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The role of the terms of trade in the trade channel of transmission of oil price shocks

The role of the terms of trade in the trade channel of propagation of oil price shocks

Alessandro Maravalle*

Abstract

This paper highlights the role of the terms of trade in the trade channel of propagation of oil price shocks both empirically and theoretically. Empirically, I show that oil price shocks have a large, persistent and statistically significant impact on the US terms of trade. Theoretically, I add oil in the model by Corsetti and Pesenti (2005) and analyse under what conditions the terms of trade plays a relevant role in the international transmission of oil price shocks. With nominal price rigidities and full exchange rate pass-through positive oil price shocks depreciate the currency of the oil importing country. The subsequent negative wealth effect adds to the recessive effect of the supply channel and may strongly reduce the consumption in the oil importing country economy. Without exchange rate pass-through oil shocks transmit to the economy only through the supply channel. The model suggests that a change in the exchange rate pass-through might contribute to explain the evidence of a weaker impact of oil price shocks on the macroeconomic activity in recent times.

Keywords: oil price shocks; macroeconomic interdependence; exchange rate pass-through; propagation; transmission.

JEL classifications: F31, F41, Q43.

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1 Introduction

The oil literature has a hard time to match the evidence of a negative correlation between the macroeconomic performance of oil-importing countries and oil price shocks with empirically sound theoretical mechanisms of propagation of oil price shocks. The empirical literature has provided quantitative measures of the impact of oil price shocks on macroeconomic variables such as the growth rate of GDP and the inflation rate (see, i.e., Hamilton 1983, Leduc and Sill 2004), employment (see, i.e., Lee and Ni 2002, Davis 1987), the stock market (Kilian and Park 2009), the terms of trade (Backus and Crucini 2000) and external balances (see, i.e., Kilian et al 2009). The theoretical literature, in an attempt to explain this evidence has investigated both demand and supply mechanisms of propagation of oil shocks to the economic activity.[1]

Recent contributions of the literature have stressed that the demand channels, which operate through a reduction of the demand for goods and services other than oil, are the key to explain the impact of oil price shocks to macroeconomic performance (Nordhaus 2007, Hamilton 2008, Kilian 2008). This paper follows this direction and focuses on the trade channel of transmission of oil price shocks, which emphasizes the role of changes in the relative prices and quantities of imports and exports in the propagation of oil price shocks to the economy. In particular, as the dollar share of oil imports in total imports is far larger and volatile than the dollar share of oil expenditures in total output, data point out the potential relevance of the terms of trade in the mechanism of adjustment to oil price shocks.[2]

Firstly, I provide empirical evidence that oil price shocks cause large variations in the terms of trade of the US, the most important oil-importing country. To this purpose, I follow the methodology suggested by Kilian and Vigfusson (2009) that allows me to obtain consistent estimates of the response of the terms of trade to oil price shocks independently of the presence of asymmetric effects of oil price increases and decreases (see, i.e., Mork 1989, Hooker 2002, Kilian and Vigfusson 2009). My main result is that a positive oil price shock has a large, persistent and statistically significant impact on the US terms of trade. I also report limited evidence of asymmetric effects of oil price shocks on the US terms of trade by mean of an impulse-response based test of symmetry. Finally, I show that the response of the terms of trade to oil price shocks increases more than proportionally with the size of the shock.

[1] The literature on the supply and demand mechanisms of propagation of oil shocks to the economy is far too vast to be surveyed here. Some of the seminal papers are Hamilton 1988 and 2008, Bernanke 1983, Davis 1987, Davis and Haltwanger 2001, Bresnahan and Ramey 1993, Bernanke et al 1996, Hamilton and Herrera 2004, Kim and Loungani 1992, Rotemberg and Woodford 1996, Atkenson and Kehoe 1999 and Finn 2000.

[2] Complementary to the trade channel there is another international channel of adjustment to oil price shocks: the financial or valuation effect. The valuation channel works through changes in the total asset returns differentials. On the role of the valuation effect in the external adjustment of economies see Ghironi et al. (2007), Lane and Milesi Ferretti (2007), Gourinchas and Rey (2007) and Deveraux and Sutherland (2008).

Secondly, I analyse the theoretical conditions that permit positive oil price shocks to produce, through the trade channel, a large negative impact on the economy of oil importing countries. To this purpose, I add oil in the production to the two-country general equilibrium model by Corsetti and Pesenti (2005) and use it to analyse the international transmission of oil price shocks under different price regimes and financial autarky. With respect to early (see, i.e., Fried and Schulze 1975, Dohner 1981 and Bruno and Sachs 1985) and recent (see, i.e., Bodenstein et al 2007, Backus and Crucini 2000) theoretical analysis of the trade channel of adjustment to oil shocks my contributions are the following. The model highlights the role of the degree of exchange rate pass-through in the propagation mechanism of oil price shocks. A positive oil price shock produces a trade imbalance that, with nominal price rigidities and full exchange rate pass-through, forces the currency of the oil importing country to depreciate to restore the balance. As a consequence of the depreciation, the oil importing country suffers a negative wealth effect and the oil exporting country a positive wealth effect, so that the terms of trade redistributes asymmetrically the cost of adjustments to positive oil price shocks in favor of the oil exporting country. This transmission mechanism makes it possible for a positive oil price shock to cause to the oil importing country an economic cost that, in terms of consumption loss, is larger than the share of oil costs in total output (supply channel). However, with nominal price rigidities but no exchange rate pass-through, the adjustment mechanism to an oil price shock changes. As export prices grow insensitive to the exchange rate the strenght of the trade channel gets weaker, up to the point in which oil shocks are transmitted to the economy only through the supply channel. A final contribution of the model is to show that the elasticity of most economic variables to oil price shocks is not constant but increases with the size of the shock.

The model suggests that a change in the exchange rate pass-through might contribute to explain the evidence of a weaker impact of oil price shocks on the economic activity in recent times (Hooker 1996 and 2002, Hamilton 1996, Balke et al. 2002, and Blanchard and Galì 2007). In fact, as the degree of exchange rate pass-through also depends on the proportion of firms that serve foreign markets by producing locally (i.e. by foreign direct investments) rather than exporting, the firms' choice of how serving foreign markets may play a role in shaping the strength of the trade channel. From these results it follows that countries more dependent on oil-imports will not necessarily suffer the most in the aftermath of a surge in the price of oil (see, i.e., Bohi 1999).

Section 2 presents evidence and the empirical analysis. Section 3 describes the theoretical model and presents results. Section 4 concludes.

2 Empirical Evidence

The top panel of Figure 1 shows the dynamic of the dollar share of US oil imports in total imports during 1973M1-2010M5 (source OECD). On average, oil imports have represented 16% of all US imports in the period, though this figure has not been constant over time: it averaged 25% in the 70s, bottomed around 10% in the mid 80s and through all the 90s, and then rose again to 15% in the 2000s. The bottom panel of figure 1 reports the dynamic of the real price of oil over the same period. The price of oil is the US crude oil imported acquisition cost by refiners in dollar per barrel (source EIA) and the price deflator is the US CPI (source IFS). In both panels the grey-shaded areas highlight episodes of large and fast variations in the price of oil, mostly related to political events affecting the oil supply.

Two facts emerge from figure 1: oil imports both are a relevant share of US total imports and follow a dynamic similar to that of the real price of oil. Consequently, it i sreasonable to assume that large variations in the price of oil, by changin the US import price index, also affect its terms of trade, that is the ratio between the US export price index and the US import price index.

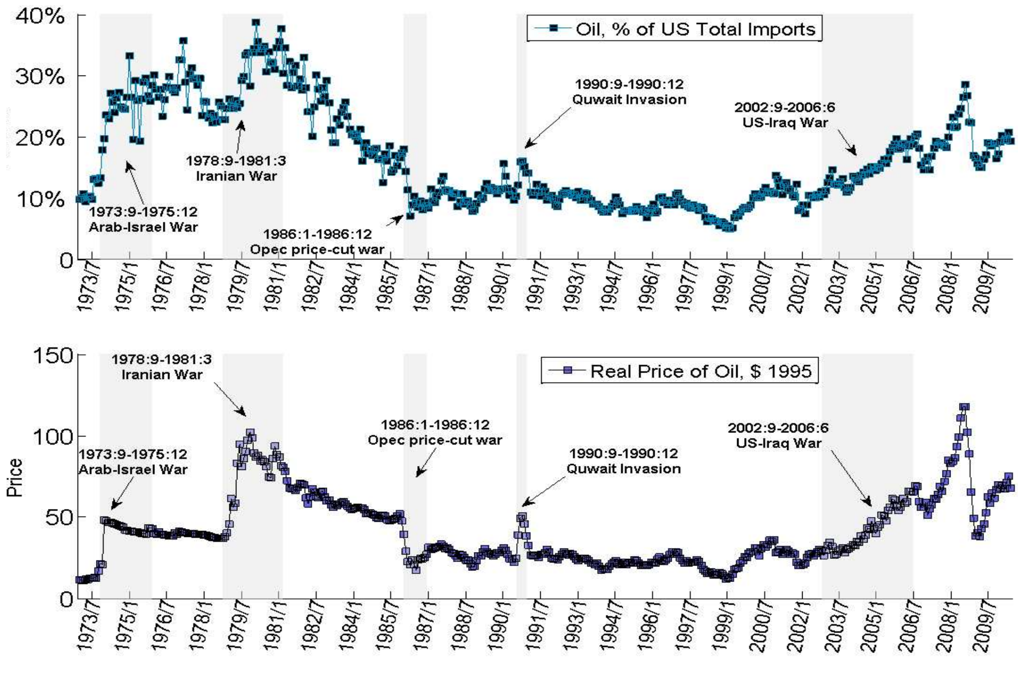

Figure 1 - Oil imports (% of total imports) and the real price of oil in the US.

The terms of trade is the key variable of the trade channel of propagation of oil shocks to the economy. A change in the terms of trade affects the level and the composition of both the aggregate demand and the trade balance, though its final effect on them depends ultimately on factors such as the elasticity of substitution between imports and exports and the degree to which the international financial markets are integrated. The elasticity of substitution between imports and exports dictates by how much a country, after a worsening in its terms of trade, will switch from imported to domestically produced goods. The degree to which the international financial markets are integrated affects the response of the trade balance to a change in the terms of trade, as the trade balance is unaffected by movements in the terms of trade in case of complete markets, while the reaction is maximised in case of financial autarky

Thus, I evaluate if a trade channel is at work after an oil price shock by focusing on the relationship between the real price of oil and the terms of trade.[3]

2.1 Data and Methodology

The price of oil is the US crude oil imported acquisition cost by refiners (dollar per barrel, source EIA). The price index is the CPI all items (index, base year 2005, source IFS). The terms of trade is constructed as the ratio between the US export price index over the US import price index (index number, base year 2005, source IFS). Data are monthly and cover the period 1973:1-2010:5.

In analysing the impact of oil shocks on the terms of trade I assume that the real price of oil is predetermined to the terms of trade.[4] This assumption amounts to imply no contemporaneous impact of terms of trade innovations on the real price of oil, and is regarded as plausible as long as the data frequency are either monthly or quarterly. The use of oil price is sometimes criticised on the ground that this measure does not distinguish among different sources of oil shocks, such as oil supply shocks, specific oil-demand shocks and aggregate demand shock in the industrial commodity market (Kilian 2009). In spite of this shortcoming, its use in the present analysis has two justifications. First, it is always possible to use the price of oil as long as the interest is on the average oil price innovation and not on specific episodes. Second, as the focus of the analysis is on the terms of trade, it is reasonable to assume that oil price shocks both supply and demand driven would produce a similar effect on the terms of trade (in this respect, in Kilian et al 2009 the external adjustment to oil shocks results qualitatively and quantitatively similar to both oil demand and oil supply shocks). In case the source of the oil price shock is the aggregate demand in the industrial commodity market, both the numerator and the denominator of the terms of trade would be affected, so that in theory the terms of trade might go either direction. However, as the role of commodities in US exports is quantitatively limited with respect to the role of oil in US imports, it is plausible to assume that even in presence of a shock to the aggregate demand in the industrial commodities it would be the dynamic of the price of oil to determine the direction of the change in the terms of trade. I also follow Nordhaus (2007)

[3] For an empirical analysis on the external adjustment to oil shocks see Kilian et al. (2009).

[4] The empirical literature has largely debated over both the nature and the identification of oil shocks (see, i.e., Lee et al 1995, Hamilton 1983 and 2003, Barsky and Kilian 2004, Kilian and Vigfusson 2009 and Kilian 2009).

and scale the price of oil for its economic importance, which in this context is represented by the share of oil imports in total imports.

In the econometric analysis I allow for increases and decreases in the price of oil to have different impacts on the terms of trade. Empirical evidence of asymmetric effects of oil price shocks on economic variables dates back to Mork (1989) and Olsen and Mysen (1994), and led to rejecting a linear relationship between oil prices and real activity, arguing that only positive oil price innovations would affect the macroeconomic performance (Mork 1989, Lee et al. 1996, Hamilton 1996). However, Kilian and Vigfusson (2009) challenge this result on the ground that it is based on standard censored VAR regression models that produce biased estimations (see also Rigoboni and Stoker 2007). As an alternative, they propose a different methodology to both control for the asymmetry of oil price shocks and to test it. More specifically, they propose to estimate a bivariate nonlinear structural model and test for symmetry by mean of an impulse-response based test. The structural nonlinear bivariate model is the following:

$$\begin{aligned} x_t &= b_{10} + B_{11}(L)x_{t-1} + B_{12}(L)y_{t-1} + \varepsilon_{1,t} \\ y_t &= b_{20} + B_{21}(L)x_t + B_{22}(L)x_t^+ + B_{23}(L)y_{t-1} + \varepsilon_{2,t} \ , \end{aligned} \quad (1)$$

where x_t is the logarithm of the first difference of the real price of oil, x_t^+ captures only the positive values of x_t, y_t is the logarithm of the terms of trade and the error terms, $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$ are mutually uncorrelated error terms, and $(B_{11}(L), B_{12}(L))$ and $(B_{21}(L), B_{22}(L), B_{23}(L))$ are polynomial matrices of coefficients of the first and second equation.

This model allows for a consistent estimation of the coefficients and the impulse responses regardless of whether the true data generation process of y_t is symmetric or asymmetric. Moreover, an equation-by-equation OLS estimation applies as the errors are mutually uncorrelated by constructions. To compute the impulse-response based test I follow Kilian and compute generalised impulse responses, as nonlinear impulse responses require to take into account both the variability of initial values for $\left(y_t, x_t, x_t^+\right)$ and the variability of future shocks $\{\varepsilon_{1,t}, \varepsilon_{2,t}\}$ (see also Koop et al 1996 and Potter 2000).

2.2 Results

I estimate the model in (1) with 2 lags, as suggested by both the Akaike and Hannan-Quinn information criteria. The impulse response analysis shows that oil price shocks have a large, persistent and statistically significant impact on the US terms of trade. After a one-standard deviation positive oil price shock (6.25%) the terms of trade starts depreciating, reaching the through after three months (top panel of Figure), and then slowly goes back to zero. The response of the terms of trade remains statistically significant (95% confidence interval) up to two and half a year after the shock. The cumulated depreciation of the terms of trade is around 14% 30 months after the shock (bottom panel of Figure 2).

The large effect of oil price shocks on the terms of trade suggests that the terms of trade, and so the trade channel, plays an important role in the transmission mechanism of oil shocks.

To test the presence of asymmetry in the response of the economy to positive and negative oil price shocks I follow Kiliand and Vigfusson (2009) and use an impulse-response based symmetry test rather than a standard slope-based symmetry test. The joint null hypothesis of the impulse-response based symmetry test is that the response of the terms of trade to positive and negative oil price shocks is symmetric up to the pre-specified horizon. Table 1 reports the pre-specified horizon (row 1) and the corresponding p-value of the test statistics under the null hypothesis of symmetry (row 2). The hypothesis of symmetry is rejected at the 5% level at the first two horizons, and at the 10% level at the third horizon (similar results apply when considering a size of the shock of two standard deviations). The test provides a weak support to the hypothesis that oil price shocks might have asymmetric effect on the economy through the terms of trade.

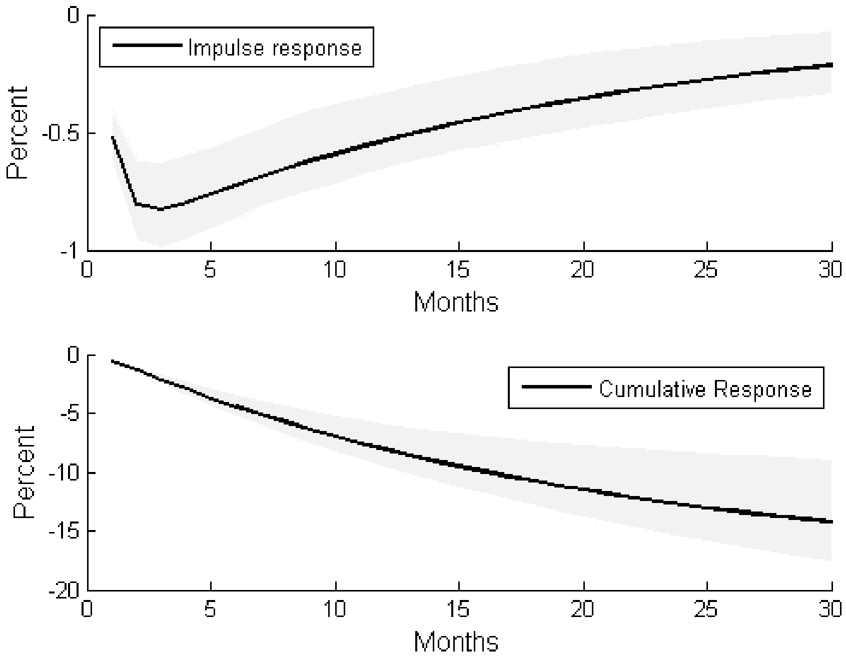

Figure 2 - Impulse (top panel) and cumulated (bottom panel) impulse response of the Terms of trade to a 1-standard deviation positive oil price shock. The shaded areas are the 95% confidence interval.

Horizon	0	1	2	3	4	5	6	7	8	9	10	11
p-values	**0,017**	**0,025**	**0,057**	0,114	0,194	0,293	0,406	0,522	0,634	0,732	0,814	0,877

Based on 1000 simulations. P-values are based on a chi-square with H+1 d.f.

Table 1 - Impulse-Response based Symmetry test

Finally, I investigate whether the response of the terms of trade depends on the size of the oil price shock. However, by rescaling the real price of oil by the oil import share, a greater weight is given to those changes in the real price of oil that occur when the price of oil is high. For oil changes of the same size to be given the same weight in the dataset I have re-estimate model (1) without scaling the real price of oil by the oil import share. Results are qualitatively and quantitatively similar, but they add a further piece of evidence on the effect of oil price shocks on the terms of trade: the response of the terms of trade to an oil price shock appear to increase with the size of the shock (Figure 3).

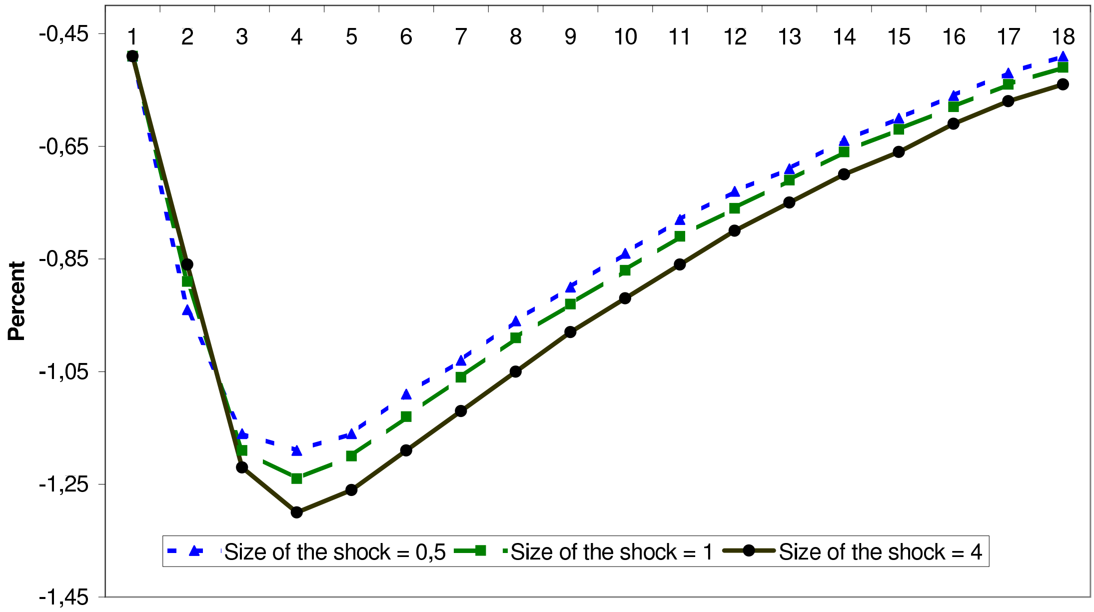

Figure 3 - The response of the Terms of trade to a Positive oil price shock by shock size. All responses have been scaled by the size of the shocks to ensure comparability.

3 Theoretical Analysis

This section presents a theoretical analysis of the trade channel of adjustment to oil price shocks and the role that the terms of trade plays in it. To this purpose, I strictly follow Corsetti and Pesenti (2005) and set up a simple two-country general equilibrium model with imperfect competition in production and incomplete international financial markets. Oil is introduced in the model as a factor of production and is traded from the oil-importing country to the oil-exporting country at a price that is determined exogenously in the currency of the home importing country.[5] The transmission mechanism of oil price shocks to the economy is then analysed under three different price regimes: flexible prices, nominal price rigidity with producer currency pricing (PCP) regime and nominal price rigidities with local currency pricing (LCP) regime.

In the next section I report the main elements of the model and present results. For technical details on how to derive the general equilibrium conditions of the model refer to appendix A. The flexible price equilibrium is derived analytically in appendix B. The equilibrium with nominal price rigidities and Producer Currency Pricing regime is derived in appendix C. The equilibrium with nominal price rigidities and Local Currency Pricing is derived analytically in appendix D.

3.1 The Model

The world consists of two countries of equal size, Home and Foreign, which are identical in any respect apart from three aspects: total factor productivity, monetary policy and oil endowment. In particular, oil is a Foreign specific resource, so that Home is the oil importing country and Foreign is the oil exporting country. Each country is inhabited by a continuum of households and firms: in the Home country households are indexed by $i \in [0,1]$ and firms are indexed by $h \in [0,1]$; in the Foreign country households are indexed by $i^* \in [0,1]$ and firms are indexed by $f \in [0,1]$. In what follows I focus on the Home economy since the Foreign economy can be described symmetrically.

Households Households cannot move across countries, share identical preferences, own domestic firms, derive utility from a final consumption good and disutility from supplying labor services to firms in exchange for wage income. The utility of household i at a given period t is given by:

$$U_t(i) = \ln C_t(i) - kL_t(i).$$

The parameter $k > 0$ determines the disutility of supplying labor and C_t, the final consumption good, is not traded internationally and is produced in a perfectly competitive final good sector by a Cobb Douglas aggregator technology that combines a Home basket of goods $(C_{H,t})$ and a Foreign basket of goods $(C_{F,t}(i))$:

$$C_t = C_{H,t}^{\frac{1}{2}} C_{F,t}^{\frac{1}{2}}.$$

[5] This last assumption aims to mimic the fact that while the price of oil is set in US dollar, the US is an oil-importing country.

$C_{H,t}(i)$ and $C_{F,t}(i)$ are CES baskets of, respectively, Home ($C_t(h,i)$) and Foreign ($C_t(f,i)$) differentiated varieties:

$$C_{H,t}(i)=\left(\int_0^1 C_t(h,i)^{\frac{\theta-1}{\theta}}dh\right)^{\frac{\theta}{\theta-1}} \quad ; \; C_{F,t}(i)=\left(\int_0^1 C_t(f,i)^{\frac{\theta-1}{\theta}}df\right)^{\frac{\theta}{\theta-1}},$$

the parameter $\theta>1$ is the elasticity of substitution across varieties, is equal across countries and is higher than the elasticity of substitution between C_H and C_F that is 1 as C_t is a Cobb Douglas aggregator.

Solving for the expenditure minimization problem I obtain both the price level (P_t) and the households' demand for a specific variety h ($C_t(h,i)$) and a specific variety f ($C_t(f,i)$):

$$\begin{aligned}
P_t &= \frac{1}{2}P_{H,t}^{\frac{1}{2}}P_{F,t}^{\frac{1}{2}}\\
C_t(h,i) &= \frac{1}{2}\left(\frac{P_t(h)}{P_{H,t}}\right)^{-\theta}\left(\frac{P_{H,t}}{P_t}\right)^{-1}C_t\\
C_t(f,i) &= \frac{1}{2}\left(\frac{P_t(f)}{P_{F,t}}\right)^{-\theta}\left(\frac{P_{F,t}}{P_t}\right)^{-1}C_t\\
P_{H,t}C_{H,t} &= P_{F,t}C_{F,t}=\frac{1}{2}P_tC_t,
\end{aligned}$$

where $P_{H,t}$ and $P_{F,t}$ are the price indices of, respectively, $C_{H,t}$ and $C_{F,t}$.

At any period t households face the following budget constraint:

$$\begin{aligned}
P_tC_t(i)+B_t(i)+\varepsilon_tB_t^*(i) \leq W\;\; & {}_tL_t(i)+\Pi_t(i)+B_{t-1}(i)(1+i_{t-1}) \\
& +\varepsilon_tB_{t-1}^*(i)(1+i_{t-1}^*).
\end{aligned} \quad (2)$$

where $P_tC_t(i)$ is nominal spending on the final consumption good, W_t is the nominal wage per unit of labor, $\Pi_t(i)$ is household's share of profit of firms in the intermediate goods sector. Households can purchase two riskless one-period bonds at any period t: $B_t(i)$, which is denominated in home currency and yields a nominal interest i_t at $t+1$, and $B_t^*(i)$, which is denominated in foreign-currency and yields a nominal interest rate i_t^* at $t+1$. The nominal exchange rate, ε_t, expresses how many units of Home currency are exchanged per one unit of Foreign currency.

Households' decisions on consumption and labor supply solve the following utility maximization problem:

$$\underset{C_t(i),L_t(i)}{Max}\,E_t\sum_{t=0}^{\infty}\beta^t\ln(C_t(i))-\kappa L_t(i),$$

subject to the stream of one-period budget constraints defined in (2).

Firms and pricing regimes The intermediate goods market is characterised by monopolistic competition: each firm supplies a single variety h that is an imperfect substitute to all other varieties. Technology is represented by a Cobb Douglas production function that is common across firms:

$$Y_t(h) = Z_t L_t^{\alpha}(h) E_t^{1-\alpha}(h).$$

$Z_t > 0$ is the total factor productivity and is common across Home firms. $\alpha \in (0,1)$ is the share of labor income and is common across firms and countries. $L_t(h)$ and $E_t(h)$ are, respectively, the amount of labor and oil that are employed in the production of variety h at the period t. The aggregate demand of a variety h at time t is:

$$Y_t(h) = \frac{1}{2}\left(\frac{P_t(h)}{P_{H,t}}\right)^{-\theta}\left(\frac{P_{H,t}}{P_t}\right)^{-1} C + \frac{1}{2}\left(\frac{P_t^*(h)}{P_{H,t}^*}\right)^{-\theta}\left(\frac{P_{H,t}^*}{P_t^*}\right)^{-1} C^*. \quad (3)$$

Any firm sets two prices for its variety h, one in the Home market and the other in the Foreign market, to maximize its profit function $\Pi_t(h)$:

$$\underset{P_t(h),\varepsilon_t^{\phi}P_t^*(h)}{Max} \quad \Pi_t(h) = (P_t(h) - MC_t(h)) \int_0^1 C_t(h,i)di + (\varepsilon_t P_t^*(h) \quad (4)$$
$$-MC_t(h)) \int_0^1 C_t^*(h,i^*)di^*,$$

subject to the aggregate demand for its good (3). The marginal cost of h is:

$MC_t(h) = MC_t = \frac{(k\mu)^{\alpha} P_{e,t}^{1-\alpha}}{Z\alpha^{\alpha}(1-\alpha)^{1-\alpha}}$, which is identical across varieties h.

The intermediate goods prices are computed under three different scenarios, each one characterised by either flexible prices or nominal price rigidities, and by the specific pricing regime that the intermediate goods firms adopt in the two countries. To define what are the possible pricing regimes that a firm can adopt let us consider that in general the Home firm, but the same line of reasoning holds for the Foreign firm, maximizes its profit in the Foreign market by setting the price $\tilde{P}_t(h) = P_t^*(h)\varepsilon_t^{\phi}$, where the parameter $\phi \in [0,1]$ is the degree of exchange rate pass-through. If $\phi = 1$ we are under the producer currency pricing (PCP) regime: the price the firm sets in the Foreign market is $\tilde{P}_t(h) = P_t^*(h)\varepsilon_t$ and is denominated in Home currency, so that any change in the nominal exchange rate fully transmits to $\tilde{P}_t(h)$. If $\phi = 0$ we are under the local currency pricing (LCP) regime: the price the firm sets in the Foreign market is $\tilde{P}_t(h) = P_t^*(h)$ and is denominated in Foreign currency, so that no change in the nominal exchange rate affects $\tilde{P}_t(h)$. An interesting way to see at the different degree of exchange rate pass-through involved by the two price regimes is to interpret it in terms of the geographical distribution of the firm's production sites. Let us consider again the case of an Home firm that produces h and let us assume that it always sets the price in the producer currency, but now it can choose how to distribute its production between the two countries. It follows that the influence of the exchange rate regime on the price set in the Foreign market will depend on how the total production of h is distributed between Home and Foreign. Full exchange pass-through would correspond to the case in which h is entirely produced at Home, while the case of no exchange pass-through would occur when the production of h has been divided across the two countries as to serve both markets as a local firm.

Under a flexible price regime the choice of the invoice currency for the price of exports does not have any effect on the propagation mechanism of oil price shocks, that is both the PCP and the LCP regime lead to the same result. However, when nominal rigidities are introduced, which one of the two regimes is on has a large effect on the way oil price shocks transmit to the economy.

Monetary Policy The monetary policy stance is defined by $\mu_t = P_t C_t$. This specification of the monetary policy allows the monetary authority to influence the aggregate nominal spending without specifying what is the exact instrument that it uses to do it.

The price of oil The nominal price of oil is exogenous [6], is denominated in the Home currency and always respects the law of one price:

$$P_{e,t}^{*} = \frac{P_{e,t}}{\varepsilon_t}.$$

Financial allocations in equilibrium A symmetric equilibrium is computed under the assumption of financial autarky, so that the agents cannot lend or borrow internationally.

3.1.1 The flexible price regime

The distinction between an oil importing and oil exporting country is the third source of cross-country asymmetry in the model equilibrium other than differences across countries in the total factor productivity and the monetary policy stance. This additional asymmetry, in equilibrium, is captured by the parameter φ^{FLP} :

$$\varphi^{FLP} = \left[\frac{\frac{\theta}{\theta-1} + (1-\alpha)}{\frac{\theta}{\theta-1} - (1-\alpha)} \right] > 1. \quad (5)$$

[6] Though an oil market is not explicitly modelled, the assumption of an exogenus price of oil amounts to considering a perfectly elastic oil supply (any quantity of oil demanded can be supplied at the given price) and zero marginal costs. The price of oil is then determined entirely by a specific tax that is set up by the government of the Foreign country, and whose revenues are equally redistributed across households as a lump sum transfer.

which is an increasing function of both the degree of monopolistic power in the Home intermediate goods sector (θ) and its share of oil costs $(1-\alpha)$:

The presence of φ^{FLP} causes the oil importing currency to depreciate in equilibrium with respect to the case of no oil in the economy (as in Corsetti and Pesenti where $\varphi^{FLP}=1$):

$$\varepsilon_t = \varphi^{FLP}\frac{\mu_t}{\mu_t^*}. \tag{6}$$

The parameter φ^{FLP} approaches 1 as both $(1-\alpha)$ goes to 0 (no oil is required to produce) and as θ approaches 1, as a larger monopolistic power implies both a lower equilibrium production, which requires fewer oil imports, and larger revenues from exports. φ^{FLP} also drives a wedge in the consumption ratio $\left(\frac{C^*}{C}\right)$ and the labor ratio $\left(\frac{L^*}{L}\right)$, so that in equilibrium Foreign households work less and consume more than Home households:

$$\frac{C_t^*}{C_t} = \varphi^{FLP} \Longrightarrow C_t^* > C_t \quad ; \quad \frac{L_t}{L_t^*} = \varphi^{FLP} \Longrightarrow L_t^* < L_t.$$

To describe the impact of oil price shocks on a variable of interest Y_t I compute its elasticity to the price of oil. For this purpose, I define by $\chi_{Y_t,P_{e,t}}$ the elasticity of the variable Y_t to the price of oil, that is the percent change in Y_t when the price of oil $P_{e,t}$ increases by one percent. The impact of oil price shocks on the world economy with flexible prices is then summed up by the following elasticities:

$$\chi_{\varepsilon_t,P_{e,t}} = 0 \tag{7}$$

$$\chi_{C_t,P_{e,t}} = \chi^*_{C_t,P_{e,t}} = -(1-\alpha) \tag{8}$$

$$\chi_{P_t,P_{e,t}} = \chi^*_{P_t,P_{e,t}} = (1-\alpha) \tag{9}$$

$$\chi_{L_t,P_{e,t}} = \chi^*_{L_t,P_{e,t}} = 0 \tag{10}$$

For example, with flexible prices a positive oil price shock does not affect either the nominal exchange rate (7) or the level of employment in the two countries (10)[7], while, in both countries, the price level increases (9) and consumption decreases (8) by the same amount. [8]

Figure 4 shows the effect of a positive oil price shock on the Aggregate Supply (AS) and the Aggregate Demand (AD) schedules of the Home economy in the space (C, L) :

[7] The increase in the demand of labor that is due to the substitution of labor for oil cancels out the decrease in the demand of labor that is caused by a lower aggregate demand.

[8] It is worth noting that in case of shocks to the real price of oil rather than to the nominal price of oil the size of $\chi_{C,Pe}, \chi_{C^*,Pe}, \chi_{P,Pe}$ and $\chi_{P^*,Pe}$ increases from $|1-\alpha|$ to $\left|\frac{1-\alpha}{\alpha}\right|$.This distinction may matter when trying to estimate the effect of oil price shocks to the economy in empirical works, though the difference between both measures is negligible if the oil share is small.

$$AS \quad : \quad C_t = \tau^{FLP} L_t$$
$$AD \quad : \quad C_t = \frac{\mu_t}{P_t}.$$

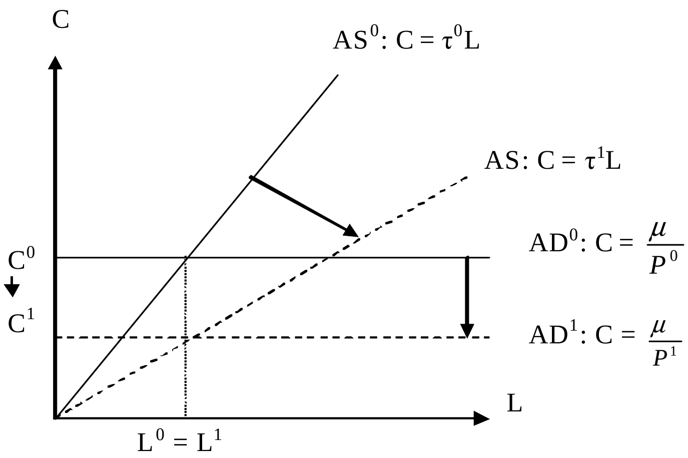

Figure 4 - The effect of a positive oil price shock on the economy when prices are flexible.

The index τ^{FLP} in the AS schedule captures both the supply channel (the condition of intratemporal marginal substitution between labor and energy) and the trade channel of transmission of oil price shocks. However, with identical technology across countries and no change in the nominal exchange rate, oil price shocks do not change the terms of trade, so that only the supply channel is at work in the transmission of the oil price shock. A positive oil price shock lowers τ^{FLP} and rotates the AS schedule downwards, from AS^0 to AS^1, because of the substitution of labor for oil, and also shifts the AD schedule downward, from AD^0 to AD^1, as the price level P increases. In the new equilibrium the level of employment L does not change, consumption decreases from C^0 to C^1 and the price level increases from P^0 to P^1. The effect of oil price shocks to the Foreign economy is perfectly symmetric to that of the Home economy.

3.1.2 Nominal Price Rigidities

Nominal price rigidities are introduced by assuming that prices are predetermined one period ahead.[9] With nominal rigidities oil price shocks have asymmetric effects across countries, and the distinction between pricing regimes (PCP or LCP) changes the propagation mechanism of oil shocks to the economy.

The PCP regime With nominal rigidities and PCP regime the exchange rate in equilibrium is an increasing function of the price of oil (**??**), the exchange rate elasticity to the price of oil is positive (**??**) and is an increasing function of the price of oil (**??**) . It follows that if a given positive oil price shock forces the oil importing currency to depreciate by δ, an oil shock twice as large will force a depreciation in the oil importing currency larger than 2δ. This result is in accordance with the empirical results shown in Figure 3 where the response of the terms of trade to oil price shocks is increasing in the size of the shock.

$$\varepsilon_t = \frac{\mu_t}{\mu_t^*}\varphi_t^{PCP}, \quad \varphi_t^{PCP} > 1 \quad \frac{\partial \varphi_t^{PCP}}{\partial P_e} > 0 \tag{11}$$

$$\chi_{\varepsilon_t, P_{e,t}} > 0 \tag{12}$$

$$\frac{\partial\left(\chi_{\varepsilon_t, P_{e,t}}\right)}{\partial(P_{e,t})} > 0 \tag{13}$$

The effects of oil price shocks on the other variables in the economy are reported below in terms of elasticities to the price of oil and expressed as a function of χ_{ε, P_E}, which is a measure of the strength of the trade channel itself:

$$\chi_{C_t, P_{e,t}} = -\frac{1}{2}\chi_{\varepsilon, Pe} < 0 \ , \ \chi_{P_t, P_{e,t}} = \frac{1}{2}\chi_{\varepsilon_t, P_{e,t}} > 0 \tag{14}$$

$$\chi_{C_t^*, P_{e,t}} = \frac{1}{2}\chi_{\varepsilon, Pe} > 0 \ , \ \chi_{P_t^*, P_{e,t}} = -\frac{1}{2}\chi_{\varepsilon_t, P_{e,t}} < 0 \tag{15}$$

$$\chi_{L_t, P_{e,t}} = \frac{\varphi_t^{PCP}(P_{e,t})}{\left(\varphi_t^{PCP}(P_{e,t}) - 1\right)}\chi_{\varepsilon_t, P_{e,t}} > 0 \tag{16}$$

$$\chi_{L_t^*, P_{e,t}} \gtrless 0. \tag{17}$$

Oil price shocks have asymmetric effects to oil importing and oil exporting countries as the change in the terms of trade redistributes asymmetrically across countries the cost of adjustment to the shocks. After a positive oil price shock the currency of the oil importing country depreciates to gain in competitiveness and make up for the higher price of oil imports. The worsening in the terms of trade of the oil importing country provokes a negative wealth effect to which

[9] Quadratic costs of price adjustment à la Rotemberg or Calvo pricing would introduce a more realistic dynamic of the economy but would not allow for an analytical solution.

households react by both consuming less (11) and, even if real wages have been driven down by a higher price level, supplying more labor services (11). Households in the oil exporting country, instead, take advantage of the change in the terms of trade, which makes imports cheaper and reduce the price level, and increase their consumption.

The final effect on the production/employment is uncertain and depends on the size of the oil price shock. By the supply channel, the increase in the price of oil causes a replacement of labor for oil in the production function. However, as the price of oil is exogenously fixed in Home currency, the input price of oil for Foreign depends also on $\chi_{\varepsilon,Pe}$. It follows that the larger the shock (and so the larger $\chi_{\varepsilon,Pe}$) the less important the supply channel in the Foreign country. Eventually, after a very large positive oil price shock the supply channel might decreases employment in the Foreign country. Thus, the supply channel increases foreign employment for small oil price shocks (elasticity) and decreases it for large shock (elasticity). By the trade cahnnel, the foreign currency appreciation both induces a worldwide replacement of oil importing for oil exporting intermediates, which contracts the demand of labor in the oil exporting country, and also withers the increase in the price of oil as measured in oil exporting currency, as the price of oil is denominated in home currency.

This is the terms of trade effect of oil shocks on the oil exporting country employment. The larger the size of the oil price shock, the bigger the probability that the latter effect will prevail and so that employment in the oil exporting country will shrink after a positive oil price shocks.

Figure 5 shows the effect of oil shocks to the oil importing economy using the AS and AD schedules in the space (C, L) :

$$\begin{aligned} AS &: \quad C_t = \tau_t^{PCP} \ L_t \\ AD &: \quad C_t = \frac{\mu_t}{P_t}. \end{aligned}$$

As in the case of flexible price, the terms τ_t^{PCP} in the AS schedule captures both the supply and the trade channel of propagation of oil shocks. A positive oil shock rotates inwards the AS schedule, from AS^0 to AS^1, while the increase in the price level, from P^0 to P^1, shifts downwards the AD schedule, from AD0 to AD1. As a result consumption falls from C^0 to C^1 and the employment increases from L^0 to L^1.

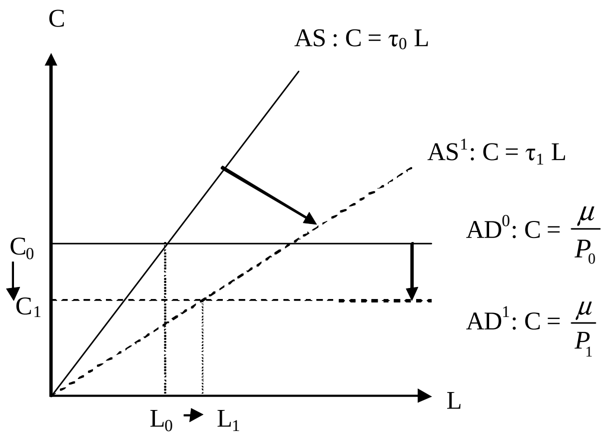

Figure 5 - The effect of a positive oil price shock on the oil importing economy with nominal rigidities and PCP pricing.

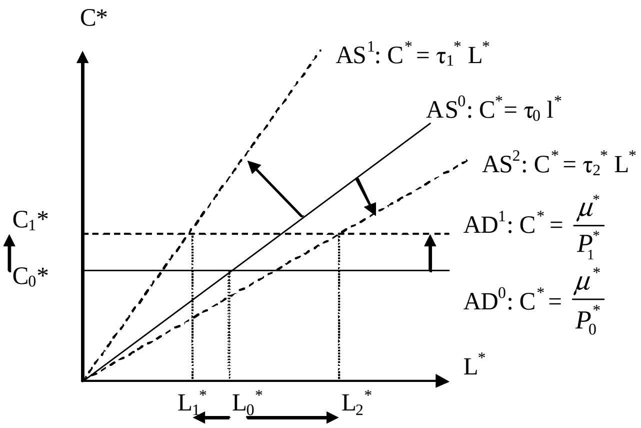

Figure 6 - The effect of a positive oil price shock on the oil exporting economy with nominal rigidities and PCP pricing.

Figure 6 shows the impact of a positive oil price shock to the oil exporting country with the aid of the AS and AD schedules. The AD schedule always shifts upwards, from AD^0 to AD^1, as the price level always decreases from P^0 to P^1. The AS schedule, instead, may rotate either upwards or downwards, depending on which one between the supply and the terms of trade effect prevails. For small oil price shocks the supply effect prevails and the AS curves will rotate downwards, from AS^0 to AS^2, causing employment in the oil exporting country to increase. For oil price shocks large enough the terms of trade effect prevails and the AS schedule rotates outwards, from A^0 to A^1, shrinking employment in the oil exporting country.

The LCP regime With a LCP regime the strength of the trade channel of adjustment to oil shocks gets reduced. The nominal exchange rate still reacts to oil price shocks (11) but the elasticity of the nominal exchange rate to oil price shocks is now bounded from above (11).

$$\varepsilon_t = \frac{\mu_t}{\mu_t^*}\varphi_t^{LCP},\ \varphi_t^{LCP}(P_{e,t}) > 1,\ \frac{\partial \varphi_t^{LCP}}{\partial P_{e,t}} > 0 \tag{18}$$

$$0 < \chi_{\varepsilon_t, P_{e,t}} < (1-\alpha) \tag{19}$$

$$0 < \frac{\partial\left(\chi_{\varepsilon_t, P_{e,t}}\right)}{\partial(P_{e,t})}. \tag{20}$$

Under a LCP regime both economies are partially insulated from oil price shocks as in both countries both the price level and consumption do not change after an oil price shock (11). Oil price shocks only change the level of employment (11) as the ratio of labor to oil in the production function reacts to the change in the relative prices of the factors of production. However, the supply effect is always less severe in the oil exporting country (11) as the change in the price of oil denominated in the oil exporting currency is moderated by the movement in the nominal exchange rate.

$$\chi_{C_t, P_{e,t}} = \chi_{C_t^*, P_{e,t}} = \chi_{P_t, P_{e,t}} = \chi_{P_t^*, P_{e,t}} = 0 \tag{21}$$

$$\chi_{L_t, P_{e,t}} = (1-\alpha) \tag{22}$$

$$\chi_{L_t^*, P_{e,t}} = (1-\alpha)\left(1-\chi_{\varepsilon_t, P_{e,t}}\right) < (1-\alpha) \tag{23}$$

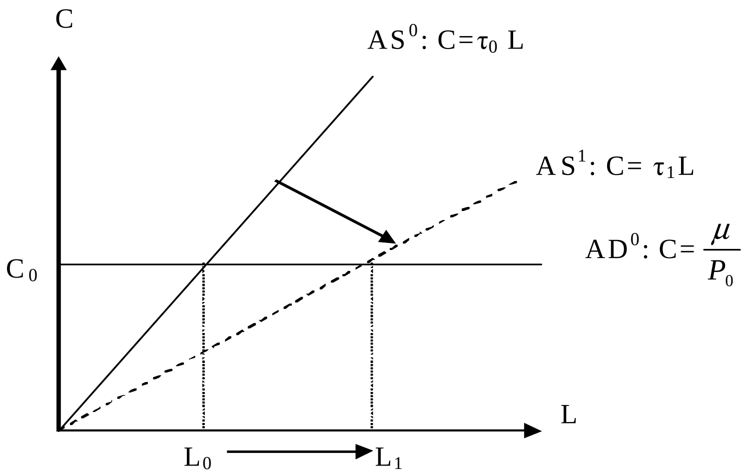

Figure 7 - The effect of a positive oil price shock on the oil importing economy with nominal rigidities and LCP pricing.

$$\begin{aligned} AS &: \quad C_t = \varphi_t^{LCP}\ L_t \\ AD &: \quad C_t = \frac{\mu_t}{P_t}. \end{aligned}$$

Figure 7 shows the effect of a positive oil price shock on the Home economy with the help of the AS and AD schedules. After a positive oil price shock the AD schedule stays put at AD^0. The AS schedule, instead, rotates inwards as labor replaces oil in the production function. The only change in the economy of the positive oil price shock is the increase in the level of employment L. The effect of a positive oil price shock on the oil exporting country is almost identical, the only difference being a reduced increase in the employment level L^*.

4 Discussion and Extensions

The model discloses two aspects of the trade channel of propagation of oil shocks, specifically the role of the exchange rate pass-through and the non linear relationship between the size of oil shocks and the response of the economy. These contributions help to better understand when oil price shocks may have a large recessive impact on oil importing country, and suggest that a change in the exchange rate pass-through might contribute to explain the evidence of a weaker impact of oil price shocks on the economic activity in recent times.

The clarity of these messages comes from the closed form solution of the model, which is obtained thorugh many simplifying assumptions. Thus, the model represents a valuable starting point for an analysis of the relationship between oil and macroeconomic performance which aims to fully reconcile data with theory. In particular, the model should be extended in three directions: endogenise the price of oil by introducing a world oil market, a more complex structure of the international financial market, and the introduction of capital.

The introduction of an international oil market would permit the model to distinguish the effects of oil price shocks according to the source of the shock. A more complex modelling of international financial markets would matter not only because it affects the strength of the trade channel but also because of the so-called evaluation effect (though it might play a minor role for oil importing country under the assumption that the assets weightings in a country's Portfolio reflected the relative economic importance of the country). Finally, the introduction of capital would allow for a more realistic and interesting dynamic of the adjustment process of the economy to oil shocks.

References

[1] Atkenson, A.J. and Kehoe, P.J. (1999), "Models of Energy Use: Putty-Putty versus Putty-Clay", American Economic Review 89, 1028-1043.

[2] Backus, D.K. and M.J. Crucini (2000), "Oil Prices and the terms of Trade", Journal of International Economics 50, 185-213.

[3] Balke, N.S., Brown, S.P.A. and M.K. Yucel (2002), "Oil Price Shocks and the U.S. Economy: Where Does the Asymmetry Originate?," The Energy Journal 23(3), 27-52.

[4] Barsky, R.B. and L. Kilian (2004), "Oil and the Macroeconomy Since the 1970," Journal of Economic Perspective 18, 115-134.

[5] Bernanke, B.S. (1983), "Irreversibility, Uncertainty, and Cyclical Investment," Quarterly Journal of Economics 98, 85-106.

[6] Bernanke, Ben S., M. Gertler, and M. Watson (1997), "Systematic Monetary Policy and the Effects of Oil Price Shocks," BPEA 1, 91–142.

[7] Blanchard, O.J., and J. Galì (2007), " The Macroeconomic Effects of Oil Price Shocks: Why are the 1970s so different from the 2000s?", NBER Working Papers 13368.

[8] Bodenstein, M., C.J. Erceg, and L. Guerrieri (2007), "Oil Shocks and External Adjustments," mimeo, Federal Reserve Board.

[9] Bohi, D.R. (1991), "Energy Price Shocks and Macroeconomic performance", Resource and Energy 13(2),145-162.

[10] Bresnahan, T. and V. Ramey (1993), "Segments Shifts and Capacity Utilization in the U.S. Automobile Industry, " American Economy Review Papers and Proceedings 83, 213-218.

[11] Bruno, M.R., and J. Sachs (1985), "Economics of Worldwide Stagflation", Harvard University Press.

[12] Corsetti, G. and P. Pesenti (2005) "The Simple Geometry of Transmission and Stabilization in Closed and Open Economies", NBER Working Paper 11341.

[13] Davis, S.J. (1987), "Allocative Disturbances and Specific Capital in Real Business Cycle Theories," American Economic Review Papers and Proceedings 77, 326-332.

[14] Davis, S.J. and J. Haltiwanger (2001), "Sectoral Job Creation and Distruction Responses to Oil Price Changes," Journal of Monetary Economics 48, 465-512.

[15] Devereux, M.B. and A. Sutherland (2010), "Valuation effects and the dynamics of net external assets," Journal of International Economics 80(1), 129-143.

[16] Dohner, R.S. (1981), "Energy Prices, Economic Activity and Inflation: survey of issues and results " in K.A. Mork (Ed.): Energy Prices, Inflation and Economic Activity. Cambridge, MA: Ballinger.

[17] Finn,M.G. (2000), "Perfect Competition and the Effects of Energy Price Increases on Economic Activity", Journal of Money Credit and Banking 32, 400-416.

[18] Fogli, A. and F. Perri. (2006), "The Great Moderation and the US External Imbalance," Monetary and Economic Studies 24(S1), 209-225.

[19] Ghironi, G, J. Lee and A. Rebucci (2007), "The Valuation Channel of External Adjustment," NBER Working Papers 12937.

[20] Gourinchas, P.O. and H. Rey (2007), "International Financial Adjustment," Journal of Political Economy 115(4), 665-703.

[21] Hamilton, J.D. (1983), "Oil and the Macroeconomy since World War II," Journal of Political Economy 91, 228-248.

[22] Hamilton, J.D. (1988), " A Neoclassical Model of Unemployment and the Business cycle", Journal of Political Economy 96, 593-618.

[23] Hamilton, J. (1996), "This Is What Happened to the Oil-Macroeconomy Relationship", Journal of Monetary Economics 38 (2), 215-220.

[24] Hamilton, J.D. (2003), "What is an Oil Shock," Journal of Econometrics 113, 363-398.

[25] Hamilton, J.D. (2008), " Oil and the Macroeconomy", in S.Durlauf and L. Blume (eds), The New Palgrave Dictionary of Economics, 2nd ed., Palgrave MacMillan Ltd.

[26] Hamilton, J. D. and A. M. Herrera (2004), "Oil Shocks and Aggregate Macroeconomic Behavior: The Role of Monetary Policy: A Comment," Journal of Money, Credit, and Banking 36 (2), 265–86.

[27] Hooker, M. (1996), "What Happened to the oil price-macroeconomy relationship?", Journal of Monetary Economics 38, 195-213.

[28] Hooker, M.A. (2002), "Are Oil Shocks Inflationary? Asymmetric and Nonlinear Specifications Versus Changes in Regime," Journal of Money, Credit, and Banking34, 540-561.

[29] Kilian, L. (2008), "The economic effects of Energy Price Shocks", Journal of Economic Literature 46(4),871-909.

[30] Kilian, L., A. Rebucci and N. Spatafora (2009), "Oil Shocks and External Balances", Journal of International Economics 77, 181-194.

[31] Kilian, L. and R. Vigfusson (2009), "Are the Responses of the US Economy Asymmetric in Energy Price Increases and Decreases," International Finance Discussion Papers.

[32] Kilian, L. (2009), "Not All Oil Price Shocks Are Alike: Disentagling Demand and Supply Shocks in the Crude Oil Market," American Economic Review 99(3), 1053-1069.

[33] Kilian, L. and C. Park (2009), " The Impact of Oil Price Shocks on the U.S. Stock Market", International Economic Review 50(4), 1267-1287.

[34] Koop, G. and M.H. Pesaran and S.M. Potter (1996), "Impulse Response Analysis in Nonlinear Multivariate Models", Journal of Econometrics 74, 119-147.

[35] Lane,P.R: and G. M. Milesi-Ferretti, (2005) "A Global Perspective on External Positions," NBER Working Papers 11589.

[36] Leduc, S. and K. Sill (2004), "A Quantitative Analysis of Oil Price Shocks, Systematic Monetary Policy and Downturns," Journal of Monetary Economics 51, 781-808.

[37] Lee, K. and S. Ni (2002), "On the Dynamics Effects of Oil Price Shocks," Journal of Monetary Economics 49, 823-852.

[38] Lee, K., S. Ni and R.A. Ratti (1995), "Oil Shocks and the Macroeconomy: The Role of Price Variability," Energy Journal 16, 39-56.

[39] Loungani, P., and M.K. Yucel (2000), "How Robust is the Oil-unemployment nexus?", mimeo.

[40] Mork, K.A. (1989), "Oil and the Macroeconomy. When Prices Go Up and Down: An Extension of Hamilton's Results," Journal of Political Economy 97, 740-744.

[41] Mendoza, E., Quadrini, V. and Rios-Rull J.V. (2007), "Financial Integration, Financial Development and Global Imbalances", NBER Working Papers 12909.

[42] Nordhaus, W. (2007), "Who's Afraid of a Big Bad Oil Shock," Brooking Papers on Economic Activity 2007-2, 219-238.

[43] Oystein, O., and H. T. Misen (1994), "Macroeconomic Responses to Oil Price Increases and Decreases in seven OECD Countries", Energy Journal15 (4), 19-35.

[44] Rigobon, R and T.M. Stoker(2009) "Bias From Censored Regressors," Journal of Business & Economic Statistics 27(3), 340-353.

APPENDIX A - General equilibrium conditions

Households The world consists of two countries of equal size, Home and Foreign, which are identical in any respect apart from total factor productivity, monetary policy and oil endowment. Oil is a Foreign specific resource, so that Home is the oil importing economy and Foreign is the oil exporting economy. Each country is inhabited by a continuum of households and firms: in the Home country households are indexed by $i \in [0,1]$ and firms are indexed by $h \in [0,1]$; in the Foreign country households are indexed by $i^* \in [0,1]$ and firms are indexed by $f \in [0,1]$. I follow the convention of labelling with an asterisk the variables of the foreign country and, when reporting results in a table, reporting results for the Home country in the first column and results for the Foreign country in the second column.

In each country households share preferences, own domestic firms, derive utility from a final consumption good (C_t or C_t^*) and disutility from supplying labor services (L_t or L_t^*) to firms in exchange for wage income (W_t or W_t^*). The utility of home household i at a given period t is given by:

$$U_t(i) = \ln C_t(i) - kL_t(i).$$

The parameter $k > 0$ determines the disutility of supplying labor and C_t is produced in a perfectly competitive final good sector by a Cobb Douglas aggregator technology that combines a Home ($C_{H,t}$) and a Foreign basket of goods ($C_{F,t}$) with equal weights:

$$C_t = C_{H,t}^{\frac{1}{2}} C_{F,t}^{\frac{1}{2}}.$$

The final consumption good cannot be traded and is entirely consumed. $C_{H,t}(i)$ and $C_{F,t}(i)$ are CES baskets of, respectively, Home ($C_t(h,i)$) and Foreign ($C_t(f,i)$) differentiated varieties:

$$C_{H,t}(i) = \left(\int_0^1 C_t(h,i)^{\frac{\theta-1}{\theta}} dh \right)^{\frac{\theta}{\theta-1}} \quad ; \; C_{F,t}(i) = \left(\int_0^1 C_t(f,i)^{\frac{\theta-1}{\theta}} df \right)^{\frac{\theta}{\theta-1}},$$

the parameter $\theta > 1$ is the elasticity of substitution across varieties, is equal across countries and is higher than the elasticity of substitution between C_H and C_F that is 1.

Symmetrically, for the foreign household i^* we have:

$$U_t^*(i^*) = \ln C_t^*(i^*) - k^* L_t^*(i^*), \qquad C_t^* = \left(C_{H,t}^*\right)^{\frac{1}{2}} \left(C_{F,t}^*\right)^{\frac{1}{2}}$$

$$C_{H,t}^*(i^*) = \left(\int_0^1 C_t^*(h,i^*)^{\frac{\theta-1}{\theta}} dh \right)^{\frac{\theta}{\theta-1}}, \quad C_{F,t}^*(i^*) = \left(\int_0^1 C_t^*(f,i^*)^{\frac{\theta-1}{\theta}} df \right)^{\frac{\theta}{\theta-1}}.$$

Given the vector of prices $\left(P_{H,t}, P_{H,t}^*, P_{F,t}, P_{F,t}^*\right)$, household's demands for $(C_{H,t}(i),\ C_{F,t}(i))$ in the Home country and household's demands for $C_{H,t}^*(i^*),\ C_{F,t}^*(i^*)$ in the Foreign country, are obtained as solutions to the following cost minimization problems:

$$\underset{C_H(i),C_F(i)}{Min}\ P_{H,t}C_{H,t}(i) + P_{F,t}C_{F,t}(i) \qquad \underset{C_H^*(i^*),C_F^*(i^*)}{Min}\ P_{H,t}^*C_{H,t}^*(i^*) + P_{F,t}^*C_{F,t}^*(i^*)$$
$$s.t.\ C_t(i) = C_{H,t}(i)^{\frac{1}{2}}C_{F,t}(i)^{\frac{1}{2}} \qquad s.t.\ C_t^*(i^*) = C_{H,t}^*(i^*)^{\frac{1}{2}}C_{F,t}^*(i^*)^{\frac{1}{2}}.$$

The first order conditions of each cost minimization problem give the demands for the baskets of Home and Foreign goods, and the lagrangian multiplier associated to the technology constraint gives the price index of the final consumption good, which is then interpreted as the minimum expenditure required to consume one unit of the final good. The following table reports Home (column 1) and Foreign (column 2) demands for the baskets of Home $(A.2a,\ A.2b)$ and Foreign goods $(A.1a,\ A.1b)$, the prices of the final consumption good $(A.3a,\ A.3b)$ and the optimal composition of nominal spending $(A.4a,\ A.4b)$

$$C_{F,t}(i) = C_t(i)\left(\frac{P_{H,t}}{P_{F,t}}\right)^{\frac{1}{2}} \quad (A.1a) \qquad C_{F,t}^*(i^*) = C_t^*(i^*)\left(\frac{P_{H,t}^*}{P_{F,t}^*}\right)^{\frac{1}{2}} \quad (A.1b)$$
$$C_{H,t}(i) = C_t(i)\left(\frac{P_{F,t}}{P_{H,t}}\right)^{\frac{1}{2}} \quad (A.2a) \qquad C_{H,t}^*(i^*) = C_t^*(i^*)\left(\frac{P_{F,t}^*}{P_{H,t}^*}\right)^{\frac{1}{2}} \quad (A.2b)$$
$$P_t = 2P_{F,t}^{\frac{1}{2}}P_{H,t}^{\frac{1}{2}} \quad (A.3a) \qquad P_t^* = 2\left(P_{F,t}^*\right)^{\frac{1}{2}}\left(P_{H,t}^*\right)^{\frac{1}{2}} \quad (A.3b)$$
$$P_tC_t = 2P_{H,t}C_{H,t} = 2P_{F,t}C_{F,t} \quad (A.4a) \qquad P_t^*C_t^* = 2P_{H,t}^*C_{H,t}^* = 2P_{F,t}^*C_{F,t}^*. \quad (A.4b)$$

Home and Foreign households' demands for varieties h and f $(C_t(h,i),\ C_t(f,i)\ and\ C_t^*(h,i^*),\ C_t^*(f,i^*))$ solve the following cost minimization problems:

$$\underset{C_{h,t}(i),C_{f,t}(i)}{Min}\int p_{h,t}C_t(h,i) + \int p_{f,t}C_{f,t}(i) \qquad \underset{C_{h,t}^*(i^*),C_{f,t}^*(i)}{Min}\int p_t^*(h)C_t^*(h,i^*) + \int p_t^*(f)C_t(f,i^*)$$
$$s.t.\ C_{H,t}(i) = \left(\int_0^1 C_t(h,i)^{\frac{\theta-1}{\theta}}dh\right)^{\frac{\theta}{\theta-1}} \qquad s.t.\ C_{H,t}^*(i^*) = \left(\int_0^1 C_t^*(h,i^*)^{\frac{\theta-1}{\theta}}dh\right)^{\frac{\theta}{\theta-1}}$$
$$s.t\ C_{F,t}(i) = \left(\int_0^1 C_t(f,i)^{\frac{\theta-1}{\theta}}df\right)^{\frac{\theta}{\theta-1}} \qquad s.t\ C_{F,t}^*(i^*) = \left(\int_0^1 C_t(f,i^*)^{\frac{\theta-1}{\theta}}df\right)^{\frac{\theta}{\theta-1}}.$$

From the first order conditions we obtain :

$$C_t(h,i) = \frac{1}{2}\left(\frac{P_t(h)}{P_{H,t}}\right)^{-\theta} C_{H,t}(i) = \frac{1}{2}\left(\frac{P_t(h)}{P_{H,t}}\right)^{-\theta}\left(\frac{P_{H,t}}{P_t}\right)^{-1} C_t(i) \qquad (A.5a)$$

$$C_t(f,i) = \frac{1}{2}\left(\frac{P_t(f)}{P_{F,t}}\right)^{-\theta} C_{F,t}(i) = \frac{1}{2}\left(\frac{P_t(f)}{P_{F,t}}\right)^{-\theta}\left(\frac{P_{F,t}}{P_t}\right)^{-1} C_t(i) \qquad (A.6a)$$

$$C_t^*(h,i^*) = \frac{1}{2}\left(\frac{P_t^*(h)}{P_{H,t}^*}\right)^{-\theta} C_{H,t}^*(i^*) = \frac{1}{2}\left(\frac{P_t^*(h)}{P_{H,t}^*}\right)^{-\theta}\left(\frac{P_{H,t}^*}{P_t^*}\right)^{-1} C_t^*(i^*) \qquad (A.5b)$$

$$C_t(f,i^*) = \frac{1}{2}\left(\frac{P_t^*(f)}{P_{F,t}^*}\right)^{-\theta} C_{F,t}^*(i^*) = \frac{1}{2}\left(\frac{P_t^*(f)}{P_{F,t}^*}\right)^{-\theta}\left(\frac{P_{F,t}^*}{P_t^*}\right)^{-1} C_t^*(i^*). \qquad (A.6b)$$

At any period t the home household i face the following one-period budget constraint:

$$P_tC_t(i) + B_t(i) + \varepsilon_t B_t^*(i) \leq W_tL_t(i) + \Pi_t(i) + B_{t-1}(i)(1+i_{t-1}) \qquad (A.7a)$$
$$+\varepsilon_t B_{t-1}^*(i)(1+i_{t-1}^*),$$

where $P_tC_t(i)$ is nominal spending on the final consumption good, W_t is the nominal wage per unit of labor, $\Pi_t(i)$ is household's share of profit of firms in the intermediate goods sector. Households can purchase two riskless one-period bonds at any period t: $B_t(i)$, which is denominated in home currency and yields a nominal interest i_t at $t+1$, and $B_t^*(i)$, which is denominated in foreign-currency and yields a nominal interest rate i_t^* at $t+1$. The nominal exchange rate, ε_t, expresses how many units of Home currency are exchanged per one unit of Foreign currency. Similarly, the one-period budget constraint for the foreign household i^* is:

$$P_t^*C_t^*(i^*) + \frac{1}{\varepsilon_t}B_t(i^*) + B_t^*(i^*) \leq W_t^*L_t^*(i^*) + \Pi_t^*(i^*) + \frac{B_{t-1}}{\varepsilon_t}(i^*)(1+i_{t-1}) \qquad (A.7b)$$
$$+B_{t-1}^*(i^*)(1+i_{t-1}^*).$$

In both countries households' decision on consumption, labor supply and financial accumulation maximize the present discounted value of utility subject to the flow of one-period budget constraints:

$$\underset{C_t(i),L_t(i),B_t(i),B_t^*(i)}{Max} E_t\sum_{t=0}^{\infty}\beta^t \ln(C_t(i)) - \kappa L_t(i) \qquad \underset{C_t^*(i^*),L_t^*(i^*),B_t(i^*),B_t^*(i^*)}{Max} E_t\sum_{t=0}^{\infty}\beta^t \ln(C_t^*(i^*)) - \kappa^* L_t^*(i^*)$$
$$s.t. \quad (A.7a) \qquad\qquad s.t. \quad (A.7b)$$

From the first order conditions we obtain:

$$\lambda_t = \frac{1}{P_tC_t(i)} \qquad (A.8a) \qquad \lambda_t^* = \frac{1}{P_t^*C_t^*(i^*)} \qquad (A.8b)$$
$$\frac{1}{1+i_t^*} = E_t\left(\beta\frac{C_t}{C_{t+1}}\frac{P_t}{P_{t+1}}\varepsilon_{t+1}\right) \qquad (A.9a) \qquad \frac{1}{1+i_t^*} = E_t\left(\beta\frac{C_t^*}{C_{t+1}^*}\frac{P_t^*}{P_{t+1}^*}\right) = E_t\left(Q_{t,t+1}^*(i^*)\right) \qquad (A.9b)$$
$$W_t = -\kappa P_tC_t(i) \qquad (A.10a) \qquad W_t^* = -\kappa^* P_t^*C_t^*(i^*) \qquad (A.10b)$$
$$\frac{1}{1+i_t} = E_t\left(\beta\frac{C_t}{C_{t+1}}\frac{P_t}{P_{t+1}}\right) = E_t\left(Q_{t,t+1}\right) \qquad (A.11a) \qquad \frac{1}{1+i_t} = E_t\left(\beta\frac{C_t^*}{C_{t+1}^*}\frac{P_t^*}{P_{t+1}^*}\frac{1}{\varepsilon_{t+1}}\right). \qquad (A.11b)$$

From $(A.10a)$, it follows that $C_t(i) = C_t$ as κ, P_t and W_t are common to all home households. Similarly, by $(A.10b)$ $C_t^*(i) = C_t^*$. $Q_{t,t+1}$ $(A.11a)$ is the nominal discount rate of home households, and $Q_{t,t+1}^*$ $(A.9b)$ is the nominal discount rate of foreign households.

Intermediate goods sector In each country the intermediate goods sector is characterised by monopolistic competition: any firm supplies a single variety, h in the Home country and f in the Foreign country, that is an imperfect substitute to all other varieties. Technology is represented by a Cobb Douglas production function and is common across all firms in the same country:

$$Y_t(h) = Z_t E_t^{1-\alpha}(h) L_t^{\alpha}(h) \quad (A.12a) \quad Y_t^*(f) = Z_t^* \left(E_t^*\right)^{1-\alpha}(f) \left(L_t^*\right)^{\alpha}(f). \quad (A.12b)$$

$Z_t > 0$ ($Z_t^* > 0$) is the total factor productivity and is common across Home (Foreign) firms. $\alpha \in (0,1)$ is the share of labor income and is common across firms and countries. $L_t(h)$ and $E_t(h)$ ($L_t^*(f)$ and $E_t^*(f)$) are, respectively, the amount of labor and oil that are employed in the production of variety h (f) at the period t. The aggregate demand for a given variety, h or f, at time t is given by aggregating Home and Foreign households' demands for that variety $(A.1a,\ A.1b,\ A.2a,\ A.2b)$:

$$Y_t(h) = \int C_t(h,i)di + \int C_t^*(h,i^*)di^* = \frac{1}{2}\left(\frac{P_t(h)}{P_{H,t}}\right)^{-\theta}\left(\frac{P_{H,t}}{P_t}\right)^{-1} C_t + \frac{1}{2}\left(\frac{P_t^*(h)}{P_{H,t}^*}\right)^{-\theta}\left(\frac{P_{H,t}^*}{P_t^*}\right)^{-1} C_t^* \quad (A.12c)$$

$$Y_t^*(f) = \int C_t(f,i)di + \int C_t^*(f,i^*)di^* = \frac{1}{2}\left(\frac{P_t(f)}{P_{F,t}}\right)^{-\theta}\left(\frac{P_{F,t}}{P_t}\right)^{-1} C_t + \frac{1}{2}\left(\frac{P_t^*(f)}{P_{F,t}^*}\right)^{-\theta}\left(\frac{P_{F,t}^*}{P_t^*}\right)^{-1} C_t^* \quad (A.12d)$$

$$C_t \equiv \int C_t(i)di, \qquad C_t^* \equiv \int C_t^*(i^*)di^*.$$

In each country intermediate goods firms take the prices of inputs as given $\left(W_t, W_t^*, P_e, P_{e,t}^*\right)$ and demand the quantity of labor services ($L_t(h)$ or $L_t^*(f)$) and oil ($E_t(h)$ or $E_t^*(f)$) that solve the following cost minimization problem subject to the technology constraint:

$$\underset{E(h),L(h)}{Min} \; P_{e,t}E_t(h) + W_t L_t(h) \qquad \underset{E_t^*(f),L_t^*(f)}{Min} \; P_{e,t}^* E_t^*(f) + W_t^* L_t^*(f)$$

$$s.t. Y_t(h) = Z_t E^{1-\alpha}(h) L^{\alpha}(h) \qquad s.t. Y_t^*(f) = Z_t^* \left(E_t^*\right)^{1-\alpha}(f) \left(L_t^*\right)^{\alpha}(f).$$

From the first order conditions we obtain the optimal ratio of factor inputs that is adopted by the Home $(A.13a)$ and Foreign $(A.13b)$ intermediate goods firm, while the lagrangian multiplier associated to the technology constraint provides the marginal cost of producing an additional unit of variety h $(A.13a)$ or f $(A.13b)$:

$$\frac{W_t}{P_{e,t}} = \frac{\alpha}{1-\alpha}\frac{E_t(h)}{L_t(h)} \quad (A.13a) \qquad \frac{W_t^*}{P_{E,t}^*} = \frac{\alpha}{1-\alpha}\frac{E_t^*(f)}{L_t^*(f)} \quad (A.13b)$$

$$MC_t(h) = MC_t = \frac{P_{E,t}^{1-\alpha} W_t^{\alpha}}{Z_t \alpha^{\alpha}(1-\alpha)^{(1-\alpha)}} \quad (A.13c) \qquad MC_t^*(f) = MC_t^* = \frac{\left(P_{E,t}^*\right)^{1-\alpha}(W_t^*)^{\alpha}}{Z_t^* \alpha^{\alpha}(1-\alpha)^{(1-\alpha)}}. \quad (A.13d)$$

Any firm has to set two prices for the variety it produces, one in the Home market and the other in the Foreign market. These two prices are set by the firm to maximize its own profit function, which is $\Pi_t(h)$ for home firms and $\Pi_t^*(f)$ for foreign firms. The profit functions $\Pi_t(h)$ and $\Pi_t^*(f)$are defined as follows:

$$\begin{aligned}\Pi_t(h) &= P_t(h)\int_0^1 C_t(h,i)di + \varepsilon_t P_t^*(h)\int_0^1 C_t^*(h,i^*)di^* - W_t L_t(h) - P_{e,t}E_t(h) \\ &= (P_t(h) - MC_t(h))\int_0^1 C_t(h,i)di + (\varepsilon_t P_t^*(h) - MC_t(h))\int_0^1 C_t^*(h,i^*)di^*\end{aligned} \qquad (A.14a)$$

$$\begin{aligned}\Pi_t^*(f) &= \tfrac{P_t(f)}{\varepsilon_t}\int_0^1 C_t(f,i)di + (P_t^*(f) - MC_t(f))\int_0^1 C_t^*(f,i^*)di^* - W_t^* L_t^*(f) - P_{e,t}^* E_t^*(f) \\ &= \tfrac{(P_t(f) - MC_t^*(f))}{\varepsilon_t}\int_0^1 C_t(f,i)di + (P_t^*(f) - MC_t^*(f))\int_0^1 C_t^*(f,i^*)di^*\end{aligned} \quad , \qquad (A.14b)$$

where the second part of the right hand side of A.$(14a)$ follows from applying $(A.12a)$, $(A.12c)$ and $(A.13a)$, and the second part of the right hand side of $(A.14b)$ results from applying $(A.12b)$, $(A.12d)$ and $(A.13b)$.

Monetary Policy In each country the monetary policy stance determines the aggregate nominal spending by setting a parameter, μ_t in the Home country and μ_t^* in the Foreign country. This specification allows the monetary authority to influence the aggregate nominal spending without having to specify the exact instrument that monetary policy uses for it.

$$\mu_t = P_t C_t \qquad (A.15a) \qquad \mu_t^* = P_t^* C_t^*. \qquad (A.15b)$$

The price of oil The nominal price of oil is exogenous [10] and is denominated in the oil importing country currency. Moreover, for the price of oil it always holds the law of one price:

$$P_{e,t}^* = \frac{P_{e,t}}{\varepsilon_t}.$$

Symmetric Equilibrium Conditions In a symmetric equilibrium the following conditions hold: $L_t(h) = L_{H,t},\ E_t(h) = E_t,\ L_t^*(f) = L_{F,t}^*,\ E_t^*(f) = E_t^*,\ P_t(f) = P_{F,t},\ P_t(h) = P_{H,t},\ P_t^*(f) =, P_{F,t}^*,\ P_t^*(h) = P_{H,t}^*,\ C_t(f,i) = C_{F,t},\ C_t(h,i) = C_{H,t},\ C_t^*(f,i^*) = C_{F,t}^*,\ C_t^*(h,i^*) = C_{H,t}^*,\ B_t = B_t(i),\ B_t^* = B_t^*(i^*)$.

[10] Though an oil market is not explicitly modelled, the assumption of an exogenus price of oil amounts to considering a perfectly elastic oil supply (any quantity of oil demanded can be supplied at the given price) and zero marginal costs. The price of oil is then determined entirely by a specific tax that is set up by the government of the Foreign country, and whose revenus are redistributed across households as a lump sum transfer.

Clearing Market Conditions Clearing market conditions for the labor markets, the intermediate goods sector and the final good sector require:

$$\int L_t(h)dh = \int L_t(i)di = L_t \qquad (A.16a) \qquad \int L_t^*(f)df = \int L_t^*(i^*)di^* = L_t^* \qquad (A.16b)$$

$$\int C_t(i)di = C_t = C_{H,t}^{\frac{1}{2}} C_{F,t}^{\frac{1}{2}} \qquad (A.16c) \qquad \int C_t^*(i^*)di = C_t^* = \left(C_{H,t}^*\right)^{\frac{1}{2}} \left(C_{F,t}^*\right)^{\frac{1}{2}} \qquad (A.16d)$$

$$\int \left[\int C_t(h,i)di + \int C(h,i^*)di^*\right] dh = \int Z_t E_t^{1-\alpha}(h) L_t^{\alpha}(h) dh \Rightarrow$$

$$C_{H,t} + C_{H,t}^* = Z_t E_t^{1-\alpha} L_t^{\alpha} \qquad (A.17a)$$

$$\int \left[\int C_t^*(f,i^*)di^* + \int C(f,i)di\right] df = \int Z_t^* \left(E_t^*(f)\right)^{1-\alpha} \left(L_t^*(f)\right)^{\alpha} df \Rightarrow$$

$$C_{F,t} + C_{F,t}^* = Z_t^* \left(E_t^*\right)^{1-\alpha} \left(L_t^*\right)^{\alpha}. \qquad (A.17b)$$

General condition for the equilibrium nominal exchange rate A general condition for the equilibrium nominal exchange rate, which is independent of the pricing regime, is found by aggregating over Home households' budget constraint:

$$P_t C_t - W_t L_t - \Pi_t + \int B_t(i)di + \int B_t^*(i)di + (1+i_{t-1})\varepsilon_t \int B_{t-1}(i)di + (1+i_{t-1}^*)\varepsilon_t \int B_t^*(i)di = 0.$$

The aggregate profit Π_t is defines as follows:

$$\begin{gathered} \Pi_t = \int \Pi_t(h)dh \\ = \int \left[P_t(h)\left(\int C_t(h,i)di\right) + \varepsilon_t P_t^*(h)\left(\int C_t(h,i^*)di\right) - W_t L_t(h) - P_{e,t}E_t(h)\right] dh \\ = P_{H,t}C_{H,t} + \varepsilon_t P_{H,t}^* C_{H,t}^* - W_t L_t - P_{e,t}E_t. \end{gathered} \qquad (A.18)$$

Let's impose financial autarky as the equilibrium financial allocations. To do this (a) consider that both B_t and B_t^* are in zero net-supply worldwide,

$$\int B_t(i)di + \int B_t(i^*)di^* = 0, \ \int B_t^*(i)di + \int B_t^*(i^*)di^* = 0,$$

(b) assume the following financial allocations: $B_t = 0$, $\varepsilon_t B_t^* = 0$, $\forall t$. The aggregate budget constraint then becomes: $P_t C_t - W_t L_t - \Pi_t = 0$. Replace in this last expression $(A.18)$ and $(A.4a)$ to find:

$$P_{H,t}C_{H,t} = \varepsilon_t P_{H,t}^* C_{H,t}^* + P_{e,t}E_t.$$

This expression states that the nominal exchange rate moves to offset imbalances in the trade balance. By replacing in it $(A.2a)$, $(A.2b)$, $(A.4a)$, $(A\ 4b)$, $(A.10a)$, $(A.13a)$, $(A.15a)$, $(A\ 15b)$, and $(A.17a)$ I find a general condition for the exchange rate that depends only on the intermediate goods equilibrium prices:

$$\left(\frac{\mu_t}{P_{H,t}} + \frac{\mu_t^*}{P_{H,t}^*}\right) = \frac{\mu_t}{MC_t} \frac{1}{1-\alpha} \left[\varepsilon_t \frac{\mu_t^*}{\mu_t} - 1\right]. \qquad (A.19)$$

To find the equilibrium of the model the last conditions that are required are the equilibrium prices of the intermediated goods. These prices are computed under three different scenarios, each one characterised either by flexible prices or nominal price rigidities, and by the specific pricing regime that the intermediate goods firms adopt in the two countries. To define what are the possible pricing regimes that a firm can adopt let us consider that in general the Home firm maximizes its profit in the Foreign market by setting the price $\tilde{P}_t(h) = P_t^*(h)\varepsilon_t^{\phi}$, where the parameter $\phi \in [0,1]$ is the degree of exchange rate pass-through. If $\phi = 1$ we are under the producer currency pricing (PCP) regime: the price the firm sets in the Foreign market is $\tilde{P}_t(h) = P_t^*(h)\varepsilon_t$ and is set in Home currency, so that any change in the nominal exchange rate fully transmits to $\tilde{P}_t(h)$. If $\phi = 0$ we are under the local currency pricing (LCP) regime: the price the firm sets in the Foreign market is $\tilde{P}_t(h) = P_t^*(h)$ and is set in Foreign currency, so that no change in the nominal exchange rate affects $\tilde{P}_t(h)$. These two price regimes can also be interpreted in term of the geographical distribution of the firm's production sites. Let us consider again the case of an Home firm that produces h and let us assume that it always sets the price in the producer currency, but now it can choose how to distribute its production between the two countries. It follows that the influence of the exchange rate regime on the price set in the Foreign market will depend on how the total production of h is distributed between Home and Foreign. Full exchange pass-through would correspond to the case in which h is entirely produced at Home, while the case of no exchange pass-through would occur when the production of h has been divided across the two countries as to serve both markets as a local firm.

The general condition to compute the Aggregate Supply (AS) of the oil importing country can be derived by replacing $(A.2a)$, $(A.2b)$, $(A.13a)$, $(A.15a)$ in $(A.17a)$:

$$C_t \left(\frac{P_{F,t}}{P_{H,t}}\right)^{\frac{1}{2}} + C_t^* \left(\frac{P_{F,t}^*}{P_{H,t}^*}\right)^{\frac{1}{2}} = L_t \frac{\kappa \mu_t}{\alpha} \frac{1}{MC_t}. \qquad (A.20a)$$

Similarly, the general condition to compute the AS of the oil exporting country is obtained by applying $(A.1a)$, $(A.1b)$, $(A.13b)$, $(A.15b)$ in $(A.17b)$:

$$C_t \left(\frac{P_{H,t}}{P_{F,t}}\right)^{\frac{1}{2}} + C_t^* \left(\frac{P_{H,t}^*}{P_{F,t}^*}\right)^{\frac{1}{2}} = L_t^* \frac{\kappa \mu_t^*}{\alpha} \frac{1}{MC_t^*}. \qquad (A.20b)$$

APPENDIX B - The symmetric equilibrium in a Flexible Price Regime

In a flexible price regime the choice of the invoice currency for sales abroad does not affect the equilibrium prices of the intermediate goods, which are obtained by solving the following profit maximization problems:

Home's firm profit maximization problem

$$\underset{P_t(h),P_t^*(h)}{Max} \left(P_t(h) - MC_t(h)\right) \tfrac{1}{2} \left(\tfrac{P_t(h)}{P_{H,t}}\right)^{-\theta} \left(\tfrac{P_{H,t}}{P_t}\right)^{-1} C_t + \left(\epsilon_t P_t^*(h) - MC_t(h)\right) \tfrac{1}{2} \left(\tfrac{P_t^*(h)}{P_{H,t}^*}\right)^{-\theta} \left(\tfrac{P_{H,t}^*}{P_t^*}\right)^{-1} C_t^*$$

Foreign's firms profit maximization problem

$$\underset{P_t(f),P_t^*(f)}{Max} \left(P_t^*(f) - MC_t(f)\right) \tfrac{1}{2} \left(\tfrac{P_t^*(f)}{P_{F,t}^*}\right)^{-\theta} \left(\tfrac{P_{F,t}^*}{P_t^*}\right)^{-1} C_t^* + \left(\tfrac{P_t(f)}{\epsilon_t} - MC_t(f)\right) \tfrac{1}{2} \left(\tfrac{P_t(f)}{P_{F,t}}\right)^{-\theta} \left(\tfrac{P_{F,t}}{P_t}\right)^{-1} C_t.$$

From the first order conditions we obtain:

$$P_{H,t} = \tfrac{\theta}{\theta-1} MC_t \qquad (B.1a) \qquad\qquad P_{H,t}^* = \tfrac{\theta}{\theta-1} \tfrac{MC_t}{\epsilon_t} \qquad (B.1b)$$
$$P_{F,t} = \tfrac{\theta}{\theta-1} \epsilon_t MC_t^* \qquad (B.2a) \qquad\qquad P_{F,t}^* = \tfrac{\theta}{\theta-1} MC_t^*. \qquad (B.2b)$$

Given the intermediate goods prices, we can use the conditions previously derived in appendix A to compute the equilibrium of the two-country economy. The equilibrium nominal exchange rate is found by replacing $(B.1a)$ and $(B.1b)$ in $(A.19)$:

$$\varepsilon_t = \varphi^{FLP} \tfrac{\mu_t}{\mu_t^*}, \; \varphi^{FP} = \left[\frac{\frac{\theta}{\theta-1} + (1-\alpha)}{\frac{\theta}{\theta-1} - (1-\alpha)}\right] > 1. \qquad (B.3)$$

The parameter φ^{FLP} captures the asymmetries in the equilibrium that are caused by the distinction between an oil importing and oil exporting country. The presence of φ^{FLP} causes the currency of the oil importing country to depreciate in equilibrium with respect to the case of no oil in the economy (as in Corsetti and Pesenti). φ^{FLP} is an increasing function of both the degree of monopolistic power in the Home intermediate goods sector (θ) and its share of oil costs $(1-\alpha)$. It approaches 1 as both $(1-\alpha)$ goes to 0 (no oil is required to produce) and θ approaches 1, as a larger monopolistic power implies both a lower equilibrium production, which requires fewer oil imports, and larger revenues from exports.
The equilibrium value of consumption is found by applying $(A.1a)$, $(A.2a)$, $(A.4a)$, $(A.15a)$, $(B.1a)$ and $(B.1b)$ to $C_t = C_{H,t}{}^{\frac{1}{2}} C_{F,t}{}^{\frac{1}{2}}$

$$C_t = \tfrac{\theta-1}{2\theta} \left(\tfrac{\alpha}{\kappa}\right)^{\alpha} \left((1-\alpha) \tfrac{\mu_t}{P_{E,t}}\right)^{1-\alpha} (Z_t Z_t^*)^{\frac{1}{2}} \varphi^{FLP - \frac{\alpha}{2}}. \qquad (B.4a)$$

Similarly, C_t^* is obtained from applying $(A.1b)$, $(A.2b)$, $(A.4b)$, $(A.15b)$, and $(B.2a)$, $(B.2b)$ to $C_t^* = C_{H,t}^*{}^{\frac{1}{2}} C_{F,t}^*{}^{\frac{1}{2}}$:

$$C_t^* = \frac{\theta-1}{2\theta}\left(\frac{\alpha}{\kappa}\right)^{\alpha}\left((1-\alpha)\frac{\mu_t}{P_{E,t}}\right)^{(1-\alpha)}(Z_tZ_t^*)^{\frac{1}{2}}\varphi^{FLP\left(1-\frac{\alpha}{2}\right)}. \quad (B.4b)$$

Equilibrium employment in the oil importing country is obtained by replacing $(B.3)$ in $(A.19)$, and in the oil exporting country by substituting $(A.4b)$, $(A.13b)$, $(A.15b)$ in $(A.17b)$:

$$L_t = L = \frac{\alpha}{\kappa}\left[\frac{\varphi^{FLP}}{\frac{\theta}{\theta-1}+(1-\alpha)}\right] \quad (B.5a) \qquad L_t^* = L^* = \frac{\alpha}{\kappa}\left[\frac{1}{\frac{\theta}{\theta-1}+(1-\alpha)}\right]. \quad (B.5b)$$

To get E_t, the quantity of oil used in equilibrium in the oil importing country, replace $(B.5a)$ in $(A.13a)$, and similarly for E_t^* replace $(B.5b)$ in $(A.13b)$:

$$E_t = \frac{\mu_t}{P_{E,t}}\left(\frac{1-\alpha}{\frac{\theta}{\theta-1}-(1-\alpha)}\right) \quad (B.6a) \qquad E_t^* = \left[\frac{1-\alpha}{\frac{\theta}{\theta-1}+(1-\alpha)}\right]\frac{\mu_t^*}{P_{E,t}^*}. \quad (B.6b)$$

The equilibrium price level of each country is found replacing the equilibrium consumption level, $(B.4a)$ for C_t and $(B.4b)$ for C_t^*, in the corresponding monetary policy stance equation, $(A.15a)$ for the oil importing country and $(A.15b)$ for the oil exporting country:

$$P_t = \mu_t^{\alpha}(Z_tZ_t^*)^{-\frac{1}{2}}\frac{2\theta}{\theta-1}\left(\frac{\kappa}{\alpha}\right)^{\alpha}\left(\frac{P_{E,t}}{1-\alpha}\right)^{1-\alpha}\varphi^{FLP\frac{\alpha}{2}} \quad (B.7a)$$
$$P_t^* = \frac{2\theta}{\theta-1}\left(\frac{\kappa}{\alpha}\right)^{\alpha}\left((1-\alpha)\frac{\mu_t}{P_{E,t}}\right)^{-(1-\alpha)}(Z_tZ_t^*)^{-\frac{1}{2}}\varphi^{FLP-\left(1-\frac{\alpha}{2}\right)}. \quad (B.7b)$$

The ratio of foreign to home consumption in equilibrium is easily computed from $(B.4a)$ and $(B.4b)$:

$$\frac{C_t^*}{C_t} = \varphi^{FLP} > 1 \Rightarrow C_t^* > C_t.$$

Similarly, $(B.7a)$ and $(B.7b)$ give the ratio of foreign to home employment in equilibrium:

$$\frac{L_t^*}{L_t} = \frac{1}{\varphi^{FLP}} < 1 \Rightarrow L_t^* > L_t.$$

Finally, the AS in the flexible price regime is obtained by applying $(B.1a)$, $(B.1b)$, $(B.2a)$, $(B.2b)$, $(B.4a)$ *and* $(B.4b)$ *to*$(A.20a)$:

$$AS^{FLP}: C_t = \tau_t^{FLP}L_t, \quad \tau_t^{FLP} = \underbrace{\frac{\kappa\mu_t}{\alpha}\frac{1}{MC_t}}_{Supply\ Channel}\underbrace{\left(\frac{\tilde{M}C_t^*}{MC_t}\right)^{\frac{1}{2}}\left[\varepsilon_t^{\frac{\alpha}{2}}\left(1+\varphi^{FLP}\right)\right]^{-1}}_{Trade\ Channel}, \ \tilde{M}C_t^* = \frac{MC_t^*}{\varepsilon_t^{1-\alpha}}.$$

The index τ_t^{FLP} in the AS schedule captures both the supply channel (the condition of intratemporal marginal substitution between labor and energy) and the trade channel of transmission of oil price shocks. However, with identical technology across countries and no change in the nominal exchange rate, oil price shocks do not change the terms of trade, so that only the supply channel is at work in the transmission of oil price shocks.

The effect of price shocks to the oil importing and oil exporting economy in a Flexible Price Regime

To understand the effects of oil price shocks to the economy I compute the elasticity of any variable of interest to the nominal price of oil. In particular, I define the elasticity of the variable Y_t to the nominal price of oil $P_{e,t}$ as $\chi_{Y_t,Pe,t} = \frac{\partial Y_t}{\partial P_{e,t}} \frac{P_{e,t}}{Y_t}$, that is the percent change in Y_t as the price of oil rises by one percent.

Proposition 1 *In a flexible price regime the nominal exchange rate is unaffected by oil price shocks.*

Proof. To prove it, it is sufficient to show $\chi_{\varepsilon_t,P_{e,t}} = 0$, which follows immediately from $(B.3)$. ■

Proposition 2 *In a flexible price regime, oil price shocks decrease the aggregate consumption in both the home importing and the oil exporting country.*

Proof. To prove it, it is sufficient to compute the elasticity of C_t and C_t^* to $P_{e,t}$. From $(B.4a)$ and $(B.4b)$ I obtain $\chi_{C_t,P_{e,t}} = \chi_{C_t^*,P_{e,t}} = -(1-\alpha) < 0$. ■

Proposition 3 *In any price regime,* $\chi_{C_t,P_{e,t}} = -\chi_{P_t,P_{e,t}}$ *and* $\chi_{C_t^*,P_{e,t}} = -\chi_{P_t^*,P_{e,t}}$.

Proof. By $(A.15a)$ follows that $\chi_{C_t,P_{e,t}} = \frac{\partial C_t}{\partial P_{e,t}} \frac{P_{e,t}}{C_t} = \frac{\partial\left(\frac{\mu_t}{P_t}\right)}{\partial P_{e,t}} \frac{P_{e,t}}{\frac{\mu_t}{P_t}} = \frac{-\mu_t \frac{\partial P_t}{\partial P_{e,t}}}{P_t^2} \frac{P_t}{\mu_t} P_{e,t} = -\frac{\partial P_t}{\partial P_{e,t}} \frac{P_{e,t}}{P_t} = -\chi_{P_t,P_{e,t}}$. Similarly, it is possible to compute $\chi_{C_t^*,P_{e,t}} = -\chi_{P_t^*,P_{e,t}}$. ■

By Proposition 3 it follows that with flexible prices oil price shocks increase the price level in both country as $\chi_{P_t,P_{e,t}} = \chi_{P_t^*,P_{e,t}} = (1-\alpha)$.

APPENDIX C - The symmetric equilibrium with Nominal Price rigidities and PCP Regime

Nominal price rigidities are introduced in the intermediate sector as firms set the prices one period ahead. Under the producer currency pricing (PCP) the firms fix their prices in the producer currency, and the equilibrium prices solve the following profit maximization problems:

Home Price setting

$$\underset{P_t(h),\varepsilon_t P_t^*(h)}{Max} E_{t-1}Q_{t-1,t}\left\{(P_t(h)-MC_t(h))\left(\frac{P_t(h)}{P_{H,t}}\right)^{-\theta}C_{H,t}+(\epsilon_t P_t^*(h)-MC_t(h))\left(\frac{\varepsilon_t P_t^*(h)}{\varepsilon_t P_{H,t}^*}\right)^{-\theta}C_{H,t}^*\right\}$$

foreign price setting

$$\underset{\frac{P_t(f)}{\epsilon_t},P_t^*(f)}{Max} E_{t-1}Q_{t-1,t}^*\left\{\left(\frac{P_t(f)}{\epsilon_t}-MC_t(f)\right)\left(\frac{\epsilon_t P_t(f)}{\epsilon_t P_{F,t}}\right)^{-\theta}C_{F,t}+(P_t^*(f)-MC_t(f))\left(\frac{P_t^*(f)}{P_{F,t}^*}\right)^{-\theta}C_{F,t}^*\right\}$$

Replacing $(A.4a,\ A.11a,\ A.15a$ and $A.15b)$ in the first order conditions of the Home profit maximization problem and replacing $(A.4b,\ A.9b,\ A.15a$ and $A.15b)$ in the of the Foreign profit maximization problem we obtain:

$$P_{H,t}=\frac{\theta}{\theta-1}E_{t-1}\left[MC_t\right] \qquad (C.1a) \qquad\qquad P_{H,t}^*=\frac{\theta}{\theta-1}\frac{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}MC_t\right]}{\varepsilon_t E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]} \qquad (C.1b)$$

$$P_{F,t}^*=\frac{\theta}{\theta-1}E_{t-1}\left[MC_t^*\right] \qquad (C.2a) \qquad\qquad P_{F,t}=\frac{\theta}{\theta-1}\varepsilon_t\frac{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]}{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}\right]}. \qquad (C.2b)$$

The equilibrium nominal exchange rate is found by replacing $(C.1a)$ and $(C.1b)$ in $(A.19)$:

$$\varepsilon_t=\varphi_t^{PCP}\frac{\mu_t}{\mu_t^*} \qquad (C.3) \qquad \varphi_t^{PCP}=\left[\frac{1+k_0MC_t}{1-k_1MC_t}\right]>1,$$

$$k_0=\frac{\theta-1}{\theta}\frac{(1-\alpha)}{E_{t-1}[MC_t]}>0, \qquad k_1=(1-\alpha)\frac{\theta-1}{\theta}\frac{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}{E_{t-1}\left[MC_t\frac{\mu_t^*}{\mu_t}\right]}>0.$$

As it makes little economic sense to have a negative nominal exchange rate, condition $(C.3)$ sets an upper bound to the magnitude of the oil price shock as $\frac{MC_t}{E[MC_t]}<\frac{\theta}{\theta-1}\frac{1}{(1-\alpha)}\frac{E_{t-1}[MC_t]E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}{E_{t-1}\left[MC_t\frac{\mu_t^*}{\mu_t}\right]}=\frac{1}{k_1}$. It is also plausible to assume $Cov\left[MC_t,\frac{\mu_t^*}{\mu_t}\right]=Cov\left[\frac{P_{e,t}^{1-\alpha}k\mu_{tt}^{\alpha}}{Z_t\alpha^{\alpha}(1-\alpha)^{(1-\alpha)}},\frac{\mu_t^*}{\mu_t}\right]\leq 0$, which amounts to set the following weak restrictions on the joint distribution of the exogenous variables $(Z_t,\mu_t^*,\mu_t):(i)$ Z_t is uncorrelated to both monetary policies and (ii) μ_t^* is not perfectly positively correlated with μ_t.

Proposition 4 *If* $Cov\left[MC_t,\frac{\mu_t^*}{\mu_t}\right]\leq 0$ *then* $k_1\geq k_0$.

Proof. $k_0 = \frac{\theta}{\theta-1}\frac{1}{(1-\alpha)}\frac{1}{E_{t-1}[MC_t]} = \frac{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}{E_{t-1}[MC_t]E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}\frac{\theta}{\theta-1}\frac{1}{(1-\alpha)} = \frac{\theta}{\theta-1}\frac{1}{(1-\alpha)}\frac{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}{E_{t-1}\left[MC_t\frac{\mu_t^*}{\mu_t}\right]-Cov\left[MC_t,\frac{\mu_t^*}{\mu_t}\right]} \leq \frac{\theta}{\theta-1}\frac{1}{(1-\alpha)}\frac{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}{E_{t-1}\left[MC_t\frac{\mu_t^*}{\mu_t}\right]} = k_1.$ ■

To find the equilibrium value of consumption in the home oil importing country we apply $(A.1a)$, $(A.2a)$, $(A.3a)$, $(A.4a)$, $(A.15a)$ and $(C.1a)$, $(C.1b)$ to $C_t = C_{H,t}{}^{\frac{1}{2}}C_{F,t}{}^{\frac{1}{2}}$:

$$C_t = \frac{1}{2}\frac{\theta-1}{\theta}\left(\mu_t\mu_t^*\right)^{\frac{1}{2}}\left(\frac{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}\right]}{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]E_{t-1}[MC_t]}\right)^{\frac{1}{2}}\left(\varphi_t^{PCP}\right)^{-\frac{1}{2}}. \qquad (C.4a)$$

Similarly, to get the equilibrium value of consumption in the oil exporting country we apply $(A.1b)$, $(A.2b)$, $(A.3b)$, $(A.4b)$, $(A.15a)$ and $(C.2a)$, $(C.2b)$ to $C_t^* = \left(C_{H,t}^*\right)^{\frac{1}{2}}\left(C_{F,t}^*\right)^{\frac{1}{2}}$:

$$C_t^* = \frac{1}{2}\frac{\theta-1}{\theta}\left(\mu_t\mu_t^*\right)^{\frac{1}{2}}\left(\frac{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}MC_t\right]E_{t-1}[MC_t^*]}\right)^{\frac{1}{2}}\left(\varphi_t^{PCP}\right)^{\frac{1}{2}}. \qquad (C.4b)$$

Equilibrium employment in the oil importing country is obtained by replacing $(C.3)$ in $(A.19)$:

$$L_t = \frac{\alpha}{2\kappa}\frac{\theta-1}{\theta}\frac{MC_t}{E_{t-1}(MC_t)}\left[\frac{\left[1+\frac{E_{t-1}[MC_t]E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}{E_{t-1}\left[MC_t\frac{\mu_t^*}{\mu_t}\right]}\right]}{1-\frac{\theta-1}{\theta}(1-\alpha)\frac{MC_tE_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}{E_{t-1}\left[MC_t\frac{\mu_t^*}{\mu_t}\right]}}\right], \qquad (C.5a)$$

while employment in the oil exporting country is obtained from applying $(A.4a)$, $(A.4b)$, $(A.13b)$, $(A.15b)$, $(C.2a)$, $(C.2b)$ to $(A.17b)$,

$$L_t^* = \frac{\alpha}{2k}\frac{\theta-1}{\theta}\frac{MC_t^*}{E_{t-1}[MC_t^*]}\left[\frac{1}{\varphi_t^{PCP}}\frac{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}\right]E_{t-1}[MC_t^*]}{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]}+1\right]. \qquad (C.5b)$$

To get E_t, the quantity of oil used in equilibrium in the oil importing country, replace $(C.5a)$ in $(A.13a)$, and similarly for E_t^* replace $(C.5b)$ in $(A.13b)$:

$$E_t = \frac{1-\alpha}{2}\frac{\theta-1}{\theta}\frac{MC_t}{E_{t-1}(MC_t)}\frac{\mu_t}{P_{e_t}}\left[\frac{\left[1+\frac{E_{t-1}[MC_t]E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}{E_{t-1}\left[MC_t\frac{\mu_t^*}{\mu_t}\right]}\right]}{1-\frac{\theta-1}{\theta}(1-\alpha)\frac{MC_tE_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}{E_{t-1}\left[MC_t\frac{\mu_t^*}{\mu_t}\right]}}\right] \qquad (C.6a)$$

$$E_t^* = \frac{1-\alpha}{2}\frac{\theta-1}{\theta}\frac{MC_t^*}{E_{t-1}[MC_t^*]}\frac{\mu_t}{P_{e,t}^*}\left[\frac{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}\right]E_{t-1}[MC_t^*]}{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]}+\varphi_t^{PCP}\right]. \qquad (C.6b)$$

The equilibrium price level of each country is found replacing the equilibrium consumption level, $(C.4a)$ for C_t and $(C.4b)$ for C_t^*, in the corresponding monetary policy stance equation, $(A.15a)$ for the oil importing country and $(A.15b)$ for the oil exporting country:

$$P_t = \frac{2\theta}{\theta-1}\left(\frac{\mu_t}{\mu_t^*}\right)^{\frac{1}{2}}\left(\frac{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}\right]}{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]E_{t-1}[MC_t]}\right)^{-\frac{1}{2}}\left(\varphi_t^{PCP}\right)^{\frac{1}{2}} \qquad (C.7a)$$

$$P_t^* = \left(\frac{\mu_t^*}{\mu_t}\right)^{\frac{1}{2}}\frac{2\theta}{\theta-1}\left(\frac{E_{t-1}[MC_t^*]E_{t-1}\left[\frac{\mu_t^*}{\mu_t}MC_t\right]}{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}\right)^{\frac{1}{2}}\left(\varphi_t^{PCP}\right)^{-\frac{1}{2}}. \qquad (C.7b)$$

Finally, with nominal rigidities and under PCP prices the AS of the oil importing country is obtained by applying $(C.1a)$, $(C.1b)$, $(C.2a)$, $(C.2b)$, $(C.4a)$ *and* $(C.4b)$ *to*$(A.20a)$:

$$AS^{PCP} : C_t = \tau_t^{PCP} L_t\ , \qquad \tau_t^{PCP} = \underbrace{\frac{\kappa\mu_t}{\alpha}\frac{1}{MC_t}}_{Supply\ Channel}\Big[\underbrace{\varepsilon_t^{\frac{1}{2}}\left(\Upsilon_P^{PCP} + \Upsilon_{P^*}^{PCP}\varphi_t^{PCP}\Upsilon_C^{PCP}\right)}_{Trade\ Channel}\Big]^{-1}$$

$$\Upsilon_C^{PCP} = \frac{\left(\frac{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}MC_t\right]E_{t-1}[MC_t^*]}\right)^{\frac{1}{2}}}{\left(\frac{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}\right]}{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]E_{t-1}[MC_t]}\right)^{\frac{1}{2}}}, \qquad \begin{array}{l}\Upsilon_P^{PCP} = \left(\frac{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]}{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}\right]E_{t-1}[MC_t]}\varepsilon_t\right)^{\frac{1}{2}} \\ \Upsilon_{P^*}^{PCP} = \left(\frac{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}MC_t\right]E_{t-1}[MC_t^*]}\varepsilon_t\right)^{\frac{1}{2}}\end{array}.$$

Following a similar procedure, the AS for the oil exporting country is:

$$AS^{PCP} : C_t^* = \tau_t^{*PCP} L_t \quad \tau_t^{*PCP} = \frac{\kappa\mu_t^*}{\alpha}\frac{1}{MC_t^*}\varepsilon_t^{\frac{1}{2}}\left[\frac{1}{\varphi_t^{PCP}\Upsilon_C^{PCP}}\frac{1}{\Upsilon_P^{PCP}} + \frac{1}{\varepsilon^{\frac{1}{2}}\Upsilon_{P^*}^{PCP}}\right]^{-1}$$

Computing the effect of oil price shocks to the oil importing and oil exporting economy

Proposition 5 *In presence of nominal price rigidities and under a PCP Regime a positive (negative) oil price shock depreciates (appreciates) the currency of the oil importing country*

Proof. To prove it, it is sufficient to show that the elasticity of ε_t to the price of oil is positive. From $(C.3)$, $\chi_{\varepsilon_t, P_{e,t}} = (1-\alpha)\, MC_t \frac{k_0+k_1}{(1-k_1 MC_t)(1+k_0 MC_t)} > 0$. ■

Proposition 6 *In presence of nominal price rigidities and under a PCP Regime the impact of an oil price shock to the economy increases more than proportionally to the size of the shock.*

Proof. To prove it, it is sufficient to show that $\chi_{\varepsilon_t, P_{e,t}}$ increases with the size of the oil price shock, $P_{e,t}$. From proposition 5 is easy to obtain:
$\frac{\partial \chi_{\varepsilon_t, P_{e,t}}}{\partial P_{e,t}} = \left(\frac{\partial MC_t}{\partial P_{e,t}}\right)(1-\alpha)(k_0+k_1)\left[(1-k_1 MC_t)(1+k_0 MC_t)\right]^{-2}\left[1+k_0 k_1 MC_t^2\right] > 0.$ ■

Proposition 7 *In presence of nominal price rigidities and under a PCP Regime a positive (negative) oil price shock reduces (increases) the aggregate consumption in the oil importing country.*

Proof. To prove it, it is sufficient to show that the elasticity of consumption of the oil importing country to the price of oil is negative, that is,

given $C_t = k_C \varepsilon_t^{-\frac{1}{2}}$, $k_C = \frac{1}{2}\mu_t \frac{\theta-1}{\theta}\left(\frac{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}\right]}{E_{t-1}[MC_t(h)]E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]}\right)^{\frac{1}{2}} > 0$, it follows that:
$\chi_{C_t, P_{e,t}} = \frac{\partial C_t}{\partial \varepsilon_t}\frac{\partial \varepsilon_t}{\partial P_{e,t}}\frac{P_{e,t}}{C_t}\frac{\varepsilon_t}{\varepsilon_t} = -\frac{1}{2}k_C \varepsilon_t^{-\frac{3}{2}}\frac{\partial \varepsilon_t}{\partial P_{e,t}}\frac{P_{e,t}}{C_t}\frac{\varepsilon_t}{\varepsilon_t} = -\frac{1}{2}C_t \frac{\partial \varepsilon_t}{\partial P_{e,t}}\frac{P_{e,t}}{\varepsilon_t}\frac{1}{C_t} = -\frac{1}{2}\chi_{\varepsilon_t, P_{e,t}}$. ■

Proposition 8 *In presence of nominal price rigidities and under a PCP Regime a positive (negative) oil price shock increases (decreases) the aggregate consumption in the oil exporting country.*

Proof. To prove it, it is sufficient to show that the elasticity of consumption to the price of oil is in the oil exporting country is positive, that is, given
$C_t^* = k_C^* \varepsilon_t^{\frac{1}{2}}$, $k_C^* = \frac{1}{2}\frac{\theta-1}{\theta}\mu_t^*\left(\frac{1}{E_{t-1}[MC_t^*]}\frac{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}MC_t\right]}\right)^{\frac{1}{2}} > 0$, it follows that:
$\chi_{C_t^*, P_{e,t}} = \frac{\partial C_t^*}{\partial \varepsilon_t}\frac{\partial \varepsilon_t}{\partial P_{e,t}}\frac{P_{e,t}}{C_t^*}\frac{\varepsilon_t}{\varepsilon_t} = \frac{1}{2}k_C \varepsilon_t^{-\frac{1}{2}}\frac{\partial \varepsilon_t}{\partial P_{e,t}}\frac{P_{e,t}}{C_t^*}\frac{\varepsilon_t}{\varepsilon_t} = \frac{1}{2}C_t^* \chi_{\varepsilon_t, P_{e,t}}\frac{1}{C_t^*} = \frac{1}{2}\chi_{\varepsilon_t, P_{e,t}} > 0.$ ■

Proposition 9 *In presence of nominal price rigidities and under a PCP Regime after a positive (negative) oil price shock employment in the oil importing country increases (decreases) more than proportionally to the depreciation (appreciation) of the nominal exchange rate.*

Proof. To prove it, it is sufficient to show that the elasticity of the oil importing country employment to the price of oil is positive and larger than the elasticity of the nominal exchange rate to the price of oil. From $(C.5a)$ it follows that $\chi_{L_t, P_{e,t}} = \frac{\partial L_t}{\partial \varepsilon_t}\frac{\partial \varepsilon_t}{\partial P_{e,t}}\frac{P_{e,t}}{L_t} = \frac{\partial L_t}{\partial \varepsilon_t}\frac{P_{e,t}}{L_t}\frac{\partial \varepsilon_t}{\partial P_{e,t}}\frac{P_{e,t}}{\varepsilon_t}\frac{\varepsilon_t}{P_{e,t}} = \frac{\partial L_t}{\partial \varepsilon_t}\frac{P_{e,t}}{L_t}\frac{\varepsilon_t}{P_{e,t}}\chi_{\varepsilon, P_E} = \frac{1}{2\kappa}\frac{\alpha}{1-\alpha}\frac{\mu_t^*}{\mu_t}\frac{\varepsilon_t}{L_t}\chi_{\varepsilon, P_{e,t}} = \frac{\varphi_t^{PCP}}{(\varphi_t^{PCP}-1)}\chi_{\varepsilon_t, P_{e,t}} > \chi_{\varepsilon_t, P_{e,t}}$., as $\frac{\varphi_t^{PCP}}{(\varphi_t^{PCP}-1)} > 1$ ■

Proposition 10 *In presence of nominal price rigidities and under a PCP Regime the larger the size of a positive oil price shock the bigger the probability that employment in the oil exporting country will shrink.*

Proof. It is sufficient to show that the elasticity of foreign employment to the price of oil is positive for oil price shocks of small size but turns negative for oil shocks of large size. From $(C.5b)$ we can compute $\chi_{L^*,P_{e,t}} = \frac{\partial L_t^*}{\partial P_{e,t}} \frac{P_{e,t}}{L_t^*} = (1-\alpha) + \chi_{\varepsilon,P_e} \left[\frac{1}{2} \frac{\left[C_{F,t}^* - C_{F,t}\right]}{\left[C_{F,t}^* + C_{F,t}\right]} - \left(\frac{3}{2} - \alpha\right) \right]$. As $\frac{\left[C_{F,t}^* - C_{F,t}\right]}{\left[C_{F,t}^* + C_{F,t}\right]} < 1$, it follows that $\left[\frac{1}{2} \frac{\left[C_{F,t}^* - C_{F,t}\right]}{\left[C_{F,t}^* + C_{F,t}\right]} - \left(\frac{3}{2} - \alpha\right) \right] < 0$,thus $\chi_{L_t^*,P_{e,t}} < 0$ for $\chi_{\varepsilon_t,P_{e,t}} > \frac{(1-\alpha)}{\left[\left(\frac{3}{2}-\alpha\right) - \frac{1}{2} \frac{\left[C_{F,t}^* - C_{F,t}\right]}{\left[C_{F,t}^* + C_{F,t}\right]}\right]} < (1-\alpha)$. By proposition 6 $\chi_{\varepsilon_t,P_{e,t}}$ increases in the magnitude of the shocks and so the larger the size of the oil price shock the more likely that L_t^* will decrease. ■

The economic intuition behind Proposition 10 comes from considering that oil price shocks affect oil exporting country employment through a supply and a trade channel. From $(A17b)$ and $(A13b)$ we obtain:

$$L_t^* = K_L^* \underbrace{(P_{e,t})^{1-\alpha}}_{Supply\ Effect} \underbrace{\varepsilon_t^{-(1-\alpha)} \left(C_{F,t} + C_{F,t}^*\right)}_{Trade\ channel}, \ K_L^* > 0,$$

where K_L^* is a combination of terms independent of $P_{e,t}$. The supply channel of oil price shocks on L_t^* passes through $P_{e,t}^{1-\alpha}$. As the production function is a Cobb Douglas, the elasticity of substitution of labor for oil is 1, so that after a positive oil price shock firms replace labor for oil. However, as the price of oil is exogenously fixed in Home currency, $P_{e,t}^*$ depends also on ε_t, that is the trade channel contrasts the supply channel. To see let's compute the elasticity of the price of oil in foreign currency to $P_{e,t}$:

$$\chi_{P_{e,t}^*,P_{e,t}} = \frac{\partial\left(\frac{P_{e,t}}{\varepsilon_t}\right)}{P_{e,t}} \frac{P_{e,t}}{P_{e,t}^*} = \frac{\varepsilon_t - P_{e,t}\partial\left(\frac{\varepsilon_t}{P_{e,t}}\right)}{\varepsilon_t^2} \varepsilon_t = (1 - \chi_{\varepsilon_t,P_{e,t}}).$$

It follows that for sufficiently small positive oil price shocks the supply channel increases foreign employment, while for large shocks it decreases it. However, the trade channel affects foreign employment also via a wealth and a substitution effect on the aggregate demand for foreign intermediate goods $\left(Y_{F,t} = C_{F,t} + C_{F,t}^*\right)$. By the wealth effect home households feel poorer, consume less and so lower the demand for foreign intermediate goods $(C_{F,t})$, as opposed to foreign households who feel richer, consume more and so increase the demand for foreign intermediate goods $\left(C_{F,t}^*\right)$. By the substitution effect both Home and Foreign firms in the final good sector switch their demand for inputs from foreign to home produced intermediate goods. The final effect of the trade channel on the aggregate demand for foreign intermediate goods $(Y_{F,t})$ depends on the specific functional forms of preferences and technology. Within the model, the trade channel shrinks $(Y_{F,t})$ for small shocks, while its impact on $(Y_{F,t})$ is ambiguous for large shocks. To prove it let's compute the elasticity of $Y_{F,t}$ to the price of oil. From $(A.1b)$, $(C.2a)$ and $(C.1b)$ we obtain : $C_{F,t}^* = \varepsilon_t^{-\frac{1}{2}} K_{CF}^* C_t^*$, $K_{CF}^* > 0$, where K_{CF}^* is a combination of terms independent of $P_{e,t}$. It follows that:

$$\chi_{C^*_{F,t},P_{e,t}} = \frac{\partial\left(K^*_{CF}C^*_t\varepsilon_t^{-\frac{1}{2}}\right)}{\partial(P_{e,t})}\frac{Pe,t}{C^*_{F,t}} = \frac{1}{2}\chi_{\varepsilon_t,P_{e,t}}\left[\chi_{\varepsilon_t,P_{e,t}} - 1\right] \lesseqgtr 0\ , \quad K^*_{CF} = 2\left(\frac{E_{t-1}\left[\frac{\mu^*_t}{\mu_t}MC_t\right]}{E_{t-1}\left[\frac{\mu^*_t}{\mu_t}\right]E_{t-1}[MC^*_t]}\right)^{\frac{1}{2}} > 0$$

Similarly, from $(A.1a)$, $(C.1a)$ and $(C.2b)$ we obtain : $C_{F,t} = \varepsilon_t^{-\frac{1}{2}}K_{CF}C_t,\ K_{CF} > 0$, and K_{CF} is a combination of terms independent of $P_{e,t}$. It follows that

$$\chi_{C_{F,t},P_{e,t}} = -\frac{1}{2}\chi_{\varepsilon_t,P_{e,t}}\left[\chi_{\varepsilon_t,P_{e,t}} + 1\right] < 0, \quad K_{CF} = 2\left(\frac{E_{t-1}[MC_t]E_{t-1}\left[\frac{\mu_t}{\mu^*_t}\right]}{E_{t-1}\left[\frac{\mu_t}{\mu^*_t}MC^*_t\right]}\right)^{\frac{1}{2}} > 0$$

Thus, the trade channel always reduces the oil importing country demand for oil exporting intermediate goods, while it reduces the oil exporting country demand for oil exporting intermediate goods only sufficiently small shocks (as $\frac{\partial\chi_{\varepsilon_t,P_{e,t}}}{\partial P_{e,t}} > 0$ and $\chi_{C^*_{F,t},Pe,t} < 0$ for $\chi_{\varepsilon_t,P_{e,t}} > 1$). The final effect of oil price shocks on the aggregate demand for Y_F is given by:

$$\chi_{Y_{F,t},P_{e,t}} = \frac{C_{F,t}}{C_{F,t}+C^*_{F,t}}\chi_{C_{F,t},P_{e,t}} + \frac{C^*_{F,t}}{C_{F,t}+C^*_{F,t}}\chi_{C^*_{F,t},P_{e,t}} = \frac{1}{2}\chi_{\varepsilon_t,P_{e,t}}\left[-\frac{C_{F,t}}{C_{F,t}+C^*_{F,t}}\left(1+\chi_{\varepsilon_t,P_{e,t}}\right) + \frac{C^*_{F,t}}{C_{F,t}+C^*_{F,t}}\left(\chi_{\varepsilon\right.\right.$$

APPENDIX D - The symmetric equilibrium with Nominal Price rigidities and LCP Regime

Nominal price rigidities are introduced in the intermediate sector as firms set the prices one period ahead. Under the local currency pricing (LCP) firms in the intermediate goods sector fix the price in the export market in the export market currency, and set the price to solve the following profit maximization problems:

Home Price setting

$$\underset{P_t(h),\varepsilon_t P_t^*(h)}{Max} E_{t-1}Q_{t-1,t}\left\{(P_t(h)-MC_t(h))\left(\frac{P_t(h)}{P_{H,t}}\right)^{-\theta}C_{H,t}+(\epsilon_t P_t^*(h)-MC_t(h))\left(\frac{\varepsilon_t P_t^*(h)}{\varepsilon_t P_{H,t}^*}\right)^{-\theta}C_{H,t}^*\right\}$$

foreign price setting

$$\underset{\frac{P_t(f)}{\epsilon_t},P_t^*(f)}{Max} E_{t-1}Q_{t-1,t}^*\left\{\left(\frac{P_t(f)}{\epsilon_t}-MC_t(f)\right)\left(\frac{\epsilon_t P_t(f)}{\epsilon_t P_{F,t}}\right)^{-\theta}C_{F,t}+(P_t^*(f)-MC_t(f))\left(\frac{P_t^*(f)}{P_{F,t}^*}\right)^{-\theta}C_{F,t}^*\right\}$$

Replacing ($A.4a$, $A.11a$, $A.15a$ and $A.15b$) in the first order conditions of the Home profit maximization problem and replacing ($A.4b$, $A.9b$, $A.15a$ and $A.15b$) in the of the Foreign profit maximization problem we obtain:

$$P_t(h)=P_{H,t}=\frac{\theta}{\theta-1}E_{t-1}\left[MC_t\right] \qquad (D.1a) \qquad P_t^*(h)=P_{H,t}^*=\frac{\theta}{\theta-1}\frac{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}MC\right]}{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\varepsilon_t\right]} \qquad (D.1b)$$

$$P_t^*(f)=P_{F,t}^*=\frac{\theta}{\theta-1}E_{t-1}\left[MC_t^*\right] \qquad (D.2a) \qquad P_t(f)=P_{F,t}=\frac{\theta}{\theta-1}\frac{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]}{E_{t-1}\left[\frac{\mu_t}{\varepsilon t\mu_t^*}\right]}. \qquad (D.2b)$$

The equilibrium nominal exchange rate is found by replacing ($D.1a$) and ($D.1b$) in ($A.19$):

$$\varepsilon_t=\frac{\mu_t}{\mu_t^*}\varphi_t^{LCP}(P_{e,t}) \qquad (D.3)$$

$$\varphi_t^{LCP}(P_{e,t})=\left(1+\frac{\theta-1}{\theta}(1-\alpha)\left(\frac{MC_t}{E_{t-1}[MC_t]}+\varphi^{FLP}\frac{MC_t\frac{\mu_t^*}{\mu_t}}{E_{t-1}\left(\frac{\mu_t^*}{\mu_t}MC_t\right)}\right)\right)>1$$

To find the equilibrium value of consumption in the home oil importing country we apply $(A.1a)$, $(A.2a)$, $(A.3a)$, $(A.4a)$, $(A.15a)$ and $(D.1a)$, $(D.1b)$ to $C_t = C_{H,t}{}^{\frac{1}{2}}C_{F,t}{}^{\frac{1}{2}}$:

$$C_t=\frac{1}{2}\frac{\theta-1}{\theta}\mu_t\left(\frac{1}{E_{t-1}[MC_t]}\frac{E_{t-1}\left[\frac{\mu_t}{\varepsilon_t\mu_t^*}\right]}{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]}\right)^{\frac{1}{2}}. \qquad (D.4a)$$

Similarly, to get the equilibrium value of consumption in the oil exporting country we apply $(A.1b)$, $(A.2b)$, $(A.3b)$, $(A.4b)$, $(A.15a)$ and $(D.2a)$, $(D.2b)$ to $C_t^* = \left(C_{H,t}^*\right)^{\frac{1}{2}}\left(C_{F,t}^*\right)^{\frac{1}{2}}$:

$$C_t^* = \frac{1}{2}\frac{\theta-1}{\theta}\mu_t^* \left(\frac{\varphi^{FP}}{E_{t-1}\left(\frac{\mu_t^*}{\mu_t}MC_t\right)} \frac{1}{E_{t-1}[MC_t^*]} \right)^{\frac{1}{2}}. \qquad (D.4b)$$

Equilibrium employment in the oil importing country is obtained by replacing $(D.3)$ in $(A.19)$:

$$L_t = \frac{\alpha}{2\kappa}\frac{\theta-1}{\theta}MC_t \left(\frac{1}{E_{t-1}[MC_t]} + \varphi^{FLP} \frac{\frac{\mu_t^*}{\mu_t}}{E_{t-1}\left(\frac{\mu_t^*}{\mu_t}MC_t\right)} \right). \quad (D.5a)$$

Employment in the oil exporting country is obtained from applying $(A.4a), (A.4b), (A.13b),$ $(A.15b), (D.2a), (D.2b)$ to $(A.17b)$,:

$$L_t^* = \frac{\alpha}{2\kappa}\frac{\theta-1}{\theta} \left[E_{t-1}\left[\frac{\mu_t}{\varepsilon_t \mu_t^*}\right] \frac{MC_t^* \frac{\mu_t}{\mu_t^*}}{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]} + \frac{MC_t^*}{E_{t-1}[MC_t^*]} \right] \quad (D.5b)$$

To get E_t, the quantity of oil used in equilibrium in the oil importing country, replace $(C.5a)$ in $(A.13a)$, and similarly to get E_t^* replace $(D.5b)$ in $(A.13b)$:

$$E_t = \frac{\kappa\mu_t}{P_{e,t}}\frac{1-\alpha}{2\kappa}\frac{\theta-1}{\theta}MC_t \left(\frac{1}{E_{t-1}[MC_t]} + \varphi^{FLP}\frac{\mu_t^*}{\mu_t}\frac{1}{E_{t-1}\left(\frac{\mu_t^*}{\mu_t}MC_t\right)} \right) \qquad (D.6a)$$

$$E_t^* = \frac{1-\alpha}{2\kappa}\frac{k\mu}{P_{e,t}}\frac{\theta-1}{\theta}\varphi_t^{LCP} \left[E_{t-1}\left[\frac{\mu_t}{\varepsilon_t \mu_t^*}\right] \frac{MC_t^* \frac{\mu_t}{\mu_t^*}}{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]} + \frac{MC_t^*}{E_{t-1}[MC_t^*]} \right] \qquad (D.6b)$$

The equilibrium price level of each country is found replacing the equilibrium consumption level, $(D.4a)$ for C_t and $(D.4b)$ for C_t^*, in the corresponding monetary policy stance equation, $(A.15a)$ for the oil importing country and $(A.15b)$ for the oil exporting country:

$$P_t = \frac{2\theta}{\theta-1}\left(E_{t-1}[MC_t]\right)^{\frac{1}{2}} \left(\frac{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]}{E_{t-1}\left[\frac{\mu_t}{\varepsilon_t\mu_t^*}\right]} \right) \qquad (D.7a)$$

$$P_t^* = \frac{2}{\varphi_t^{LCP}}\frac{\theta}{\theta-1}\left(E_{t-1}\left(\frac{\mu_t^*}{\mu_t}MC_t\right) E_{t-1}[MC_t^*] \right)^{\frac{1}{2}} \qquad (D.7b)$$

Finally, with nominal rigidities and under LCP prices the AS of the oil importing country is obtained by applying $(D.1a)$, $(D.1b)$, $(D.2a)$, $(D.2b)$, $(D.4a)$ *and* $(D.4b)$ *to*$(A.20a)$:

$$AS^{LCP} : C_t = \tau_t^{LCP} L_t \qquad \tau_t^{LCP} = \underbrace{\frac{\kappa\mu_t}{\alpha}\frac{1}{MC_t}}_{Supply\ Channel} \underbrace{\left[\Upsilon_P^{LCP} + \Upsilon_C^{LCP}\Upsilon_{P^*}^{LCP}\right]^{-1}}_{Trade\ Channel}$$

$$\Upsilon_C^{LCP} = \frac{\mu_t^*}{\mu_t}\left(\varphi^{FLP}\frac{\frac{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]}{E_{t-1}\left[\frac{\mu_t^*}{\mu_t}MC_t\right]}}{\frac{E_{t-1}[MC_t^*]}{E_{t-1}[MC_t]}E_{t-1}\left[\frac{\mu_t}{\varepsilon_t\mu_t^*}\right]} \right)^{\frac{1}{2}} \qquad \Upsilon_P^{LCP} = \left(\frac{E_{t-1}\left[\frac{\mu_t}{\mu_t^*}MC_t^*\right]}{E_{t-1}\left[\frac{\mu_t}{\varepsilon_t\mu_t^*}\right]E_{t-1}[MC_t]} \right)^{\frac{1}{2}},$$

$$\Upsilon_{P^*}^{LCP} = \left(\frac{E_{t-1}[MC_t^*]E_{t-1}\left(\frac{\mu_t^*}{\mu_t}\varepsilon_t\right)}{E_{t-1}\left(\frac{\mu_t^*}{\mu_t}MC_t\right)} \right)^{\frac{1}{2}}$$

Computing the effect of oil price shocks to the oil importing and oil exporting economy

Proposition 11 *In presence of nominal price rigidities and under a LCP Regime a positive (negative) oil price shock depreciates (appreciates) the currency of the oil importing country.*

Proof. To prove it, it is sufficient to show that the elasticity of the nominal exchange rate to the price of oil is greater than zero. From D.3,

$$\chi_{\varepsilon_t,P_{e,t}} = (1-\alpha)\frac{\frac{MC_t}{E_{t-1}[MC]}\left(\frac{1}{\varphi FLP}+\varphi_{E,t}\right)}{\left(1+\frac{MC_t}{E_{t-1}[MC]}\left(\frac{1}{\varphi FLP}+\varphi_{E,t}\right)\right)} < (1-\alpha)\,,\ \varphi_{E,t} = \frac{MC_t}{E_{t-1}[MC]}\frac{E_{t-1}[MC]E_{t-1}\left[\frac{\mu_t^*}{\mu_t}\right]}{E_{t-1}\left[MC\frac{\mu_t^*}{\mu_t}\right]} >$$

0. ■

Proposition 12 *In presence of nominal price rigidities and under a LCP Regime in both the oil importing and oil exporting country oil price shocks affect neither the consumption nor the price level*

Proof. To prove it, let's compute the elasticity of C_t and C_t^* to the price of oil. From $(D.4a)$ and $(D.4b)$, $\chi_{C_t,P_{e,t}} = \chi_{C_t^*,P_{e,t}} = 0$. By proposition 3 it follows that $\chi_{P_t,P_{e,t}} = -\chi_{C_t,P_{e,t}} = 0$ *and* $\chi_{P_t^*,P_{e,t}} = -\chi_{C_t^*,P_{e,t}} = 0$. ■

Proposition 13 *In presence of nominal price rigidities and under a LCP Regime a positive (negative) oil price shock increases (decreases) employment in the oil importing country.*

Proof. To prove it, let's compute the elasticity of L_t to the price of oil. From $(D.5a)$. $\chi_{L_t,P_{e,t}} = \frac{\partial L_t}{\partial P_{e,t}}\frac{P_{e,t}}{L_t} = (1-\alpha)\frac{L_t}{P_{E,t}}\frac{P_{e,t}}{L_t} = (1-\alpha)$. ■

Proposition 14 *In presence of nominal price rigidities and under a LCP Regime after a positive (negative) oil price shock employment in the oil exporting country increases (decreases), but by less than the increase in the oil importing country.*

Proof. To prove it, let's compute the elasticity of L_t to the price of oil. From $(D.5b)$. $\chi_{L_t^*,P_{e,t}} = \frac{\partial L_t^*}{\partial P_{e,t}}\frac{P_{e,t}}{L_t^*} = \frac{L_t^*}{P_{e,t}}(1-\alpha)\left(1-\frac{P_{e,t}}{\varepsilon_t}\frac{\partial \varepsilon_t}{\partial P_{e,t}}\right)\frac{P_{e,t}}{L_t} = (1-\alpha)\left(1-\chi_{\varepsilon_t,P_{e,t}}\right) < (1-\alpha) = \chi_{L_t,P_{e,t}}$. ■