Optimal Pass-Through of Oil Prices*

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Abstract

In many developing and emerging market economies, governments intervene to limit the degree to which oil-price increases are passed through to domestic fuel prices. This paper investigates whether, and to what extent, this intervention is warranted. It computes the welfare-maximizing level of pass-through of oil prices in an artificial oil-importing economy characterized by nominal price rigidities. We find that, to the extent that monetary policy is capable of stabilizing the economy, government intervention in the oil market should be avoided. On the other hand, when complete stabilization is not attainable, as is the case under CPI inflation targeting, the government can improve social welfare by limiting the degree of pass-through of oil prices. We find, however, that the welfare gain from pursuing such a policy is negligible.

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1. Introduction

How, if at all, should governments respond to oil-price shocks? Interest in this question has been revived by the recent episode of rapid and sustained increase in international oil prices, which started towards the end of 2003. This episode has led several developing and emerging market economies to adopt a number of policies aimed at cushioning the adverse effects of oil-price increases. Many of these policies sought to avoid the full pass-through of oil-price increases to domestic consumers by controlling retail fuel prices, providing explicit fuel subsidies, lowering fuel taxes, and reducing the profit margins of state-owned oil companies. According to two recent studies by the World Bank (2006) and Baig et al. (2007), roughly half of the developing and emerging market economies surveyed have not fully passed through the increase in international fuel prices between the end of 2003 and mid-2006. In contrast, in most industrialized countries, governments have abstained from intervening in the oil market, opting to maintain a full-pass-through policy. This behavior is consistent with the conventional wisdom that fuel prices ought to be completely deregulated. As is well known from the literature on regulation, however, this view is valid in a frictionless environment but may not be justified in the presence of market failure.

The objective of this paper is to determine whether, and to what extent, government intervention in the oil market is warranted in an economy characterized by nominal price rigidities in the goods market. More specifically, we investigate whether limiting the degree of pass-through of oil prices in such an environment could be welfare improving relative to a full-pass-through policy. For this purpose, we consider a theoretical small open economy that uses oil as an input in the production process. Oil is imported by the government at the world price and sold to domestic producers at a domestic price that is determined according to a specified rule. This assumption is justified by the fact that in many oil-importing countries, the government sets domestic fuel prices according to ad hoc pricing formulae that aim at smoothing oil-price changes. In our model, the government sets the domestic price of oil in a given period as a convex combination of the current world price expressed in local currency and last period's domestic price. The coefficient attached to the world price is then interpreted as the degree of pass-through. Any value of this coefficient that is strictly less than 1 implies incomplete pass-through of oil prices and the resulting wedge between the world price of oil and its domestic counterpart, i.e., the subsidy, is financed through lump sum taxes. Importantly, our analysis assumes that the government can pre-commit to the announced pricing rule and that agents are aware of both the rule and the pre-committment.

In addition to oil, domestic producers use non-oil intermediate goods as inputs. These goods have sticky prices, which means that there is scope for monetary policy to affect real variables. We consider two alternative policy regimes, one in which the monetary authority strictly targets CPI inflation, and one in which it fixes the nominal exchange rate. We focus on these two specific cases because they describe the conduct of monetary policy in a large number of developing and emerging market economies.

Our baseline results indicate that, under CPI inflation targeting, the optimal level of pass-through is about 20 per cent. That is, aggressive stabilization of oil prices on the part of the government is desirable. On the other hand, under a fixed exchange rate regime, complete pass-through is optimal. The intuition for these results is the following. Under CPI inflation targeting and complete pass-through of oil prices, domestic prices are not completely stabilized. This in turn induces inefficiently large movements in the real exchange rate and causes output (and other real variables) to over-react to the oil-price shock and thus to deviate from the efficient allocation. On the other hand, a zero-pass-through policy stabilizes domestic prices, but does so at the expense of stabilizing the real exchange rate, thereby leading to insufficient variations in output. The departure of the economy from the efficient allocation in this case is simply a reflection of the distortionary effects of the subsidy involved. The optimal degree of pass-through, therefore, involves weighing the benefits of stabilizing domestic prices against the costs of destabilizing output (or alternatively, the real exchange rate). Our analysis suggests that the trade-off between inflation stability and output stability is resolved at a rather low degree of pass-through of oil prices. Under fixed exchange rates and complete pass-through of oil prices, the economy's response to an oil-price shock coincides with the efficient allocation, because the latter involves stabilizing the nominal marginal cost of domestic producers, which, given our market structure, is tied down by the nominal exchange rate. Any attempt to limit the pass-through of oil prices in this case would generate a welfare loss, which will be larger the lower the degree of pass-through.

Notwithstanding that under CPI inflation targeting the optimal pricing rule deviates significantly from complete pass-through, the resulting welfare gain is negligible (less than 0.01 per cent of permanent consumption). Our sensitivity analysis reveals that under strict CPI inflation targeting, the optimal degree of pass-through increases with the price-elasticity of oil demand, decreases with the share of oil in production, and is essentially insensitive to the extent of financial frictions. In each of these cases, the welfare gain associated with the optimal degree of pass-through remains very small. When import prices are assumed to be sticky, however, the optimal degree of pass-through falls to roughly 10 per cent and the associated welfare gain is significantly higher, exceeding 0.12 per cent of permanent consumption.

Of the vast literature on the macroeconomic effects of oil-price shocks, one particular stream is more closely related to our work.[1] It consists of studies that examine the role of monetary policy in shaping the relationship between oil-price shocks and the macroeconomy. Some of these contributions are based on vector autro-regressions (e.g., Bernanke, Gertler and Watson 1997, Hooker 2002, Hamilton and Herrera 2004), while others use dynamic general-equilibrium models (e.g., Leduc and Sill 2004, Medina and Soto 2005, and Blanchard and Galì 2007).[2] The main focus of this literature, however, is to determine whether the downturns that follow large oil-price shocks are caused by the systematic (contractionary) response of monetary policy to the inflationary pressure brought about by these shocks, rather than the shocks themselves.[3]

Our paper is also related to the recent literature on the welfare implications of macroeconomic policies in small open economies, as exemplified by the work of Kollmann (2002, 2006), Galì and Monacelli (2003), Ambler, Dib, and Rebei (2004), Monacelli (2005), and Devereux, Lane, and Xu (2006), among others. None of these studies, however, explicitly examines the optimality of government intervention in response to oil-price shocks.

The rest of the paper is structured as follows. Section 2 discusses the empirical evidence on pass-through of oil prices. Section 3 describes the model. Section 4 studies the dynamic response of the economy to an oil-price shock. Section 5 performs a welfare analysis. Section

[1]For comprehensive surveys of this literature, see Barsky and Kilian (2004) and Hamilton (2005).

[2]Studies based on dynamic general-equilibrium models build on earlier papers by Kim and Loungani (2002), Rotemberg and Woodford (1996), Finn (2000), and Backus and Crucini (2000). These papers, however, consider real economies and abstract from money.

[3]Blanchard and Galì (2007), on the other hand, find that monetary policy is one of the factors that account for the fact that oil-price shocks seem to have smaller effects on economic activity in the 1990s than in the 1970s.

6 examines the sensitivity of our results to alternative modelling assumptions. Section 7 concludes and discusses possible future extensions of the model.

2. Empirical Evidence on Pass-Through of Oil Prices

Although it is well established that several developing and emerging market economies have attempted to limit the extent to which increases in the world price of oil are passed through to domestic fuel prices, little empirical work has been done to formally measure and compare the degree of pass-through of oil prices across countries. The only two studies that we are aware of those by the World Bank (2006) and Baig et al. (2007), which use survey data from, respectively, 38 and 44 developing and emerging market countries to compute pass-through estimates for gasoline and diesel between January 2004 and mid-2006. In both cases, pass-through is measured as the ratio of the (absolute) change in domestic retail fuel prices (measured in local currency) to the (absolute) change in the international price (converted to local currency). Their results are summarized in Table 1. For comparison, results for six industrialized countries are also reported. With a few exceptions, the two studies report similar estimates for countries that are common to both samples.

Table 1 shows substantial heterogeneity in the degree of pass-through across countries. Estimates range from 0 to 2.5 in the study by the World Bank and from −0.17 to 2.8 in the study by Baig et al. More importantly, of the 38 countries surveyed by the World Bank, 19 (22) have not fully passed through the oil-price increase to domestic gasoline (diesel) prices. Baig et al. also document incomplete pass-through to gasoline (diesel) prices in 21 (19) of the 44 countries in their sample. Therefore, roughly half of the developing and emerging market economies surveyed have not passed through the increase in the world price of oil. In a third of these countries, pass-through was less than 50 per cent. In contrast, with the exception of Japan, most industrialized countries have allowed oil-price increases in the world market to be fully passed through to domestic fuel prices.

[To be completed]

3. The Model

3.1 Overview of the Model

The economy consists of households, firms, a government, and a monetary authority. There are four types of goods: a final good, a composite non-oil good, oil, and intermediate goods. The final good, which serves consumption and investment purposes, is produced by perfectly competitive firms using oil and a non-oil composite good as inputs. The non-oil composite good is produced by mixing domestically produced and imported intermediate goods. Domestic intermediate goods are produced by monopolistically competitive firms that use domestic labor and capital as inputs. Domestically produced intermediate goods are also exported to the rest of the world. Export prices are determined at the world market and are exogenous to the economy. Foreign intermediate goods are imported by monopolistically competitive importers at the world price. These goods are then sold to local firms at domestic-currency prices. Prices set by monopolistic firms are costly to change, and are thus sticky. Price stickiness introduces a role for monetary policy in removing the distortions associated with the costly adjustment of nominal prices. It is assumed that the monetary authority sets the nominal interest rate according to a Taylor-type rule, which nests strict CPI inflation targeting and fixed exchange rates as special cases.

Oil used to produce the final good is imported by the government who plays the role of an intermediary, buying oil at the world price, P_t^{o*}, and reselling it to domestic firms at the domestic price P_t^o. These two prices need not be identical even after converting the world price to domestic currency. Depending on the way in which the government sets P_t^o, pass-through from the world price to the local price of oil will be full or incomplete. In the model, the government follows a rule that can yield any degree of pass-through between zero and 100 per cent.

Access to international financial markets can be limited, depending on the severity of credit constraints that a given country faces. Countries that have only limited access to international financial markets cannot buffer shocks and smooth consumption by resorting to international borrowing. This feature is captured in the model by assuming portfolio-adjustment costs.

The rest of this section provides a detailed description of the model, derives the first-order conditions, and describes the equilibrium. Throughout the paper, variables that originate in the rest of the world are denoted by an asterisk, and variables that do not have a time subscript refer to steady-state values.

3.2 Households

The representative household maximizes its lifetime utility given by

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t, h_t\right), \tag{1}$$

where β is the subjective discount factor ($0 < \beta < 1$), u is the instantaneous utility function, c_t is consumption, and h_t denotes hours worked by the household.[4] The instantaneous utility function is assumed to be

$$u(\cdot) = \frac{\gamma}{\gamma - 1} c_t^{\frac{\gamma-1}{\gamma}} + \varpi \log\left(1 - h_t\right), \tag{2}$$

where γ, η and ϖ are positive parameters.

The representative household enters period t with B_t domestic bonds, B_{t-1}^* foreign-currency bonds and a stock of capital, k_t. In period t, the household receives dividends, D_t, from monopolistic firms. It also receives total factor payments of $W_t h_t + Q_t k_t$ from selling labor and renting capital to domestic intermediate-good producers, where W_t and Q_t denote the nominal wage and rental rates, respectively. The household's income in period t is allocated to consumption, investment, money holdings, and the purchase of nominal bonds. Acquiring foreign bonds entails paying (nominal) portfolio-adjustment costs:[5]

$$\frac{\psi_b}{2} e_t P_t^* \left(\frac{B_t^* - B^*}{P_t^*}\right)^2$$

where ψ_b is a positive parameter and e_t is the nominal exchange rate defined as the number of units of domestic currency needed to purchase one unit of foreign currency. Investment, i_t, increases the household's stock of capital according to

$$k_{t+1} = (1 - \delta) k_t + i_t, \tag{3}$$

[4] In each period, the household's total endowment of time is normalized to unity.

[5] Without portoflio-adjustment costs, the model would have a unit root because the bond holdings process would follow a random walk.

where $\delta \in (0,1)$ is the depreciation rate of capital. Investment is subject to quadratic adjustment costs:

$$\frac{\psi_k}{2}\left(\frac{i_t}{k_t}-\delta\right)^2 k_t,$$

where $\psi_k \geq 0$. The household's budget constraint is given by:

$$P_t(c_t+i_t)+B_t+e_tB_t^* \\ \leq W_th_t+Q_tk_t+R_{t-1}B_{t-1}+e_tR_{t-1}^*B_{t-1}^*+D_t+\frac{\psi_k}{2}P_t\left(\frac{i_t}{k_t}-\delta\right)^2 k_t-\frac{\psi_b}{2}e_tP_t^*(\frac{B_t^*-B^*}{P_t^*})^2, \tag{4}$$

where P_t the price of the final good and will henceforth be referred to as the CPI, $D_t \equiv D_t^d + D_t^m$, with D_t^d being dividends received from domestic intermediate-good producers and D_t^m those received from importers of foreign intermediate goods, R_t denotes the gross domestic nominal interest rate, and R_t^* denotes the gross world nominal interest rate.

The representative household chooses c_t, h_t, B_t^*, and k_{t+1} to maximize its lifetime utility subject to its budget constraint (4), the capital accumulation equation (3), and a no-ponzi-game condition on its holdings of assets. The household's first-order conditions are

$$\lambda_t = c_t^{-\frac{1}{\gamma}}, \tag{5}$$

$$w_t = \frac{\varpi\,(1-h_t)^{-1}}{\lambda_t}, \tag{6}$$

$$\lambda_t = \beta R_t E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right), \tag{7}$$

$$\lambda_t = \beta R_t^*\left(1+\psi_b\frac{B_t^*-B^*}{P_t^*}\right)^{-1} E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\frac{e_{t+1}}{e_t}\right), \tag{8}$$

$$\lambda_t = \frac{\beta E_t\{\lambda_{t+1}[1+q_{t+1}-\delta+\psi(\frac{i_{t+1}}{k_{t+1}}-\delta)+\frac{\psi}{2}(\frac{i_{t+1}}{k_{t+1}}-\delta)^2]\}}{1+\psi(\frac{i_t}{k_t}-\delta)}, \tag{9}$$

where λ_t is the Lagrange multiplier associated with the budget constraint expressed in real terms; $w_t \equiv W_t/P_t$ is the real wage; $q_t \equiv Q_t/P_t$ is the real rental rate; and $\pi_t \equiv P_t/P_{t-1}$ is the gross inflation rate between $t-1$ and t.

3.3 Production

3.3.1 Final good

Firms in the final-good sector are perfectly competitive. They combine oil and a non-oil composite good to produce a single homogenous good using the following constant elasticity of substitution (CES) technology:

$$y_t = \left[\phi^{\frac{1}{\nu}} (y_t^o)^{\frac{\nu-1}{\nu}} + (1-\phi)^{\frac{1}{\nu}} (y_t^{no})^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}}, \tag{10}$$

where $\phi > 0$ is the weight of oil in the production of the final good and $\nu > 0$ is the elasticity of substitution between oil and non-oil inputs. Oil is imported by the government, who plays the role of an intermediary, buying oil at the world price, P_t^{o*}, and reselling it to domestic firms at the domestic price P_t^o.

The representative final-good producer solves

$$\max_{\{y_t^d, y_t^m\}} P_t y_t - P_t^o y_t^o - P_t^{no} y_t^{no}, \tag{11}$$

where y_t is given by (10). Profit maximization implies

$$y_t^o = \phi \left(\frac{P_t^o}{P_t}\right)^{-\nu} y_t. \tag{12}$$

and

$$y_t^{no} = (1-\phi) \left(\frac{P_t^{no}}{P_t}\right)^{-\nu} y_t, \tag{13}$$

Hence, the parameter ν also represents the price-elasticity of oil demand. The zero-profit condition implies that the price of the final good, P_t, is given by

$$P_t = \left[\phi (P_t^o)^{1-\nu} + (1-\phi) (P_t^{no})^{1-\nu}\right]^{\frac{1}{1-\nu}}. \tag{14}$$

3.3.2 Non-oil composite good

The non-oil composite good is produced by perfectly competitive firms using the following Cobb-Douglas technology

$$y_t^{no} = \Gamma (y_t^d)^{\sigma} (y_t^m)^{1-\sigma}, \tag{15}$$

where $\Gamma \equiv \sigma^{-\sigma}(1-\sigma)^{\sigma-1}$ is a positive parameter; $y_t^d \equiv \left(\int_0^1 y_t^d(i)^{(\theta-1)/\theta} di\right)^{\theta/(\theta-1)}$ and $y_t^m \equiv \left(\int_0^1 y_t^m(i)^{(\vartheta-1)/\vartheta} di\right)^{\vartheta/(\vartheta-1)}$ are aggregates of domestic and imported intermediate goods, respectively; and θ $(\vartheta) > 1$ is the elasticity of substitution between domestic (foreign) intermediate goods. Define $P_t^d \equiv \left(\int_0^1 P_t^d(i)^{1-\theta} di\right)^{1/(1-\theta)}$ and $P_t^m \equiv \left(\int_0^1 P_t^m(i)^{1-\vartheta} di\right)^{1/(1-\vartheta)}$ as the price indexes associated with the aggregators y_t^d and y_t^m. Then, demands for individual domestic and imported intermediate goods are, respectively, given by

$$y_t^d(i) = \left(\frac{P_t^d(i)}{P_t^d}\right)^{-\theta} y_t^d, \qquad i \in (0,1), \tag{16}$$

and

$$y_t^m(i) = \left(\frac{P_t^m(i)}{P_t^m}\right)^{-\vartheta} y_t^m, \qquad i \in (0,1). \tag{17}$$

where y_t^d, y_t^m, and P_t^{no} are given by, respectively

$$y_t^d = \sigma \left(\frac{P_t^d}{P_t^{no}}\right)^{-1} y_t^{no}, \tag{18}$$

$$y_t^m = (1-\sigma) \left(\frac{P_t^m}{P_t^{no}}\right)^{-1} y_t^{no}. \tag{19}$$

and

$$P_t^{no} = \left(P_t^d\right)^{\sigma} \left(P_t^m\right)^{1-\sigma}. \tag{20}$$

3.3.3 Domestic intermediate goods

Domestic intermediate-good producers have identical Cobb-Douglas production functions given by

$$z_t(i) \equiv y_t^d(i) + y_t^x(i) = A_t k_t(i)^{\alpha} h_t(i)^{1-\alpha}, \tag{21}$$

where $\alpha \in (0,1)$; $k_t(i)$ and $h_t(i)$ are capital and labour inputs used by firm i; and A_t is an aggregate technology shock.

Let $P_t^d(i)$ denote the price that firm i chooses for its sales in the domestic market. Changing the domestic price entails quadratic adjustment costs à la Rotemberg (1982):

$$\frac{\psi_d}{2}\left(\frac{P_t^d(i)}{\pi^d P_{t-1}^d(i)} - 1\right)^2,$$

where $\psi_d \geq 0$; and π^d is the steady-state value of $\pi_t^d \equiv P_t^d / P_{t-1}^d$. On the other hand, the domestic-currency export price, $P_t^x(i)$, once converted to foreign currency, is equal to the world price, P_t^*. That is,

$$P_t^x(i) = e_t P_t^*. \tag{22}$$

This assumption reflects the fact that the small open economy has no control over the world price of exported goods. In turn, it implies that the law of one price holds for these goods. Under these assumptions, firm i solves the following dynamic problem:

$$\max_{\{h_t(i), k_t(i), P_t^d(i), y_t^x(i)\}} E_t \sum_{s=0}^{\infty} \beta^s \left(\frac{\lambda_{t+s}}{\lambda_t}\right) \frac{D_{t+s}^d(i)}{P_{t+s}}, \tag{23}$$

where

$$D_t^d(i) \equiv P_t^d(i)y_t^d(i) + P_t^x(i)y_t^x(i) - W_t h_t(i) - Q_t k_t(i) - \frac{\psi_d}{2}\left(\frac{P_t^d(i)}{\pi^d P_{t-1}^d(i)} - 1\right)^2 P_t^d(i)y_t^d(i).$$

Given the demand function (16), the first-order conditions for firm i are

$$w_t = (1-\alpha)\xi_t(i)\frac{z_t(i)}{h_t(i)}, \tag{24}$$

$$q_t = \alpha\xi_t(i)\frac{z_t(i)}{k_t(i)}, \tag{25}$$

$$\begin{aligned} -\theta\frac{\xi_t(i)}{p_t^d(i)} &= (1-\theta)\left[1 - \frac{\psi_d}{2}\left(\frac{\pi_t^d(i)}{\pi^d} - 1\right)^2\right] \\ &\quad - \psi_d\left[\frac{\pi_t^d(i)}{\pi^d}\left(\frac{\pi_t^d(i)}{\pi^d} - 1\right) - \beta E_t\frac{\lambda_{t+1}}{\lambda_t}\frac{\left(\pi_{t+1}^d(i)\right)^2}{\pi_{t+1}\pi^d}\left(\frac{\pi_t^d(i)}{\pi^d} - 1\right)\frac{y_{t+1}^d(i)}{y_t^d(i)}\right], \end{aligned} \tag{26}$$

$$p_t^x(i) = \xi_t(i), \tag{27}$$

where $\xi_t(i)$ is the Lagrange multiplier associated with equation (21) and is equal to the real marginal cost of firm i; $p_t^d(i) \equiv P_t^d(i)/P_t$; $p_t^x(i) \equiv P_t^x(i)/P_t$, $\pi_t^d(i) \equiv P_t^d(i)/P_{t-1}^d(i)$; and $\pi_t^* \equiv P_t^*/P_{t-1}^*$ is the gross inflation rate in the rest of the world, which is normalized to 1.

Equations (22) and (27) imply that the marginal cost of the domestic intermediate-good producer is tied down by the exchange rate, both in nominal and real terms. This result will be important for understanding the intuition behind the paper's main findings.

3.3.4 Imported intermediate goods

Foreign intermediate goods are imported by monopolistically competitive firms at the world price, P_t^*. Importing firms then sell those goods in domestic currency to final-good producers. Resale prices, $P_t^m(i)$ are also subject to quadratic adjustment costs:

$$\frac{\psi_m}{2}\left(\frac{P_t^m(i)}{\pi^m P_{t-1}^m(i)} - 1\right)^2,$$

where π^m is the steady-state value of $\pi_t^m \equiv P_t^m/P_{t-1}^m$. The importing firm i solves the following problem:

$$\max_{\{P_t^m(i)\}} E_t\sum_{s=0}^{\infty}\beta^s\left(\frac{\lambda_{t+s}}{\lambda_t}\right)\frac{D_{t+s}^m(i)}{P_{t+s}}, \tag{28}$$

where

$$D_t^m(i) = \left(P_t^m(i) - e_t P_t^*\right) y_t^m(i) - \frac{\psi_m}{2}\left(\frac{P_t^m(i)}{\pi^m P_{t-1}^m(i)} - 1\right)^2 P_t^m(i) y_t^m(i). \tag{29}$$

The first-order condition for this problem is

$$\begin{aligned}\vartheta \frac{s_t}{p_t^m(i)} &= (1-\vartheta)\left[1 - \frac{\psi_m}{2}\left(\frac{\pi_t^m(i)}{\pi^m} - 1\right)^2\right] \\ &\quad -\psi_m\left[\frac{\pi_t^m(i)}{\pi^m}\left(\frac{\pi_t^m(i)}{\pi^m} - 1\right) - \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{\left(\pi_{t+1}^m(i)\right)^2}{\pi_{t+1}\pi^m}\left(\frac{\pi_t^m(i)}{\pi^m} - 1\right)\frac{y_{t+1}^m(i)}{y_t^m(i)}\right]\end{aligned} \tag{30}$$

where $p_t^m(i) \equiv P_t^m(i)/P_t$ and $\pi_t^m(i) \equiv P_t^m(i)/P_{t-1}^m(i)$.

3.4 The government

It is assumed that the government sets the domestic price of oil in a given period as a convex combination of the current world price expressed in local currency and last period's domestic price. Formally,

$$P_t^o = (1-\chi)P_{t-1}^o + \chi e_t P_t^{o*}. \tag{31}$$

Thus, if $\chi = 1$, there is complete pass-through from the world price of oil to the domestic price. If $\chi = 0$, there is zero pass-through. The rule (31) is admittedly ad hoc inasmuch as it is not derived from an explicit optimization problem of the government. This specification, however, is a convenient and parsimonious way to capture the fact that, in many developing and emerging market economies, domestic fuel prices are determined according to ad-hoc pricing formulae, while allowing the degree of pass-through of oil prices to take any value between 0 and 1.

The government's revenues include receipts from selling oil to domestic firms and taxes. The government's expenditures include the cost of acquiring oil. Hence, the government's budget constraint is given by

$$e_t P_t^{o*} y_t^o = P_t^o y_t^o + T_t.$$

In what follows, we will assume that the real price of oil, $p_t^{o*} \equiv \frac{P_t^{o*}}{P_t^*}$, evolves according to the following process

$$\log p_t^{o*} = (1-\rho_o)\log(p^{o*}) + \rho_o \log(p_{t-1}^{o*}) + \epsilon_{ot}, \tag{32}$$

3.5 Monetary authority

It is assumed that the central bank manages the short-term nominal interest rate according to the following Taylor-type policy rule:

$$\log(R_t/R) = \varrho_\pi \log(\pi_t/\pi) + \varrho_e \log(e_t/e).$$

This rule encompasses two polar monetary-policy/exchange-rate regimes. When $\varrho_\pi \to \infty$ and $\varrho_e = 0$, we obtain a strict CPI inflation targeting regime. Alternatively, when $\varrho_e \to \infty$ and $\varrho_\pi = 0$, the rule above represents a fixed exchange rate regime.

3.6 Symmetric equilibrium

In a symmetric equilibrium, all intermediate-good producers make identical decisions. That is, $z_t(i) = z_t$, $k_t(i) = k_t$, $h_t(i) = h_t$, $P_t^d(i) = P_t^d$, $P_t^m(i) = P_t^m$, and $P_t^x(i) = P_t^x$ for all $i \in (0,1)$. Hence, a symmetric equilibrium for this economy is a collection of 30 sequences $(c_t, h_t, i_t, k_{t+1}, y_t, y_t^d, y^o, y_t^{no}, y_t^m, y_t^x, z_t, w_t, q_t, \xi_t, \lambda_t, \pi_t, \pi_t^d, \pi_t^{no}, \pi_t^m, \pi_t^x, R_t, s_t, e_t, b_t^*, p_t^d, p_t^o,$ $p_t^{no}, p_t^m, p_t^x, P_t)_{t=0}^{\infty}$ satisfying the private agents' first-order conditions, the oil pricing rule, the monetary policy rule, market-clearing conditions, and a balance of payments equation (the model's equations are listed in the appendix).[6] The model is solved up to a second-order approximation around a deterministic steady state in which all variables are constant.

3.7 Calibration

To study the behavior of the economy under different degrees of pass-through of oil prices, we need to assign values to the model parameter and to steady-state values of the variables. We start by calibrating a baseline version of the model in which only domestic prices are rigid. Import prices are fully flexible and obey the law of one price. Under this assumption, the non-oil terms of trade are always constant (since both import and export prices are equal to $e_t P_t^*$) and the flexible-price allocation, which is obtained when both domestic and import prices are fully flexible and when there is complete pass-through of oil prices, is efficient.[7] The flexible-price allocation, therefore, provides a benchmark for evaluating and comparing alternative pricing policies in this case.

[6] The variable b_t^* denotes B_t^*/P_t^*.

[7] Strictly speaking, the flexible-price allocation is constrained-efficient (rather than Pareto efficient) because the existence of monoplistic competition among intermediate-good producers leads to an ineffciently low level of output.

The baseline model is calibrated at a quarterly frequency. The subjective discount factor, β, is set to 0.99, which implies that the annual real interest rate is equal to 4 per cent in the deterministic steady state. The elasticity of intertemporal substitution is set to 0.5. The preference parameter ϖ is chosen so that the fraction of hours worked in the deterministic steady state is equal to 0.3. The capital's share in production, α, is set to 0.36, while the depreciation rate, δ, is chosen to be 0.025. These values, which have become quite standard in the literature, were used, for example, by Backus and Crucini 2000. Following Bouakez and Rebei (2006), we set the capital adjustment cost parameter, ψ_k to 30, which implies an elasticity of investment with respect to the price of capital of 1.33. The parameter governing portfolio-adjustment costs is set to 0.0007, the value suggested by Schmitt-Grohé and Uribe (2004). The share of domestic intermediate goods in the non-oil composite good, σ, is chosen to be 0.65. The elasticity of substitution between domestic intermediate goods, θ, and its analogous for imported goods, ϑ, are set to 10, implying a markup of 11 per cent in the deterministic steady state. The price-adjustment-cost parameter ψ_d is calibrated so that, up to a first-order approximation, the resulting nominal rigidity is equivalent to that implied by a Calvo-type staggered price setting with an average duration of price contracts of 4 quarters.

The parameters that describe the way in which the production technology depends on oil are crucially important to our analysis. We set the price-elasticity of oil demand (which is also the elasticity of substitution between oil and non-oil inputs), ν, to 0.05. This value is consistent with the evidence that oil demand is highly insensitive to price changes. For example, Gately and Huntington (2002) estimate the short-run elasticity of demand for crude oil to be 0.05 for OECD countries and between 0.02 and 0.03 for a group of non-OECD countries. Cooper (2003) provides individual estimates for 23 countries that range between 0 and 0.11. These studies indicate, however, that the short-run price elasticity of oil demand is significantly lower than the long-run elasticity.[8] Given that the specification of the production function (10) does not allow us to distinguish between the short-run and the long run elasticity of oil demand, our calibration reflects the fact that we mainly focus on the short-run rather than the secular effects of oil-price shocks.

The steady-state oil share in production is given by the parameter ϕ. Because the model

[8]Gately and Huntington (2002) estimate the long-run elasticity to be 0.64 for OECD countries and 0.18 for the non-OECD group, while Cooper (2003) report estimates ranging between 0 and 0.57.

economy does not produce oil, ϕ is also the steady-state ratio of oil imports to output. In the data, this ratio differs substantially across countries, but it is generally much lower in industrialized countries than in developing and emerging market economies. Since the end of 2001, however, there has been a widespread increase in the oil import bill as a result of rising oil prices and the inelastic demand for oil. For example, the average ratio of oil imports to GDP in African countries rose from about 4 per cent in 2001 to roughly 6 per cent by the end of 2004. A similar pattern has also been observed in a number of Asian and Latin American countries: In 2003, the share of oil imports in GDP reached 3.8 per cent in India, 5 per cent or more in Singapore, Korea, Thailand, Taiwan and the Philippines, and 4.9 per cent on average for Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama.[9] These numbers are likely to have increased since then given that oil prices continued to rise. Based on these considerations, we set the parameter ϕ to 0.04.

To obtain values for the parameters ρ_o and σ_{ϵ_o}, we estimate an AR(1) process using data on the real price of oil over the period 1974Q1–2006Q4. The real price of oil is measured by the average spot price of West Texas Intermediate crude oil, divided by the U.S. GDP deflator and expressed in logarithm. Both series are taken from the Federal Reserve Bank of Saint-Louis database. Our estimation yields $\rho_o = 0.962$ and $\sigma_{\epsilon_o} = 0.137$.

Table 2 summarizes our baseline calibration. In Section 5, we consider alternative values of the elasticity of oil demand, the share of oil in production, and the portfolio-adjustment-cost parameter, as well as the case with sticky import prices (that is, $\psi_m \neq 0$).

4. Impulse Response Analysis

The purpose of this section is to contrast the dynamic response of the economy to an oil-price increase under complete and zero pass-through. The comparison is made under two alternative scenarios about monetary policy: strict CPI inflation targeting and a fixed exchange rate regime. We focus on these two particular cases because they represent the stance of monetary policy in a wide range of oil-importing small open economies. As a benchmark, we also compute the efficient response of the economy, which is obtained when the following two conditions are met: (i) domestic prices are completely stabilized and (ii) there is complete pass-through of oil prices. Indeed, under these conditions, the equilibrium

[9] United Nations Conference On Trade And Development (2005).

allocation coincides with the flexible-price allocation, which, as argued in Section 3.7, is efficient.

4.1 Strict CPI inflation targeting

Figure 1 depicts the impulse response of output, consumption, investment, domestic and CPI inflation, the nominal and real interest rate, and the nominal and real exchange rate to a standard-deviation (0.137) increase in the world price of oil under CPI inflation targeting. Consider first the case with complete pass-through ($\chi = 1$). The shock triggers a persistent decline in output, consumption and investment, which then converge to their steady-state levels from below. This outcome is attributed to a combination of two effects of the higher oil price: a direct income effect, through the balance of payments, and an indirect effect on production, through higher costs of inputs. The former decreases consumption and increases labor supply. The latter decreases demand for non-oil inputs and, by extension, demand for labor and capital. The net effect on hours worked is, in principle, ambiguous and depends on the model parameters, but labor income unambiguously falls due to a substantial decrease in the real wage. Moreover, the lower return on capital leads households to cut investment.

Because the domestic price of oil enters the composition of the CPI, the rise in the world price of oil tends, under full pass-through, to increase CPI inflation. To eliminate the upward pressure on inflation, the nominal interest rate rises substantially, and given that expected inflation is zero, the real interest rate rises by the same amount. The large increase in the real interest rate leads to a sharp appreciation of the nominal and the real exchange rate.[10] This appreciation is needed to (partially) offset the increase in the world price of oil, i.e., to limit the degree of pass-through of the oil-price increase to CPI inflation.

Figure 1 shows that the initial fall in output is significantly larger under strict inflation targeting than under the efficient allocation of resources (0.8 versus 0.4 percent), and that the wedge persists for more than four quarters. This discrepancy is due to the inability of the monetary authority to stabilize the economy under CPI inflation targeting. Indeed, in the baseline version of the model, only domestic prices are rigid. The optimal policy, therefore, involves targeting domestic-price inflation. As explained above, such a policy sustains the flexible-price allocation. A regime that targets CPI inflation, on the other

[10]The nominal and and the real exchange rate exhibit identical responses because the latter is computed using the CPI, which is completely stabilized under strict CPI inflation targeting.

hand, stabilizes a combination of domestic and import prices. As Figure 1 shows, however, domestic prices are not completely stabilized under this policy, which in turn causes output to depart from its efficient response. The reason for this departure is the exaggerated (and, hence, inefficient) response of the real exchange rate, which appreciates by more than it would have under the efficient allocation.

Next, consider the case with zero pass-through of the oil-price increase ($\chi = 0$). Following the shock, output and consumption decrease for several periods before returning to their pre-shock levels, whereas investment rises on impact and converges to its steady-state level from above. In all cases, however, the magnitude of the response is substantially smaller than under complete pass-through. The reason is obvious: a zero-pass-through policy implies that the firms' real cost of acquiring oil is unaffected by the oil-price increase if not for changes in the real exchange rate. As a result, input demand and production fall only slightly in the short run relative to the case with complete pass-through case.[11] Given that the oil-price increase is not passed through to CPI inflation, the nominal (and the real) interest rate need not increase by as much as in the complete-pass-through case. In fact, the nominal interest rate remains virtually unchanged in this case, leading to roughly constant nominal and real exchange rates.

The figure shows that the zero-pass-through policy goes a long way toward stabilizing domestic prices. Yet, the response of output deviates markedly from the efficient one. In other words, targeting CPI inflation stabilizes domestic prices but destabilizes output. The reason for this result is that the flexible-price allocation is not attainable when there is incomplete pass-through of oil prices, due to the distortionary effects of the subsidy involved. Higher degrees of pass-through (that is, higher values of χ) have two offsetting effects on output. On the one hand, higher pass-through entails smaller distortions to the economy, and this effect tends to bring output closer to its efficient level. On the other hand, when pass-through is high, targeting CPI inflation leads to inefficiently large swings in the real exchange rate, which tends to destabilize output. This discussion suggests that to determine

[11] It is worth emphasizing, however, that the effects of an oil-price increase are not permanently smaller (in absolute value) under zero than under complete pass-through. Because the government must raise taxes to finance any oil-price subsidy given to firms, deviating from complete pass-through amounts to transferring the higher cost of oil from firms to households. The muted effects under zero pass-through therefore simply reflect the households' ability to smooth consumption over time via borrowing and lending. Eventually, for sufficiently long horizons, the effects of the oil-price shock will be larger under incomplete than under complete pass-through.

the optimal degree of pass-through, the stabilizing benefits of the government's intervention have to be weighed against the distortionary costs of the implied subsidy. Given that, under CPI inflation targeting, both zero and complete pass-through lead to significant departures from the efficient allocation, it is likely that the optimal pricing rule involves a partial degree of pass-through in this case. This conjecture will be formally verified in Section 5.

4.2 Fixed exchange rate regime

Figure 2 shows the dynamic responses to an oil-price shock under a fixed exchange rate regime. Under complete pass-through, the economy's response coincide with the efficient allocation. In order to understand this result, it is useful to recall that the efficient allocation requires that the markup of domestic intermediate good producers be constant in each period. In order to achieve this outcome, the monetary authority needs to completely stabilize domestic prices, or alternatively, the nominal marginal cost of domestic good producers. Because those firms also sell abroad and take export prices as given, their marginal cost is tied down by the nominal exchange rate (assuming that the world price, P^*, remains constant). Hence, the efficient allocation involves stabilizing the nominal exchange rate.[12] Note, however, that efficiency requires that the real exchange rate appreciates despite the fixity of the nominal exchange rate. Under the efficient allocation, the CPI does move, which allows the nominal and the real exchange rate to have distinct dynamics.

Under zero pass-through, both domestic prices and the CPI are stabilized. Domestic prices are stabilized because the monetary authority fixes the nominal exchange rate and thus the nominal marginal cost of domestic intermediate-good producers. The stabilization of the CPI originates from two sources: the zero-pass-through of the oil-price increase and the fixity of the nominal exchange rate, which implies that both components of the price of the non-oil input are stabilized. The constancy of the CPI in turn implies that the real

[12] This discussion suggests that, from a welfare standpoint, a fixed exchange rate regime dominates strict CPI inflation targeting. This result seems to contradict the conclusion reached by Devereux, Lane, and Xu (2006) who show that fixing the nominal exchange rate greatly destabilizes the economy in response to external shocks. This different conclusion stems from differences in the modelling assumptions. In the model developed by Devereux, Lane and Xu, there is a traded and a non-traded good, which are produced by distinct production units. A crucial assumption in their setting is that the traded good is not sold on the domestic market, which implies that the nominal marginal cost (and therefore the price of the non-traded good) is not pinned down by the nominal exchange rate. Under these conditions, a peg prevents the real exchange rate from playing its role of a shock absorber, so that the full impact of the shocks is passed through to domestic output.

exchange rate inherits the fixity of the nominal exchange rate. As is apparent in Figure 2, the lack of flexibility of the real exchange rate leads output to deviate substantially from its efficient level. Given that the equilibrium allocation under a fixed exchange rate regime and complete pass-through replicates the efficient allocation, any policy that seeks to limit the degree of pass-through of oil prices will necessarily be welfare deteriorating. Formal welfare evaluation, performed in Section 5 will confirm this intuition.

5. Welfare Analysis

In this section, we study the welfare implications of the government's intervention to limit the degree of pass-through of oil prices. That is, we seek to (*i*) determine whether, and under which circumstances, such a policy is optimal, and (*ii*) evaluate the welfare gain associated with the optimal policy relative to full pass-through. The optimal policy will be defined as the one that maximizes welfare within the class of pricing rules given by (31). Finding the optimal policy, therefore, amounts to selecting the value of χ that maximizes the mean of the representative household's lifetime utility. Formally, this problem is written as follows:

$$\max_{\chi} E\left\{u\left(c_t, h_t\right)\right\}. \tag{33}$$

To solve this problem, we compute a second-order approximation of the model's equilibrium conditions and the utility function. Figure 3 depicts our welfare metric for different values of χ under CPI inflation targeting and a fixed exchange rate regime.

First, consider the case with CPI inflation targeting. The upper panel of Figure 3 shows that welfare is a non-monotonic function of pass-through, reaching its maximum when $\chi = 0.18$. Hence, both complete and zero pass-through are sub-optimal. Instead, the welfare-maximizing policy involves partially stabilizing the domestic price of oil. By assigning a relatively large weight to the lagged domestic price of oil, the optimal pricing rule implies a significant amount of inertia in oil prices.

How large is the welfare gain associated with the optimal pricing rule relative to a complete-pass-through policy? As is standard in the literature, we measure the welfare gain by means of the compensating variation in consumption, that is, the percentage change in consumption under complete pass-through that would give households the same unconditional expected utility as under the optimal pricing rule. The compensating variation is defined as follows:

$$E\left\{u\left(c_t(1+\zeta),h_t\right)\right\} = E\left\{u(\tilde{c}_t,\tilde{h}_t)\right\}, \tag{34}$$

where variables without tildes refer to variables under complete pass-through, and variables with a tilde refer to variables under the optimal pricing rule.

The fourth column of Table 3 shows that the fraction of permanent consumption that must be offered to households to make them as well of under complete pass-through as under the optimal pass-through policy is less than 0.01 per cent. This gain is clearly very small by any conventional standard. Therefore, opting for complete pass-through of oil prices, albeit sub-optimal, does not entail important welfare costs in the baseline model.

The bottom panel of Figure 3 shows that under a peg, welfare increases unambiguously with χ, although it flattens significantly for large value of χ. That is, the higher the degree of pass-through, the better off the economy. Hence, the optimal policy is to let changes in the world price of oil be fully passed through to domestic prices. This result should not come as a surprise: the impulse-response analysis in Section 4.2 shows that, conditional on oil-price shocks, the fixed exchange rate regime replicates the efficient allocation under complete pass-through. Therefore, any attempt to limit the degree of pass-through must be welfare deteriorating in this case. Because complete pass-through is optimal, the compensating variation in consumption is obviously nil, as shown in the last column of Table 3.

In sum, our analysis suggests that, to the extent that monetary policy is capable of stabilizing the economy, government intervention in the oil market should be avoided. On the other hand, when complete stabilization is not attainable, as is the case under CPI inflation targeting, the government can improve social welfare by limiting the degree of pass-through of oil prices. We find, however, that the welfare gain from pursuing such a policy is negligible.

6. Sensitivity Analysis

We now discuss the sensitivity of our results to changes in the assumptions underlying the baseline model. More specifically, we consider (*i*) alternative values of the price-elasticity of oil demand, (*ii*) alternative shares of oil in production, and (*iii*) different degrees of financial frictions, and (*iv*) the case of sticky import prices,

6.1 Price-elasticity of oil demand

We begin our sensitivity analysis by studying the effect of varying the price-elasticity of oil demand, ν. Figure 4 depicts the optimal degree of pass-through as a function of this elasticity. The top panel of the figure shows that, under strict CPI inflation targeting, the optimal degree of pass-through increases with the elasticity of demand for oil. This result is quite intuitive: higher values of ν imply a larger drop in the quantity of imported oil following the oil-price increase, inducing firms to substitute non-oil inputs for oil.[13] Greater substitutability tends to mitigate the adverse effects of the oil-price shock. At the same time, it implies that, everything else being equal, the welfare cost of a given subsidy is larger, which in turn weakens the argument for a price-based stabilization policy.

The top panel of Figure 4 shows that as the elasticity of demand approaches 0.5, the optimal degree of pass-through tends towards 100 per cent. Such a high elasticity, however, is more in line with the long-run estimates reported by existing empirical studies. Values of ν that fall in the range of available short-run estimates imply that the welfare-maximizing extent of pass-through is less than 30 per cent. The welfare gain associated with such a policy, however, is even smaller than in the baseline case, as indicated by the value of the compensating variation in consumption of 0.006 per cent.

The bottom panel of Figure 4 shows that, under a fixed exchange rate regime, complete pass-through of oil prices is always optimal regardless of the degree of responsiveness of oil demand to oil-price increases. This is because the fixed exchange regime allows to replicate the efficient allocation for any value of the elasticity of demand. As a result, the compensating variation in consumption associated with the complete-pass-through policy is always zero, as shown in Table 3.

6.2 Share of oil in production

Next, consider the impact of varying the share of oil in production. As stated above, in net oil-importing industrialized countries, oil imports represent a smaller percentage of GDP than in the median developing or emerging market economy. Indeed, the average share of oil imports in GDP in major industrialized countries was less than 2 per cent in 2004, although it is likely to have increased lately. On the other hand, several developing countries

[13] Note that ν is also the elasticity of substitution between oil and non-oil inputs.

are heavily dependent on oil, with an oil-import bill that was already above 6 per cent of GDP in 2004 (e.g., Kenya, Seychelles, and Sierra Leone). In order to account for this heterogeneity across countries, we consider values of ϕ ranging from 0.02 to 0.06.

Obviously, the more oil-intensive the production process, the larger the impact of an oil-price increase on economic activity. This statement does not imply, however, that there is greater scope for stabilization. Such would be the case only if the economy deviates further from the efficient allocation as the share of oil in production becomes larger. Figure 5 shows that this is indeed the case under strict CPI inflation targeting. The top panel of the figure indicates that optimal degree of pass-through of oil prices is a decreasing function of the oil share. The model implies, however, that the optimal pass-through falls by only 10 percentage points as the oil share increases from 0.02 to 0.06. More importantly, the welfare gain associated with the optimal pricing rule is still tiny regardless of the oil share in production: Even when this share is as high as 0.06, consumption would have to permanently increase by less then 0.03 per cent in the model with complete pass-through in order for consumers to be as well off as with the optimal pricing rule.

Again, under a fixed exchange rate regime, the ability of the monetary authority to replicate the efficient allocation is independent of the weight of oil in production. Therefore, complete pass-through continues to be optimal under alternative values of the oil share, as illustrated in the bottom Panel of Figure 5, while the corresponding compensating variation in consumption continues to be zero.

6.3 Financial frictions

In the third sensitivity experiment, we study the effect of varying the degree of financial frictions, as measured by the portfolio-adjustment-cost parameter, ψ_b. Financial frictions impede access to international financial markets, thus preventing agents from smoothing fluctuations in their income as much as they would like in response to the oil-price shock. This situation characterizes a number of heavily indebted poor countries, which are plagued by their lack of solvency. Larger portfolio-adjustment costs obviously entail larger welfare losses at any given level of pass-through of oil prices. The direction in which these costs alter the optimal degree of pass-through, however, is ambiguous and depends on the way in which they affect the trade-off between the stabilizing benefit of government's intervention and the inherent welfare loss.

The top panel of Figure 6 shows that the relationship linking the optimal degree of pass-through to the degree of financial frictions is rather flat. Even very large (and even implausible) values of the parameter ψ_b yield an optimal pass-through of roughly 15 per cent, just 5 percentage points below the optimal level of pass-through in the baseline model. Furthermore, the welfare gain associated with the optimal pricing rule is almost unchanged as one moves from almost zero to prohibitive portfolio-adjustment costs.

On the other hand, the degree of financial frictions does not alter the mechanism whereby the fixed exchange rate regime yields the efficient allocation of resources, which implies that complete pass-through of oil prices is optimal irrespective of the value of ψ_b.

6.4 Sticky import prices

When import prices are sluggish (that is, when ψ_m is strictly positive), exchange rate pass-through to import prices becomes incomplete and, as a result, the law of one price no longer holds for imported goods. Import-price stickiness also means that the non-oil terms of trade vary endogenously in response to oil-price shocks. This in turn implies that, except in special cases, the flexible-price allocation is no longer optimal, because the monetary authority can strategically affect the terms of trade in a way that improves welfare.[14]

To introduce stickiness in import prices, we set $\psi_m = 100$. Figure 7 shows welfare as a function of pass-through in this case. Our results indicate that under strict CPI inflation targeting, the optimal degree of pass-through is about 10 per cent. Hence, with sticky import prices, the optimal pricing rule involves a higher degree of stabilization of the domestic price of oil compared with the case of flexible import prices. As the top panel of Figure 7 shows, welfare decreases rapidly as pass-through increases. This is reflected in the size of the variation in consumption required to leave agents indifferent between complete pass-through and the optimal pricing rule, which is more than 12 times larger than in the baseline case. These results can be explained as follows. Under sticky import prices, the appreciation of the real exchange rate does not translate into cheaper foreign intermediate goods for the producers of the non-oil good (as would be the case under flexible import prices). As a result, the negative impact of the oil-price increase is much larger than in the

[14] See, for example, Corsetti and Pesenti (2001), Benigno and Benigno (2003) and Monacelli (2005).

baseline model at any given level of pass-through.

In the case of a fixed exchange rate regime, on the other hand, welfare under sticky import prices is exactly identical, at any value of χ, to what is obtained under flexible import prices. This result, which can be verified by comparing the bottom panels of Figures 3 and 7, emanates from the fact that under fixed exchange rates, the nominal marginal cost of importing firms is constant, which also means that nominal import prices are constant. Therefore, the magnitude of the price-adjustment-cost parameter, ψ_m, is irrelevant to the dynamics of the economy. In turn, this implies that our results regarding the optimal degree of pass-through and the associated welfare gain are identical to those pertaining to the baseline model.

7. Conclusion

This paper has shown that, to the extent that monetary policy is unable to stabilize the economy in the wake of an oil-price shock, the government of an oil-importing country can find it optimal to limit the degree of pass-through of oil prices to domestic consumers. This would be the case of economies where the monetary authority strictly targets CPI inflation. On the other hand, countries where the nominal exchange rate is pegged (to the currency in which oil prices are denominated) have no incentive to deviate from the full-pass-through policy. Whenever the optimal pricing rule requires deviating from full pass-through, we find, however, that the resulting welfare gain is negligible.

Our framework lends itself to a number of potentially interesting extensions. One would be to add wage stickiness to the model. Real wage rigidity would render the adjustment of the economy to oil-price shocks more painful than with a perfectly competitive labor market, because the households' unwillingness to accept wage cuts would imply a larger drop in labor demand, employment and production, thus amplifying the welfare loss associated with sub-optimal pricing policies. Second, it would be worthwhile to depart from the Ricardian environment assumed in this paper, and to allow for the possibility that the government relies on debt rather than taxes to finance fuel subsidies. This assumption is certainly more realistic in countries where the tax base is narrow. Escalating oil prices would in this case require increasingly large subsidies, leading to potentially unsustainable fiscal imbalances and increasing the likelihood that the government's borrowing constraint becomes binding.

A third possible extension would be to allow for heterogeneity across agents in terms of wealth and/or liquidity constraints. This setup would enable one to study the distributional effects of government intervention.

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Appendix

The model's equations are:

$$
\begin{aligned}
\lambda_t &= c_t^{-\frac{1}{\gamma}}, \\
w_t &= \frac{\varpi\,(1-h_t)^{-1}}{\lambda_t}, \\
\lambda_t &= \beta R_t E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right), \\
\lambda_t &= \beta R_t^*\left(1+\psi_b\left(b_t^*-b^*\right)\right)^{-1} E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\frac{e_{t+1}}{e_t}\right), \\
\lambda_t &= \frac{\beta E_t\{\lambda_{t+1}[1+q_{t+1}-\delta+\psi(\frac{i_{t+1}}{k_{t+1}}-\delta)+\frac{\psi}{2}(\frac{i_{t+1}}{k_{t+1}}-\delta)^2]\}}{1+\psi(\frac{i_t}{k_t}-\delta)}, \\
k_{t+1} &= (1-\delta)k_t+i_t, \\
y_t &= \left[\phi^{\frac{1}{\nu}}(y_t^o)^{\frac{\nu-1}{\nu}}+(1-\phi)^{\frac{1}{\nu}}\,(y_t^{no})^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}}, \\
y_t^{no} &= \Gamma(y_t^d)^{\sigma}(y_t^m)^{1-\sigma} \\
y_t^o &= \phi\,(p_t^o)^{-\nu}\,y_t \\
y_t^{no} &= (1-\phi)\,(p_t^{no})^{-\nu}\,y_t, \\
y_t^d &= \sigma\left(\frac{p_t^d}{p_t^{no}}\right)^{-1} y_t^{no}, \\
y_t^m &= (1-\sigma)\left(\frac{p_t^m}{p_t^{no}}\right)^{-1} y_t^{no} \\
y_t &= c_t+i_t+\textit{ all adjustment costs} \\
z_t &= y_t^d+y_t^x, \\
z_t &= A_t k_t^{\alpha} h_t^{1-\alpha}, \\
\xi_t &= p_t^x, \\
w_t &= (1-\alpha)\xi_t\frac{z_t}{h_t}, \\
q_t &= \alpha\xi_t\frac{z_t}{k_t}, \\
b_t^* &= R_{t-1}^*\frac{b_{t-1}^*}{\pi_t^*}+p_t^x y_t^x-p_t^{o*}y_t^o-y_t^m \\
\log(R_t/R) &= \varrho_\pi\log(\pi_t/\pi)+\varrho_e\log(e_t/e)
\end{aligned}
$$

$$
\begin{aligned}
-\theta \frac{\xi_t}{p_t^d} &= (1-\theta)\left[1-\frac{\psi_d}{2}\left(\frac{\pi_t^d}{\pi^d}-1\right)^2\right] \\
&\quad -\psi_d\left[\frac{\pi_t^d}{\pi^d}\left(\frac{\pi_t^d}{\pi^d}-1\right)-\beta\frac{\lambda_{t+1}}{\lambda_t}\frac{\left(\pi_{t+1}^d\right)^2}{\pi_{t+1}\pi^d}\left(\frac{\pi_t^d}{\pi^d}-1\right)\frac{y_{t+1}^d}{y_t^d}\right], \\
\vartheta \frac{s_t}{p_t^m} &= (1-\vartheta)\left[1-\frac{\psi_m}{2}\left(\frac{\pi_t^m}{\pi^m}-1\right)^2\right] \\
&\quad -\psi_m\left[\frac{\pi_t^m}{\pi^m}\left(\frac{\pi_t^m}{\pi^m}-1\right)-\beta E_t\frac{\lambda_{t+1}}{\lambda_t}\frac{\left(\pi_{t+1}^m\right)^2}{\pi_{t+1}\pi^m}\left(\frac{\pi_t^m}{\pi^m}-1\right)\frac{y_{t+1}^m}{y_t^m}\right], \\
p_t^x &= s_t \\
p_t^o &= (1-\chi)\left(p_{t-1}^o/\pi_t\right)+\chi s_t p_t^{o*}, \\
\pi_t &= \frac{P_t}{P_{t-1}} \\
\pi_t^m &= \frac{p_t^m}{p_{t-1}^m}\pi_t, \\
\pi_t^d &= \frac{p_t^d}{p_{t-1}^d}\pi_t, \\
\pi_t^x &= \frac{p_t^x}{p_{t-1}^x}\pi_t, \\
\pi_t^{no} &= (\pi_t^d)^\sigma\,(\pi_t^m)^{1-\sigma} \\
s_t &= \frac{e_t P_t^*}{P_t}.
\end{aligned}
$$

Table 1. **Summary of Available Estimates of Pass-through Coefficients**

	Gasoline		Diesel	
Country	World Bank	Baig et al.	World Bank	Baig et al.
Afghanistan	–	0.23	–	0.82
Albania	–	1.28	–	–
Argentina	0.02	0.09	–	0.83
Armenia	–	0.88	–	1.09
Azerbaijan	–	0.20	–	1.01
Bangladesh	0.79	0.09	0.43	0.43
Brazil	0.64	1.14	0.84	2.92
Bolivia	–	0.21	–	–
Cambodia	1.06	1.36	0.93	1.08
Cameroon	0.91	0.83	0.98	–
Chile	1.15	–	1.11	–
China	0.71	–	0.53	–
Colombia	–	0.74	–	0.65
Congo, D. R. of	–	1.34	–	1.35
Congo, R. of	–	0.43	–	0.39
Dominican R.	–	1.78	–	1.29
Egypt	0.00	0.17	0.00	0.21
Ethiopia	0.48	0.77	0.64	0.75
Gabon	–	0.21	–	0.21
Georgia	–	1.05	–	1.28
Ghana	1.33	1.45	1.21	1.35
Guatemala	0.93	–	0.99	–
Honduras	0.60	–	0.87	–
India	1.25	1.08	0.66	0.72
Indonesia	1.20	0.95	1.02	0.82
Jordan	–	1.03	–	0.79
Kenya	0.97	1.03	0.79	1.06
Kosovo	–	0.90	–	0.93
Kyrgyz R.	0.19	0.48	2.35	0.69
Lao PDR	1.86	1.41	1.35	1.10
Lebanon	–	−0.17	–	–
Madagascar	1.46	–	1.55	–
Malawi	1.14	1.26	1.22	1.53
Malaysia	0.75	–	0.84	–
Mexico	0.15	–	0.11	–
Mozambique	1.10	–	1.01	–
Nicaragua	0.95	–	0.88	–
Nigeria	0.84	–	–	–

Table 1 (Cont.)

Country	Gasoline		Diesel	
	World Bank	Baig et al.	World Bank	Baig et al.
Pakistan	1.98	1.24	0.78	0.75
Peru	–	1.64	–	0.99
Philippines	1.29	1.32	1.30	1.16
Russia	–	0.89	–	1.17
Rwanda	0.98	–	0.76	–
Senegal	–	0.98	–	1.53
Serbia	–	1.41	–	1.45
South Africa	–	1.58	–	1.65
Sri Lanka	1.80	1.17	0.83	0.52
Tanzania	1.57	1.23	1.52	1.10
Thailand	1.37	–	1.15	–
Tunisia	0.53	–	0.66	–
Turkey	–	2.30	–	2.78
Uganda	1.23	1.41	1.14	1.05
Ukraine	–	0.74	–	1.37
Uruguay	–	1.40	–	1.14
Venezuela	0.00	–	0.00	–
Vietnam	1.03	–	0.70	–
Yemen	–	0.47	–	0.34
Zambia	2.20	1.53	1.93	1.30
Industrialized countries				
Canada	1.06	–	0.96	–
France	1.30	–	1.07	–
Germany	1.20	–	0.98	–
Japan	0.85	–	0.65	–
United Kingdom	1.25	–	1.08	–
United States	1.02	0.89	1.05	–

Notes: Pass-through is computed as the ratio of the (absolute) change in domestic retail prices (measured in local currency) to the (absolute) change in the international price (converted to local currency). Estimates reported by the World Bank (2006) are for the period 2004:1 – 2006:04. Those reported by Baig et al. (2007) are for the period end-2003 – 2006:06

Sources: World Bank (2006) and Baig et al. (2007).

Table 2. Baseline Calibration

Description	Parameter	Value
Structural parameters		
Discount factor	β	0.99
Elasticity of intertemporal substitution	γ	0.5
Elasticity of output with respect to capital	α	0.36
Depreciation rate of capital	δ	0.025
Elasticity of substitution between domestic intermediate goods	θ	10
Elasticity of substitution between imported intermediate goods	ϑ	10
Price-adjustment-cost parameter for domestic intermediate goods	ψ_d	100
Price-adjustment-cost parameter for imported intermediate goods	ψ_m	0
Capital-adjustment-cost parameter	ψ_k	30
Portfolio-adjustment-cost parameter	ψ_b	0.0007
Share of oil in production	ϕ	0.04
Price-elasticity of oil demand	ν	0.05
Share of domestic intermediate goods in the non-oil composite good	σ	0.65
Inflation coefficient in the Taylor rule	ϱ_π	$\infty, 0$
Nominal-exchange-rate coefficient in the Taylor rule	ϱ_e	$0, \infty$
Steady-state values		
Ratio of foreign debt to output in the steady state	κ	0.4
Foreign interest rate	R^*	1.008

Table 3. Welfare Results

	CPI inflation targeting			Fixed exchange rate regime		
	$\chi^{optimal}$	Welfare	C.V.	$\chi^{optimal}$	Welfare	C.V.
Baseline model	0.1821	−203.0927	0.0095	1	−203.0779	0
Sensitivity analysis						
Price-elasticity of oil demand						
$\nu = 0.1$	0.2764	−203.0750	0.0062	1	−203.0561	0
$\nu = 0.2$	0.4731	−203.0363	0.0027	1	−203.0131	0
$\nu = 0.3$	0.6628	−202.9953	0.0011	1	−202.9701	0
$\nu = 0.4$	0.8027	−202.9532	0.0005	1	−202.9271	0
$\nu = 0.5$	0.8971	−202.9107	0.0001	1	−202.8841	0
Share of oil in production						
$\phi = 0.02$	0.2654	−202.8708	0.0018	1	−202.8661	0
$\phi = 0.03$	0.2111	−202.9819	0.0048	1	−202.9726	0
$\phi = 0.05$	0.1641	−203.2033	0.0154	1	−203.1819	0
$\phi = 0.06$	0.1520	−203.3135	0.0227	1	−203.2846	0
Portfolio adjustment costs						
$\psi_b = 0.001$	0.1802	−203.0891	0.0095	1	−203.0744	0
$\psi_b = 0.01$	0.1627	−203.0810	0.0099	1	−203.0670	0
$\psi_b = 0.1$	0.1478	−203.0796	0.0104	1	−203.0662	0
$\psi_b = 1$	0.1451	−203.0792	0.0105	1	−203.0661	0
Sticky import prices	0.1046	−203.0963	0.1240	1	−203.0779	0

Note: C.V. denotes the compensating variation in consumption, ζ, in percentage.

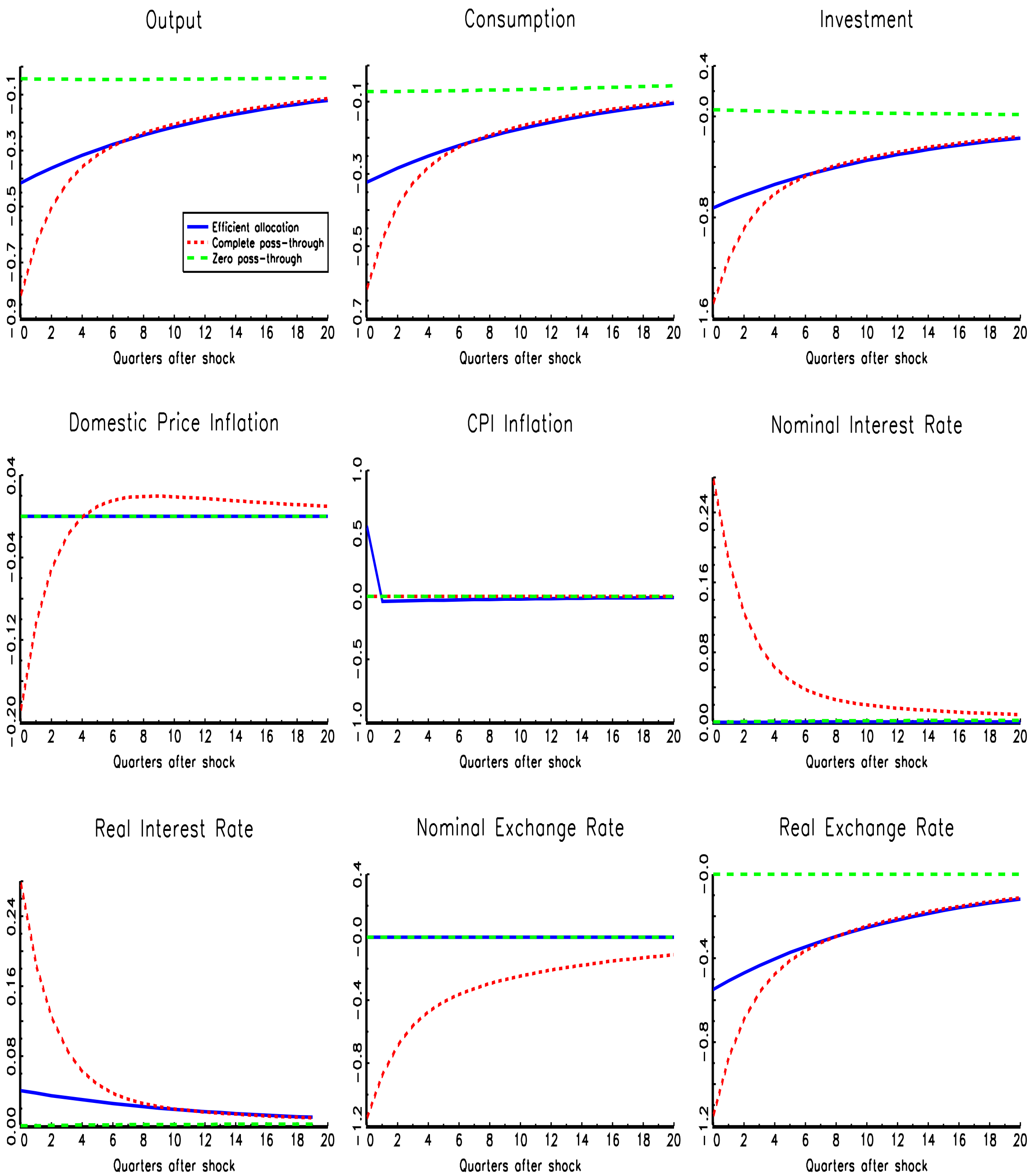

Figure 1: Impulse responses to a 13.7 per cent oil-price increase under strict CPI inflation targeting.

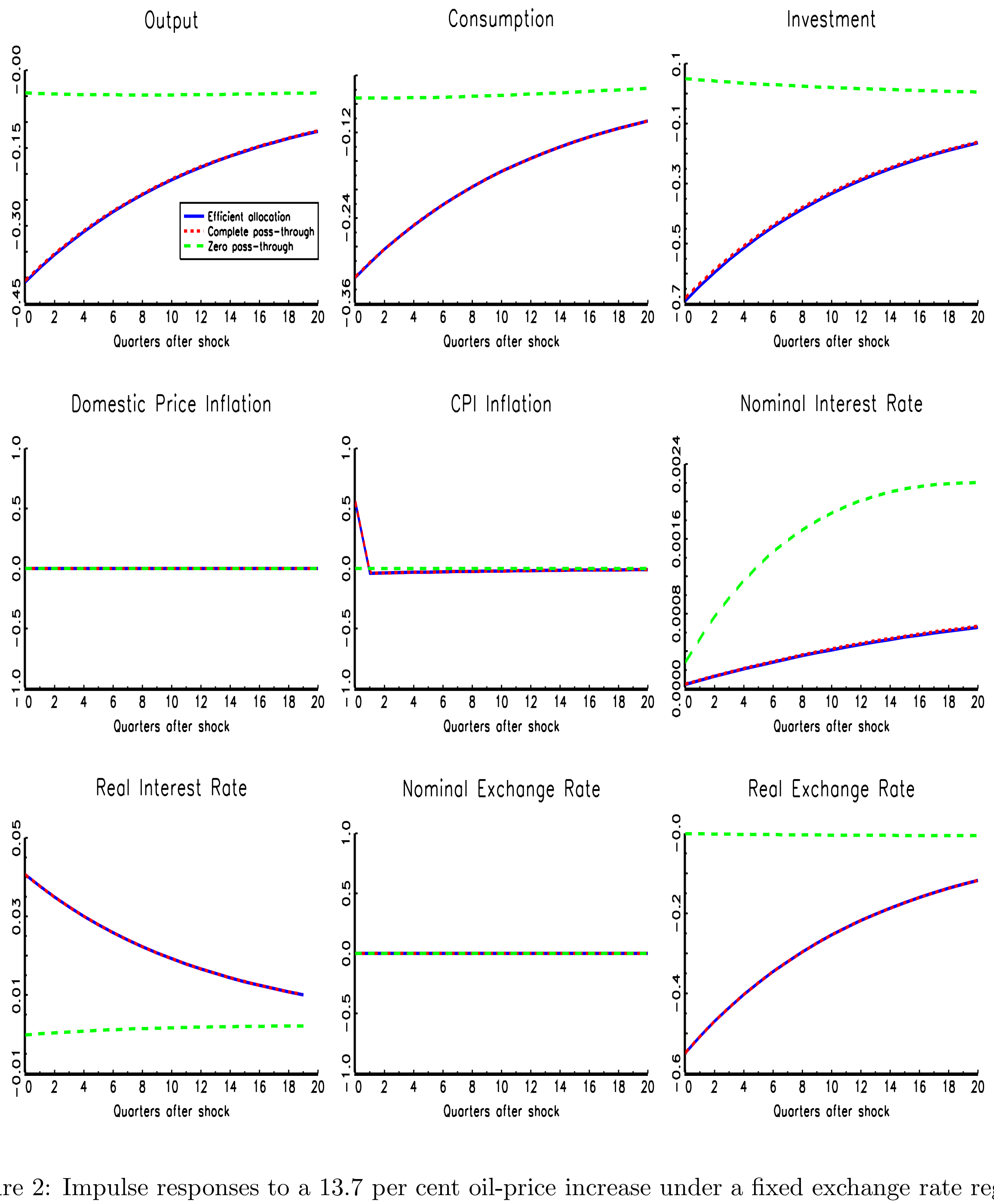

Figure 2: Impulse responses to a 13.7 per cent oil-price increase under a fixed exchange rate regime.

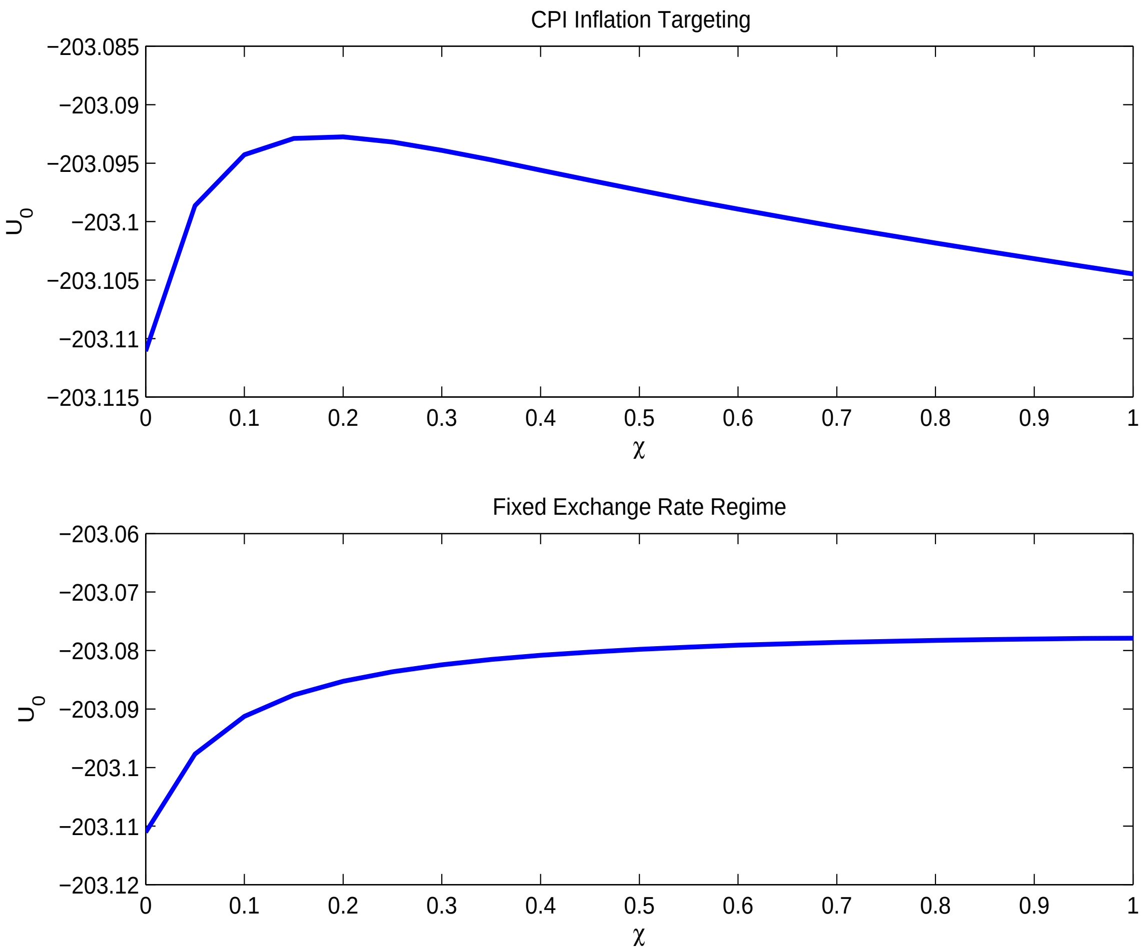

Figure 3: Welfare for different degrees of pass-through.

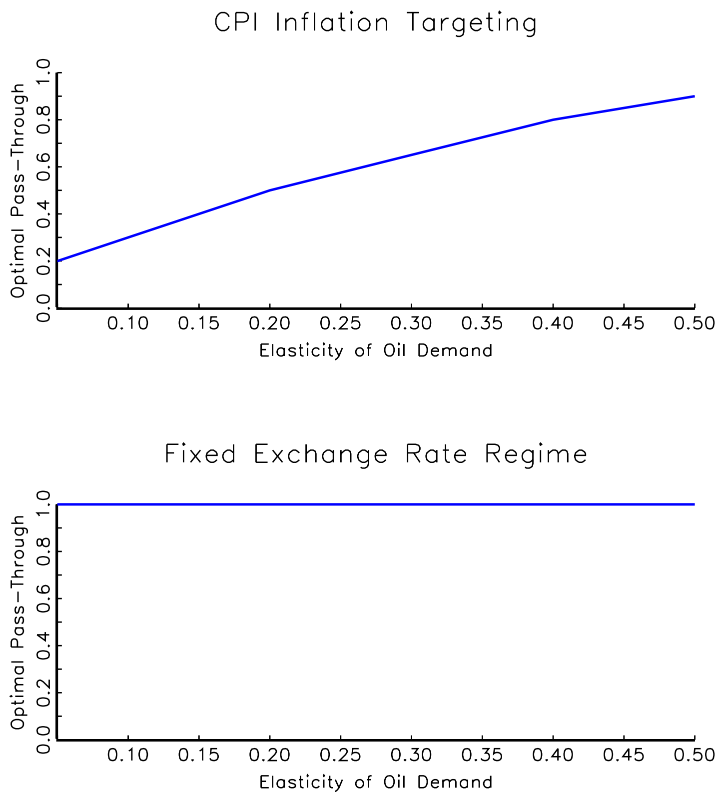

Figure 4: Sensitivity anlaysis: Optimal pass-through as a function of the price-elasticity of oil demand, ν.

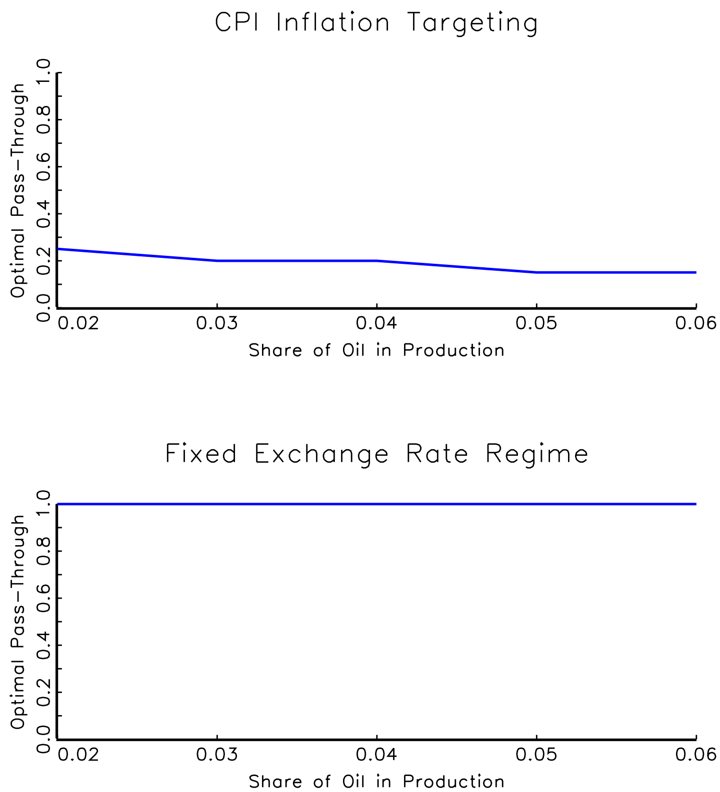

Figure 5: Sensitivity anlaysis: Optimal pass-through as a function of the share of oil in production, ϕ.

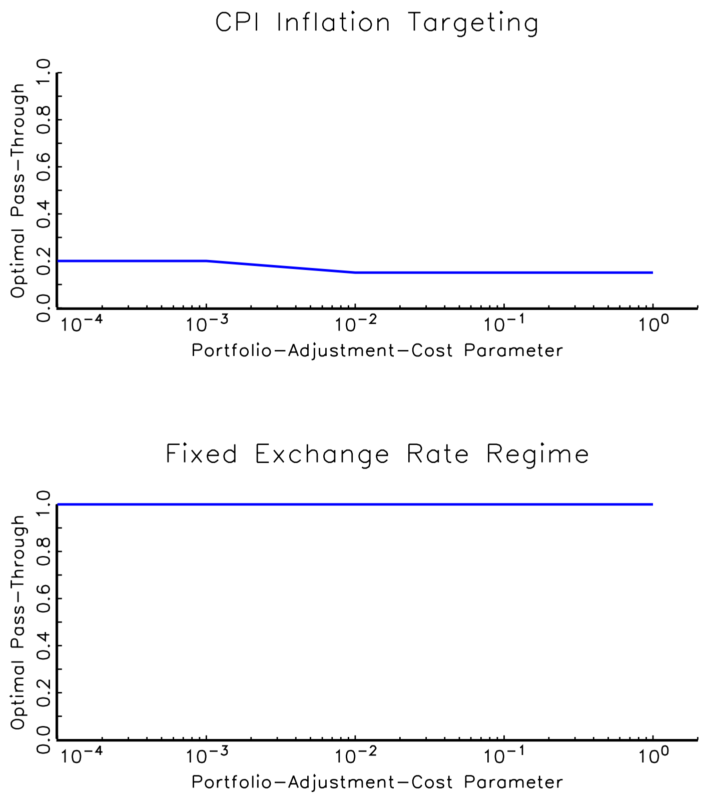

Figure 6: Sensitivity anlaysis: Optimal pass-through as a function of the degree of financial frictions.

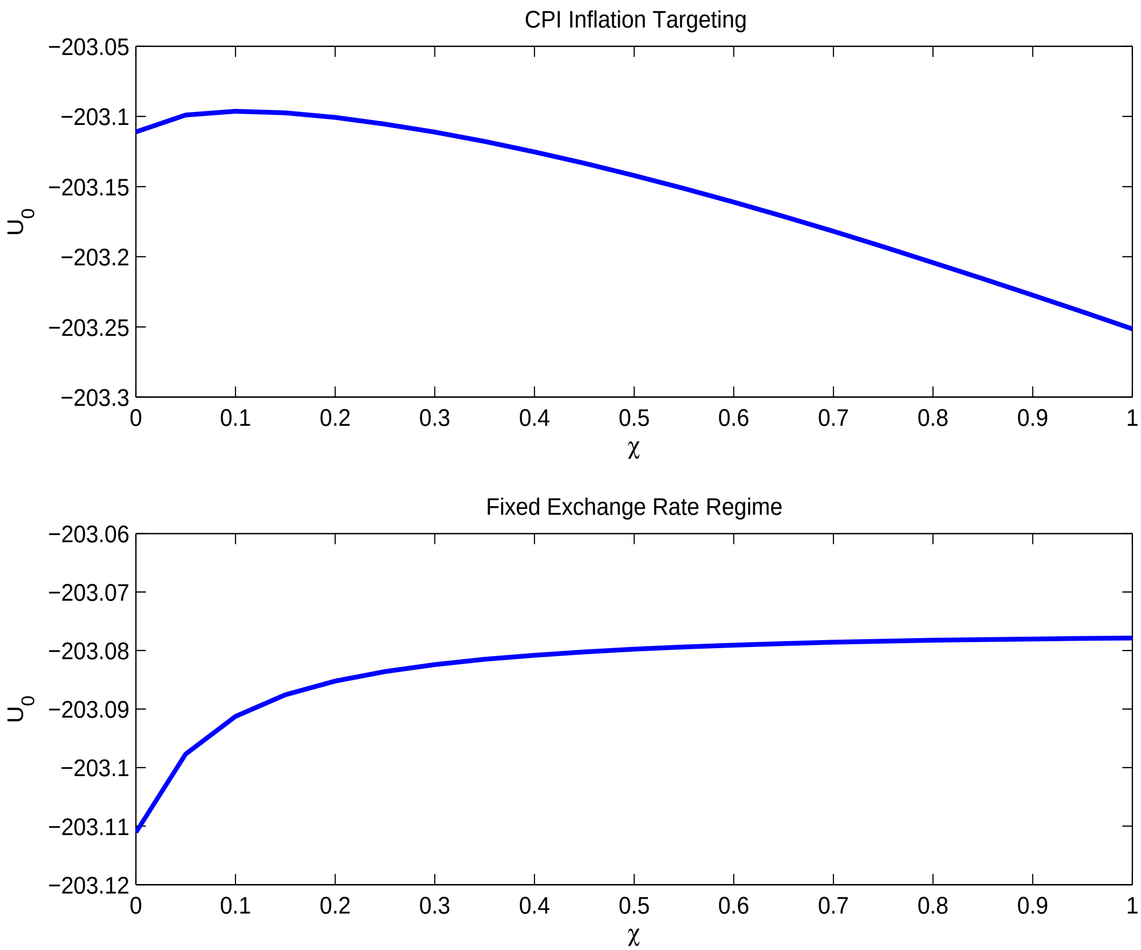

Figure 7: Sensitivity anlaysis: Welfare for different degrees of pass-through under sticky import prices.