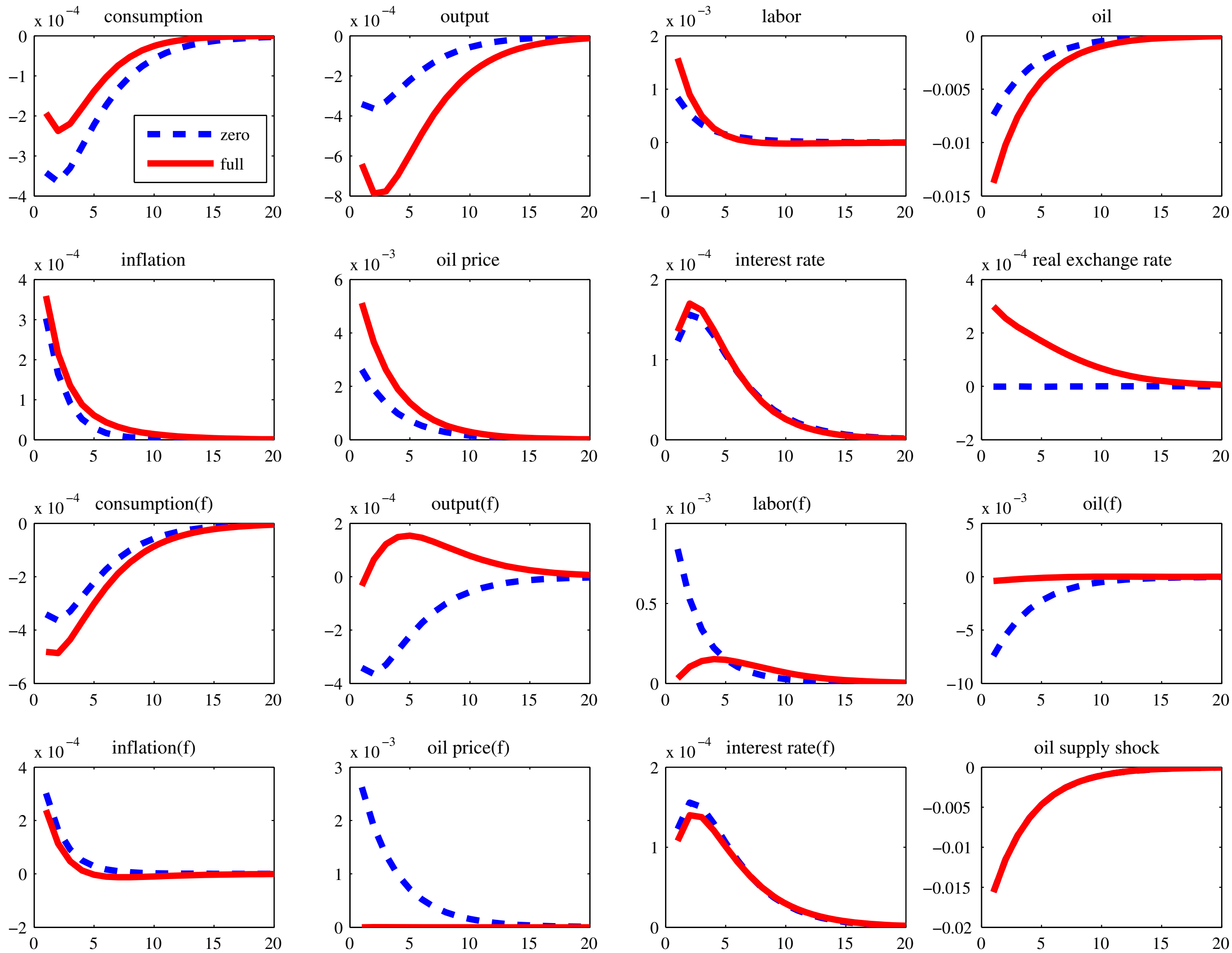

Fig. 2. Responses of Economies to an Oil Supply Shock under Zero and Full Stabilization.

to a negative oil supply shock (a decrease of oil supply). For comparison, we report two extreme cases: zero stabilization and full stabilization. Fig. 2 depicts the impulse responses of consumption, output, labor, oil, inflation, real oil price, interest rates, and real exchange rate to a one standard-deviation (0.0156) decrease in world oil supply. For simplicity, we consider a complete financial market.

Fig. 2 shows that, without oil price stabilization in the foreign country ($v = 0$), the responses of real variables in the home and foreign countries are very similar. The decline of world oil supply pushes up the oil price and leads to the decrease in output and consumption. On the production side, the firm will hire more labor and reduce its demand for oil. Due to the presence of nominal rigidities, the increase of oil price will only pass-through gradually into inflation, which eventually leads to the increase of interest rates. In this setting, the home and foreign countries are almost symmetric except for the export pricing,[22] so the responses to a common world shock do not lead to movements in the real exchange rate.

When the foreign government fully stabilizes the domestic oil price ($v = 1$), the responses of the home economy and foreign economy variables are substantially different. In the foreign country, the real price of oil remains at the target level. Thus, we observe small substitution between labor and oil and small increases in inflation and interest rates. In the home country, the rise of oil price still causes higher demand for labor and lower demand for oil. Meanwhile, the responses of domestic inflation and interest rate to the oil supply shock are similar to those in the case with zero stabilization. A common oil shock leads to asymmetric effects between home and foreign economies due to the stabilization policy. The home output falls while the foreign output rises slightly. This asymmetry also causes real exchange rate depreciation. With complete financial market, the real depreciation can offset the decline of consumption, which is driven by the negative oil supply shock. Therefore, under a full stabilization policy, the home consumption decreases much less than the foreign consumption.

Obviously, the oil price stabilization policy has substantial effects on both home and foreign economies. In the following subsection, we will study the optimal level of oil price stabilization and conduct rigorous welfare analysis of the oil price stabilization policy.

6.3. Welfare results

The welfare measure we use is the conditional expected lifetime utility of the representative household at time zero. Following Schmitt-Grohe and Uribe (2004), the expected lifetime utility is computed conditional on the initial state being the deterministic steady state, which is the same for all policy regimes. To measure the magnitude of welfare differential across regimes, we define ζ_k as the percentage

[22] Note that in the model with dynamic price setting, the asymmetry between two countries due to export pricing is very small. This leads to similar responses of real variables in both home and foreign countries.

Table 4
Welfare results under complete market.

$\sigma_r(\sigma_r^*)$	ζ_k	$v^{optimal}$	$\zeta_k(v=0)$	$\zeta_k(v=v^{optimal})$	$\Delta\zeta_k$
0.01	Home		−0.0824	−0.0962	−0.0138
	Foreign	0.76	0.014	0.0209	0.0069
0.005	Home		−0.0203	−0.0226	−0.0023
	Foreign	0.40	0.0034	0.0048	0.0014
0.0025	Home		−0.0049	−0.0053	−0.0004
	Foreign	0.10	0.0009	0.0011	0.0002
0	Home		0.0001	0.0001	0
	Foreign	0	0.0001	0.0001	0

Table 5
Welfare results under balanced trade.

$\sigma_r(\sigma_r^*)$	ζ_k	$v^{optimal}$	$\zeta_k(v=0)$	$\zeta_k(v=v^{optimal})$	$\Delta\zeta_k$
0.01	Home		0.0040	−0.0104	−0.0144
	Foreign	0.71	−0.0856	−0.0770	0.0086
0.005	Home		0.0014	−0.0021	−0.0035
	Foreign	0.18	−0.0216	−0.0192	0.0024
0.0025	Home		0.0006	0.0006	0
	Foreign	0	−0.0055	−0.0055	0
0	Home		0.0001	0.0001	0
	Foreign	0	0.0001	0.0001	0

change of deterministic steady-state consumption that will give the same conditional expected utility EU under policy regime k. That is, ζ_k is given implicitly by

$$\frac{\frac{1}{1-\rho}\left[(1+\zeta_k\%)\overline{C}\right]^{1-\rho}-\frac{\eta}{1+\psi}\overline{L}^{1+\psi}}{1-\beta}=EU_k \tag{6.1}$$

where a bar over a variable denotes the deterministic steady state of that variable. If $\zeta_k>0$ (<0), the welfare under regime k is implied to be higher (lower) than that of the steady-state.

Welfare results in Tables 4 and 5 show that, given the size of oil supply shock, when the interest rate shocks become smaller, the foreign country will have less and less incentive to stabilize oil prices. This finding implies that if the central bank can implement monetary policy perfectly, then there is no need for the government to stabilize oil prices. The simple intuition is as follows. If the shocks to interest rates are small enough, it is easier for the central bank to achieve inflation stability, which requires the firm to have a stable marginal cost. In this sense, the monetary policy that targets inflation can be considered as a substitute for the oil price stabilization policy.[23] We also find that the home country does not gain from the oil price stabilization in the foreign country. This implies that our results in the analytical model hold in the quantitative analysis. Tables 4 and 5 also imply that these findings do not depend on financial structure.

The comparison between Tables 4 and 5 shows that, given the size of monetary shocks and oil supply shock, the optimal degree of oil price stabilization chosen by the foreign country under financial autarky is lower than that under complete financial market. Intuitively, when the foreign country stabilizes its oil price, on the one hand, it implies more stable marginal cost and thus domestic inflation; on the other hand, oil price stabilization may also drive more fluctuation in employment and output. With complete market, the latter negative effects on consumption and household utility due to oil price stabilization will be mitigated. So the foreign country will choose a higher degree of oil price stabilization. However, without risk-sharing across countries, the foreign country needs to take the negative effect into consideration. This will reduce its incentive to stabilize oil prices.

Can other endogenous monetary policy rules substitute for oil price stabilization policy? To answer this question, we consider some other forms of the Taylor rules. To focus on the comparison of different rules, we assume $\sigma_r=\sigma_r^*=0$. The first rule is a strict inflation targeting rule, in which interest rate only responds to inflation. The rules in the home and foreign country are given by

$$\log\left(R_t/\overline{R}\right)=\alpha_\pi\log\left(\pi_t/\overline{\pi}\right), \tag{6.2}$$

$$\log\left(R_t^*/\overline{R}\right)=\alpha_\pi^*\log\left(\pi_t^*/\overline{\pi}\right). \tag{6.3}$$

[23] If we introduce multiple sectors with heterogeneity (such as non-tradable sector or different oil intensities across sectors) into the model, these results may be affected. The analysis of multi-sector models is beyond the scope of this paper, but we think it is an important issue that is worth investigating in another paper.

In our quantitative exercise, we set the inflation coefficient $\alpha_\pi=\alpha_\pi^*=900$; The second rule is a standard Taylor rule which targets the real exchange rate besides output and inflation,

$$\log\left(R_t/\overline{R}\right)=(1-\rho_r)\log\left(R_{t-1}/\overline{R}\right)+\rho_r\left[\alpha_\pi\log\left(\pi_t/\overline{\pi}\right)+\alpha_y\log\left(Y_t/\overline{Y}\right)\right] + \alpha_e\log\left(e_t/\overline{e}\right) \tag{6.4}$$

$$\log\left(R_t^*/\overline{R}\right)=(1-\rho_r^*)\log\left(R_{t-1}^*/\overline{R}\right)+\rho_r^*\left[\alpha_\pi^*\log\left(\pi_t^*/\overline{\pi}\right)+\alpha_y^*\log\left(Y_t^*/\overline{Y}\right)\right] + \alpha_e^*\log\left(e_t^{-1}/\overline{e}^{-1}\right) \tag{6.5}$$

where $e_t=\frac{S_tP_t^*}{P_t}$ is the real exchange rate. Following Clarida et al. (1998) and Engel and West (2006), we set $\alpha_e=\alpha_e^*=0.1$. With $\alpha_e=\alpha_e^*>0$, the monetary authorities are assumed to raise interest rates when the real exchange rate is above (the currency depreciates relative to) its long-run level. The other parameters are the same as those in the benchmark Taylor rules.

In addition to these Taylor rules, we also consider an exogenous money growth rule. In this exercise, a money-in-utility function same as that in the analytical mode is introduced. This gives a home money demand $\frac{M_t}{P_t}=\chi C_t^{\rho}\frac{R_t}{R_t-1}$.For simplicity, we assume both countries adopt constant money supply, which is similar to the monetary policy rule $a=b=0$ in the analytical model. Table 6 shows that, without interest rate shocks, all three Taylor rules deliver similar welfare results and the foreign country will choose zero oil price stabilization. In contrast to Taylor rules, under the exogenous money supply rule, the foreign country will choose a positive level of oil price stabilization. These results also support our findings in the analytical model.

In the above analysis, we assume that monetary shocks in the home and foreign countries are of the same size. In reality, we usually observe more volatile monetary shocks in developing countries. Therefore, it is important to investigate how asymmetric monetary shocks affect the optimal degree of oil price stabilization and its welfare consequences. In the following experiment, we still consider Taylor rules in both countries, but keep $\sigma_r=0.0025$ unchanged and increase the value of σ_r^* from 0.0025 to 0.01. Table 7 shows that the increase in the foreign monetary shock volatility unilaterally generates similar results as those in our benchmark model.

Table 6
Welfare Results under Different Monetary Rules.

Rules	ζ_k	$v^{optimal}$	$\zeta_k(v^{optimal})$
Standard Taylor rule	Home		0.00011
	Foreign	0	0.00011
Strict Inflation targeting rule	Home		0.00020
	Foreign	0	0.00020
Taylor rule with ER targeting	Home		0.00012
	Foreign	0	0.00012
Exogenous money supply rule	Home		0.00013
	Foreign	0.095	0.00007

Table 7
Welfare results under asymmetric monetary shocks.

$\sigma_r = 0.0025$	ζ_k	$v^{optimal}$	$\zeta_k(v=0)$	$\zeta_k(v=v^{optimal})$	$\Delta\zeta_k$
$\sigma_r^* = 0.01$	Home		−0.1005	−0.1135	−0.0130
	Foreign	0.85	0.0741	0.0807	0.0066
$\sigma_r^* = 0.0075$	Home		−0.0559	−0.0613	−0.0054
	Foreign	0.65	0.0399	0.0428	0.0029
$\sigma_r^* = 0.005$	Home		−0.0240	−0.0255	−0.0015
	Foreign	0.41	0.0155	0.0164	0.0009
$\sigma_r^* = 0.0025$	Home		−0.0049	−0.0053	−0.0004
	Foreign	0.10	0.0009	0.0011	0.0002

Table 8
Welfare results change with country size *(n)*.

n	ζ_k	$v^{optimal}$	$\zeta_k(v=0)$	$\zeta_k(v=v^{optimal})$	$\Delta\zeta_k$
0.8	Home		−0.0113	−0.0115	−0.0002
	Foreign	0.41	0.0026	0.0049	0.0023
0.65	Home		−0.0156	−0.0169	−0.0013
	Foreign	0.40	0.0048	0.0068	0.0020
0.5	Home		−0.0203	−0.0226	−0.0023
	Foreign	0.40	0.0034	0.0048	0.0014
0.35	Home		−0.024	−0.0274	−0.0033
	Foreign	0.40	−0.0004	0.0003	0.0007
0.2	Home		−0.0252	−0.0277	−0.0025
	Foreign	0.16	−0.0054	−0.0052	0.0002

Finally, the welfare gain of foreign country from oil price stabilization is clearly quite small by any conventional standard. This finding is similar to that in Bouakez et al. (2008).

6.4. Sensitivity analysis

In this subsection, we discuss the sensitivity of our results to changes in some parameter values such as home country size, price elasticity of oil supply, and the share of oil in production. In addition, we also investigate how the introduction of technology shocks affects our results. In the sensitivity analysis, we still consider complete financial market and Taylor interest rules with $\sigma_r = \sigma_r^* = 0.005$.

Firstly, we discuss the sensitivity of our results to changes in home country size. Table 8 shows that given the size of monetary shocks ($\sigma_r = \sigma_r^* = 0.005$) and oil supply shocks ($\sigma_x = 0.0156$), our result that the home country may lose from oil price stabilization holds for a wide range of values for n. This finding implies that the negative spill-over effect of oil price stabilization on the home country does not depend on the country size. Quantitatively, however, the negative impact of oil price stabilization on home country decreases when home country size increases. This is not surprising because the foreign country is more like a small open economy when n is sufficiently large.

From Table 8, we also see that, when n is small, the degree of optimal oil price stabilization is small.[24] However, when home country size n is above a threshold value, the increase of n does not affect the optimal degree of oil price stabilization for the foreign economy. This implies that in the dynamic model, the relationship between n and optimal v is non-monotonic. This is because in the dynamic general equilibrium model, the country size affects the optimal degree of oil price stabilization through various channels. For example, the country size n not only affects the demand structure and price setting but also affects responses of monetary policy to shocks.

We also consider alternative values of the price elasticity of oil supply and the share of oil in production. The results are given in Tables 9 and 10. Empirical evidence suggests that the elasticity of oil supply is extremely small, so we consider a range for φ from zero to an upper bound of 0.1, which is consistent with estimates in the literature, such as Kilian (2009). From Table 9, we can see that changes

[24] Our paper focuses on the US and the developing countries, so a small n does not seem realistic for the calibration of country size of the US.

Table 9
Welfare results change with price elasticity of oil supply (φ).

φ	ζ_k	$v^{optimal}$	$\zeta_k(v=0)$	$\zeta_k(v=v^{optimal})$	$\Delta\zeta_k$
0.10	Home		−0.0208	−0.0231	−0.0023
	Foreign	0.40	0.0034	0.0047	0.0013
0.04	Home		−0.0203	−0.0226	−0.0023
	Foreign	0.40	0.0034	0.0048	0.0014
0	Home		−0.0199	−0.0220	−0.0021
	Foreign	0.40	0.0034	0.0047	0.0013

Table 10
Welfare results change with oil share in production (α).

α	ζ_k	$v^{optimal}$	$\zeta_k(v=0)$	$\zeta_k(v=v^{optimal})$	$\Delta\zeta_k$
0.08	Home		−0.0203	−0.0226	−0.0023
	Foreign	0.40	0.0034	0.0048	0.0014
0.06	Home		−0.0198	−0.0219	−0.0021
	Foreign	0.40	0.0030	0.0044	0.0014
0.04	Home		−0.0192	−0.0211	−0.0019
	Foreign	0.18	0.0024	0.0038	0.0014

in φ, the price elasticity of oil supply, do not affect the optimal degree of oil price stabilization. Its impact on welfare is also negligible. With regard to the share of oil in production, the more oil-intensive the economy, the larger the impact of oil supply shock on the economy. From Table 10, we find that the optimal level of oil price stabilization under $\alpha = 0.08$ is higher than that under $\alpha = 0.04$.However, the optimal degree of oil price stabilization is not very sensitive to changes in α.For example, when α decreases from 0.08 to 0.06, the optimal level of oil price stabilization does not change.

Finally, we also introduce technology shocks into this dynamic model. We assume that production function is given by $Y(i) = A(\theta L(i))^{1-\alpha}O(i)^{\alpha}$. θ is a country-specific labor-augmenting productivity shock in the home country, following a stochastic process, $log\theta_{t+1} = \rho_\theta log\theta_t + \epsilon_{\theta t}$. The foreign productivity has a similar stochastic process, but with an independent shock $\epsilon_{\theta t}^*$.In our quantitative analysis, we set the persistence of technology shocks $\rho_\theta = \rho_\theta^* = 0.9$ and change the value of σ_θ (σ_θ^*) from 0 to 0.008, which is in the range of empirical estimation.

There are two interesting findings in Table 11. Firstly, given the size of oil supply shocks, when the technology shock is small, a standard Taylor rule without monetary shocks can still replace oil price stabilization policy. That is, the foreign country will choose $v = 0$. However, when the shock size increases, then the optimal oil price stabilization for the foreign country is positive. Secondly, when the foreign country chooses positive level of oil price stabilization ($v > 0$), the home country also loses from this stabilization policy.[25]

How to explain these findings? Our previous analysis shows that, both monetary policy and oil price stabilization can be used to stabilize the oil prices, so there exist cases where oil price stabilization policy can be replaced by endogenous monetary policies. However, when technology shocks are considered, then the endogenous monetary policy needs to respond to both oil shocks and technology shocks. So policy makers will face a trade-off. If the technology shock is small, monetary policy can still respond to oil shock effectively, which implies the foreign country will choose zero oil price stabilization policy. However, if the technology shock is large, then monetary policy will respond mainly to technology shocks. As a result, oil price stabilization policy may be needed. In some sense, introducing technology shocks is similar to introducing monetary shocks, which implies the monetary policy cannot respond effectively to oil shocks. This may explain why the results in Table 11 are very similar

[25] In the analytical model, if productivity shocks are introduced, optimal monetary policy (without monetary shocks) can replace oil price stabilization policy. This is because with one-period setting the optimal monetary policy can respond to the oil price shock and productivity shocks efficiently.

Table 11
Welfare results with technology shocks ($\sigma_\theta(\sigma_\theta^*)$).

$\sigma_\theta(\sigma_\theta^*)$	ζ_k	$v^{optimal}$	$\zeta_k(v=0)$	$\zeta_k(v=v^{optimal})$	$\Delta\zeta_k$
0.008	Home		0.0131	0.0022	−0.0109
	Foreign	0.6	−0.0198	−0.0090	0.0108
0.005	Home		0.0039	−0.0022	−0.0061
	Foreign	0.30	−0.0085	−0.0030	0.0055
0.0025	Home		0.0016	−0.0015	−0.0031
	Foreign	0.30	−0.0026	−0.0003	0.0023
0.0005	Home		0.0003	0.0003	0
	Foreign	0	−0.0002	−0.0002	0
0	Home	0	0.0001	0.0001	0
	Foreign	0	0.0001	0.0001	0

to those in our benchmark case. This finding also has policy implication. That is, it is better for developing countries to adopt oil price stabilization policy when they are subject to large productivity shocks.

Overall, our results in the quantitative analysis are consistent with the findings in the analytical model. In the analytical model, we show that oil price stabilization can be replaced by some endogenous monetary policies without monetary shocks. In the quantitative analysis, we find that standard Taylor rules can also be substitutes for the oil price stabilization when interest rate shocks are small enough. This result is useful for those developing countries who adopt Taylor rule type monetary policies. We also find that, for empirically plausible parameters values, the US cannot gain from the oil price stabilization in developing countries. This result indicates that the US may not gain from huge oil subsidies in developing countries through trade, contrary to common conjecture. The quantitative analysis also shows that our results are robust to changes in financial structure, monetary policies, and some parameter values.

A few simplifications are applied in our model. First, we do not consider distortionary tax to support oil price stabilization in this model. This is because even with lump-sum tax or transfer, we show that oil price stabilization policy can be replaced by monetary policy. If we introduce some extra costs of oil price stabilization, it will be straightforward to show that the foreign country will have even lower incentive to adopt oil price stabilization. Second, we do not consider home bias in our model. In the open-economy macroeconomics literature, home bias can be considered as a short-cut way to model openness. For example, a less open economy puts less weight on the consumption of imported goods, and in the limit the economy becomes closed if it does not import any goods. The impact of home bias on our results seems ambiguous. On the one hand, if the home country does not trade much with developing countries, the oil price stabilization policy in these countries will be less relevant for the home country. On the other hand, home bias substantially affects the real exchange rate movements and thus monetary policy. Therefore, there might exist a non-monotonic relationship between the home bias and the optimal level of oil price stabilization.

7. Conclusion

In this paper, we investigate how oil price stabilization policies in developing countries affect the global welfare, especially the US welfare, in a two-country model. We find that whether developing countries should adopt oil price stabilization policies depends critically on monetary policies. Our analysis shows that when monetary policies can respond to oil shocks effectively, developing countries do not need to rely on oil price stabilization policies. Hence, our paper suggests an alternative policy instrument to stabilize oil price for developing countries. Regarding the welfare implication, we find that in most situations, the US cannot gain from the oil price stabilization. In other words, there is no positive spill-over effect of oil price stabilization policy in developing countries. Given the small welfare gain from oil price stabilization, should developing countries abandon their oil price stabilization policies? To answer this question, further investigation will be necessary since oil price stabilization may lead to other benefits that are not explored in the current framework. Given the resources devoted to oil price stabilization in developing countries, investigating the welfare implication of oil price stabilization policy will be an important topic for future research.

Appendix A

A.1. Proof of Proposition 1

Monetary authorities are assumed to commit to the following form of state-contingent monetary rules

$$m = aq + u, \quad m^* = bq + u^* \tag{8.1}$$

where u and u^* denote the disturbances to money aggregate and a and b represent the policy parameters. The monetary authorities thus choose policy parameters a and b respectively to maximize the expected utility for home and foreign households. We solve the optimal monetary policy parameters $\{a,b\}$ by solving the Nash game.

$$\max_a EU(a, b^n), \quad \max_b EU^*(a^n, b)$$

Given pre-set prices and money demand functions, we may solve for consumption and employment levels in each country explicitly.

$$C = \left[\frac{1}{\chi}\frac{M}{P_{hh}^n P_{fh}^{1-n}}\right]^{\frac{1}{\rho}}, \quad C^* = \left[\frac{1}{\chi}\frac{M^n M^{*(1-n)}}{P_{hf}^n P_{ff}^{*\,1-n}}\right]^{\frac{1}{\rho}} \tag{8.2}$$

We simplify the exposition first and focus on a special case where $\rho = 1$.[26] When $\rho = 1$, the expected labor supplies for both countries are a function of constant parameters,[27] $EL = EL^* = \frac{1-\alpha}{\eta\hat{\lambda}}$. Thus, the expected utility for the home country depends on the mean of log consumption; and the variance of log consumption has no impact on the expected utility of households.

$$EU = Ec - \frac{1-\alpha}{\hat{\lambda}} \tag{8.3}$$

From the money demand function $c = -ln\chi + m - p$ and the assumption $Em = 0s$, we can show that the expected utility for home country is fully determined by the expected log price level.

$$EU = -ln\chi - \frac{1-\alpha}{\hat{\lambda}} - Ep. \tag{8.4}$$

Using the price index for home country, we have

$$P = P_{hh}^n P_{fh}^{1-n} = \hat{\lambda}E[MC]^n E\left[MC^* S\right]^{1-n} \tag{8.5}$$

From the marginal cost and the optimal conditions for money and labor, we have

$$P = \hat{\lambda}\left(\frac{\eta}{\chi}\right)^{1-\alpha} E\left[(M)^{1-\alpha}Q^{\alpha}\right]^n E\left[(M^*)^{1-\alpha}\left(\overline{Q}\right)^{v}\left(\frac{Q}{S}\right)^{1-v}\Big)^{\alpha} S\right]^{1-n} \tag{8.6}$$

[26] The general case where $\rho > 1$ can be referred to the Technical Appendix, which is available upon request.
[27] This is very straightforward when we substitute the pricing equations and risk-sharing condition into the labor market clearing conditions. More details can be referred to the Appendix A of Devereux et al. (2010).

It is assumed that $ln\overline{Q} = 0$. Using the log normal property of these shocks and taking log, we can get

$$Ep = ln\hat{\lambda}\left(\frac{\eta}{\chi}\right)^{1-\alpha} + \frac{n}{2}\left\{[(1-\alpha)a+\alpha]^2\sigma_q^2 + (1-\alpha)^2\sigma_u^2\right\} + \frac{1-n}{2}\left\{[(1-\alpha+\alpha v)a-\alpha vb+\alpha(1-v)]^2\sigma_q^2 + \left[(1-\alpha+\alpha v)^2+\alpha^2v^2\right]\sigma_u^2\right\} \tag{8.7}$$

Using the price index for foreign country, we have

$$P^* = \left[\frac{P_{hf}}{S}\right]^n\left(P_{ff}\right)^{1-n} = S^{-n}\hat{\lambda}E[MC]^nE[MC^*]^{1-n} \tag{8.8}$$

From the marginal cost functions and the optimal conditions for money and labor, we have

$$P^* = S^{-n}\hat{\lambda}\left(\frac{\eta}{\chi}\right)^{1-\alpha}E\left[(M)^{1-\alpha}Q^\alpha\right]^nE\left[(M^*)^{1-\alpha}\left(\overline{Q}^v\left(\frac{Q}{S}\right)^{1-v}\right)^\alpha\right]^{1-n} \tag{8.9}$$

Note that $\Gamma = 1$, so $ElnS = 0$. Using the log normal property of these shocks and taking log, we can get

$$Ep^* = ln\hat{\lambda}\left(\frac{\eta}{\chi}\right)^{1-\alpha} + \frac{n}{2}\left\{[(1-\alpha)a+\alpha]^2\sigma_q^2 + (1-\alpha)^2\sigma_u^2\right\} + \frac{1-n}{2}\left\{[(1-\alpha v)b-\alpha(1-v)a+\alpha(1-v)]^2\sigma_q^2 + \left[(1-\alpha v)^2+\alpha^2(1-v)^2\right]\sigma_u^2\right\} \tag{8.10}$$

The Nash solution to the international monetary game can be derived as

$$a = -\frac{\alpha}{1-\alpha}\left[1-\frac{(1-n)(1-\alpha+\alpha v)v}{\phi}\right] \tag{8.11}$$

$$b = \frac{-\alpha(1-v)(1-\alpha+\alpha v-n\alpha v)}{(1-\alpha)\phi} \tag{8.12}$$

where $\phi = \alpha nv(\alpha-2)+(1-\alpha+\alpha v)$. Using the solutions a and b, we may derive the expected utilities for home and foreign countries as

$$EU = \Lambda - \left\{\frac{(1-n)n\left[(1-n)(1-\alpha+\alpha v)^2+n(1-\alpha)^2\right]v^2\alpha^2}{2\phi^2}\sigma_q^2 + \left[\frac{(1-\alpha)^2}{2}+(1-n)(1-\alpha+\alpha v)\alpha v\right]\sigma_u^2\right\} \tag{8.13}$$

$$EU^* = \Lambda - \left\{\frac{n(1-n)^2(1-\alpha+\alpha v)^2v^2\alpha^2}{2\phi^2}\sigma_q^2 + \left[\frac{(1-\alpha)^2}{2}+(1-n)\alpha(1-v)(1-\alpha v)\right]\sigma_u^2\right\} \tag{8.14}$$

where $\Lambda = -ln\chi - \frac{1-\alpha}{\lambda} - ln\hat{\lambda}\left(\frac{\eta}{\chi}\right)^{1-\alpha}$.

A.2. Proof of Proposition 2 and 3

The first order condition with respect to v for the foreign country is derived as:

$$\frac{\partial EU^*}{\partial v} = -\frac{(1-n)^2n(1-\alpha+\alpha v)v\alpha^2[(1-\alpha+\alpha v)(1-\alpha)+\alpha v\phi]}{\phi^3}\sigma_q^2 + \alpha(1-n)(1+\alpha-2\alpha v)\sigma_u^2 \tag{8.15}$$

where the first term is negative and the second term is positive. Hence, when $\sigma_u^2 = \sigma_{u^*}^2 = 0$, the optimal v is equals to 0. In the environment with monetary disturbance, if σ_u^2 is sufficiently large, the sign of first order condition is determined by the second term. This implies that the foreign country may choose full stabilization. However, for any $\sigma_u^2 > 0$, we have

$$\frac{\partial EU^*}{\partial v}|_{v=0} = \alpha(1-n)(1+\alpha)s\sigma_u^2 > 0$$

So there must exist a $v > 0$ that delivers higher welfare than $v = 0$.

The expected utility for the home country is also a function of v, since

$$\frac{\partial EU}{\partial v} = -\left\{\frac{(1-n)^2n(1-\alpha+\alpha v)v\alpha^2[\alpha vn(1-\alpha)(2-\alpha)+\phi]}{\phi^3} + \frac{(1-n)n^2(1-\alpha)^3v\alpha^2}{\phi^3}\right\}\sigma_q^2 - \alpha(1-n)(1-\alpha+2\alpha v)\sigma_u^2 \tag{8.16}$$

Since $\frac{\partial EU}{\partial v} < 0$ and $v \in [0,1]$, so $v = 0$ is optimal for the home country. In other words, the home country does not have welfare gain from oil price stabilization when the foreign country chooses any $v > 0$.

A.3. Proof of Proposition 5

It is assumed that both home and foreign countries adopt an endogenous monetary policy and respond negatively to an increase in oil price, and there is no implementation error/shocks in the conduct of monetary policy. That is, $a < 0$, $b < 0$, and $\sigma_u^2 = 0$. Nevertheless, these endogenous monetary policies may not be optimally chosen. When the foreign country chooses the optima degree of oil price stabilization, the monetary policy (a,b) will be taken as given.

A.3.1. The foreign country

From Eq. (8.10) in the Appendix A, we have

$$\frac{\partial EU^*}{\partial v} = \alpha(1-n)[(1-\alpha v)b-\alpha(1-v)a+\alpha(1-v)][b-a+1]. \tag{8.17}$$

If endogenous monetary policies make oil price stabilization policy unnecessary, then we should have $\frac{\partial EU^*}{\partial v} \le 0$ given a, b. From Eq. (8.17), we have the condition that supports $\frac{\partial EU^*}{\partial v} \le 0$,

$$[b-\alpha a+\alpha-\alpha v(b-a+1)](b-a+1) \le 0 \tag{8.18}$$

Now we discuss three cases,

i) If $(b - a + 1) > 0$, since $0 \le v \le 1$, we must have $-\alpha(b-a+1) \le -\alpha v(b-a+1) \le 0$, this gives us

$$(1-\alpha)b \le [b-\alpha a+\alpha-\alpha v(b-a+1)] \le b-\alpha a+\alpha. \tag{8.19}$$

Therefore, if $a-1 < b \le \alpha(a-1) < 0$ and $a < 0$, we have $\frac{\partial EU^*}{\partial v} \le 0$ and the optimal degree of oil price stabilization is $v = 0$.

ii) If $(b-a+1) = 0$, then $\frac{\partial EU^*}{\partial v} = 0$. In this case, v does not have any effect on the foreign welfare. This case is not interesting and we will not consider it.

iii) If $(b-a+1) < 0$, since $0 \le v \le 1$, we have $0 < -\alpha v(b-a+1) < -\alpha(b-a+1)$, which yields

$$b-\alpha a+\alpha-\alpha v(b-a+1) < b-\alpha a+\alpha-\alpha(b-a+1) = b(1-\alpha) < 0. \tag{8.20}$$

This implies that $\frac{\partial EU^*}{\partial v} > 0$ and $v = 0$ is not supported in this case. Hence, when $a-1 < b \le \alpha(a-1) < 0$ and $a < 0$, we will have $\frac{\partial EU^*}{\partial v} \le 0$ and the foreign country will choose $v = 0$.

A.3.2. The home country

Given $a-1<b\leq\alpha(a-1)<0$ and $a<0$, we check how the home country welfare will be affected. From Eq. (8.7) in the Appendix A, we have

$$\frac{\partial EU}{\partial v}=\alpha(1-n)(b-a+1)[(1-\alpha)a+\alpha-\alpha v(b-a+1)] \tag{8.21}$$

If $\frac{\partial EU}{\partial v}<0$, it implies that $v=0$ is also optimal for the home country. Since $0\leq v\leq 1$ and $b-a+1>0$, we have

$$a-\alpha b\leq(1-\alpha)a+\alpha-\alpha v(b-a+1)\leq(1-\alpha)a+\alpha \tag{8.22}$$

Hence, a sufficient condition for $\frac{\partial EU}{\partial v}<0$ is $a<\frac{-\alpha}{1-\alpha}$.Also, when $a=\frac{-\alpha}{1-\alpha}$, $\frac{\partial EU}{\partial v}=0$.In this case, the home country also prefers zero stabilization. Therefore, $a-1<b\leq\alpha(a-1)$ and $a\leq\frac{-\alpha}{1-\alpha}$ is the feasible monetary policy set in which the foreign county will choose $v=0$ and the home country will also prefer zero oil price stabilization policy.

A.4. Proof of Proposition 6

When there is no endogenous monetary policy, $a=0$ and $b=0$, the expected utilities for home and foreign countries are given as:

$$EU=\Lambda-\left\{\frac{\alpha^2}{2}\left[n+(1-n)(1-v)^2\right]\sigma_q^2+\left[\frac{(1-\alpha)^2}{2}+(1-n)(1-\alpha+\alpha v)\alpha v\right]\sigma_u^2\right\} \tag{8.23}$$

$$EU^*=\Lambda-\left\{\frac{\alpha^2}{2}\left[n+(1-n)(1-v)^2\right]\sigma_q^2+\left[\frac{(1-\alpha)^2}{2}+(1-n)\alpha(1-v)(1-\alpha v)\right]\sigma_u^2\right\} \tag{8.24}$$

The first order condition for the foreign country is given by

$$\frac{\partial EU^*}{\partial v}=\alpha^2(1-n)(1-v)\sigma_q^2+(1-n)(1+\alpha-2\alpha v)\alpha\sigma_u^2>0 \tag{8.25}$$

So the optimal v chosen by foreign country is 1. Since the foreign country chooses $v=1$, the welfare gain from full oil price stabilization for home country is given by

$$\Delta EU=EU(v=1)-EU(v=0)=(1-n)\alpha\left(\alpha\sigma_q^2-\sigma_u^2\right) \tag{8.26}$$

Hence, the home country can gain from oil price stabilization if and only if $\alpha\sigma_q^2-\sigma_u^2>0$.

References

Baig, T., Mati, D. Coady, Ntamatungiro, J., 2007. Domestic petroleum product prices and subsidies: recent developments and reform strategies. IMF Working Paper No. 07/71.

Baumeister, Christiane, Peersman, Gert, 2011. The role of time-varying price elasticities in accounting for volatility changes in the crude oil market. Working Papers. Bank of Canada, pp. 11–28.

Benigno, Pierpaolo, 2009. Price stability with imperfect financial integration. J. Money, Credit, Bank. 41 (s1), 121–149.

Bodenstein, Martin, Guerrieri, Luca, 2011. Oil efficiency, demand, and prices: a tale of ups and downs. International Finance Discussion Papers 1031, Board of Governors of the Federal Reserve System (U.S.).

Bouakez, Hafedh, Rebei, Nooman, Vencatachellum, Desire, 2008. Optimal pass-through of oil prices in an economy with nominal rigidities. CIRPEE working paper No. 08-31.

Chari, V.V., Kehoe, Patrick J., McGrattan, Ellen R., 2002. Can sticky price models generate volatile and persistent real exchange rates? Rev. Econ. Stud. 69 (3), 533–563.

Clarida, Richard, Gali, Jordi, Gertler, Mark, 1998. Monetary policy rules in practice: some international evidence. Eur. Econ. Rev. 42, 1033–1068.

Clarida, Richard, Gali, Jordi, Gertler, Mark, 2000. Monetary policy rules and macroeconomic stability: evidence and some theory. Q. J. Econ. 115 (1), 147–180.

Clarida, Richard, Gali, Jordi, Gertler, Mark, 2002. A simple framework for international monetary policy analysis. J. Monet. Econ. 49 (5), 879–904.

Devereux, Michael B., Engel, Charles, 2003. Monetary policy in the open economy revisited: price setting and exchange rate flexibility. Rev. Econ. Stud. 70 (4), 765–783.

Devereux, Michael B., Shi, Kang, Juanyi, Xu., 2005. Friedman Redux: restricting monetary policy rules to support flexible exchange rates. Econ. Lett. 87 (3), 291–299.

Devereux, Michael B., Shi, Kang, Juanyi, Xu., 2007. The global monetary policy under a dollar standard. J. Int. Econ. 71, 113–132.

Devereux, Michael B., Shi, Kang, Xu, Juanyi, 2010. Oil currency and dollar standard: a simple analytical model of an international trade currency. J. Money, Credit, Bank. 42 (4), 521–550.

Dong, Wei, 2012. The role of expenditure switching in the global imbalance adjustment. J. Int. Econ. 86 (2), 237–251.

Crude Measures: Not Everybody is Paying Higher Prices for Oil. Economist (May 29th).

Engel, Charles, 2011. Currency misalignments and optimal monetary policy: a reexamination. Am. Econ. Rev. 101, 2796–2822.

Engel, Charles, West, Kenneth D., 2006. Taylor rules and the Deutschemark–Dollar real exchange rate. J. Money, Credit, Bank. 38, 1175–1194.

Gali, Jordi, 2011. Monetary policy and unemployment. In: Friedman, B., Woodfords, M. (Eds.), Handbook of Monetary Economics, vol. 3A, pp. 487–546.

Goldberg, Linda, Tille, Cedric, 2008. Vehicle currency use in international trade. Federal Reserve Bank of New York Staff Report 200.

Gopinath, Gita, Rigobon, Roberto, 2008. Sticky borders. Q. J. Econ. 123 (2), 531–575.

Kilian, Lutz, 2009. Oil price shocks, monetary policy and stagflation. CEPR Discussion Papers 7324, CEPR Discussion Papers.

Krichene, N., 2002. World crude oil and natural gas: a demand and supply model. Energy Econ. 24, 557–576.

Leduc, Sylvain, Sill, Keith, 2003. Monetary policy, oil shocks, and TFP: accounting for the decline in U.S. volatility. Working Paper 03-22. Federal Reserve Bank of Philadelphia.

Lubik, Thomas A., Schorfheide, Frank, 2003. Estimating monetary policy rules in small open economies: a structural approach. Computing in Economics and Finance 2003. Society for Computational Economics, p. 225.

Mork, Knut A., Hall, Robert E., 1980. Energy prices, inflation, and recession. Energy J. 15, 31–63.

Obstfeld, Maurice, Rogoff, Kenneth, 1998. Risk and exchange rates. NBER Working Papers 6694.

Obstfeld, Maurice, Rogoff, Kenneth, 2002. Global implications of self-oriented national monetary rules. Q. J. Econ. 117 (2), 503–535.

Schmitt-Grohe, Stephanie, Uribe, Martin, 2004. Solving dynamic general equilibrium models using a second-order approximation to the policy function. J. Econ. Dyn. Control. 28, 755–775.

World Bank, 2006. Coping with higher fuel prices. Report No. 323/06.

World Bank, 2009. Government response to oil price volatility.