ABSTRACT

AL-ABRI, ALMUKHTAR. Essays on Economic Variability, Dynamics of Adjustment, and Exchange Rate Flexibility. (Under the direction of Douglas K. Pearce and Barry K. Goodwin.)

This dissertation revisits the literature on the role of exchange rate flexibility in smoothing the adjustments of the economy to different disturbances. Recently, the role of flexible exchange rates in stabilizing the economy against real shocks has been challenged by the new open economy models, which build on some empirical regularities, such as the low pass-through from nominal exchange rates to import prices. We take three approaches in an attempt to enrich this literature. Firstly, we incorporate factors of production into welfare analyses of fully-specified general equilibrium models. We find flexible exchange rate regimes reduce terms of trade and consumption volatility for primary commodity economies, particularly oil-exporting. Secondly, in an empirical investigation, using a panel Vector Autoregressive Regression of nine of the OECD’s major oil-importing countries and the Reinhart and Rogoff’s de facto classification of exchange rate regimes, we find support for the hypothesis that flexible exchange regimes better absorb oil-price shocks. We also document feedback from the real effective exchange rate and inflation rate to the domestic-currency real oil price shocks, supporting the growing notion that oil price shocks are not purely exogenous to developed economies. Thirdly, in a micro-level empirical investigation, we find a significant improvement in estimating the degree of nominal exchange rate pass-through to import prices when the adjustment costs and the equilibrium degree of pass-through assumptions are considered. More specifically, using a vector threshold cointegration model, we find increases in both the initial reaction and the long-run equilibrium response of import prices to nominal exchange rate changes for five industries in 16 OECD countries, especially for the manufacturing industry.
ESSAYS ON ECONOMIC VARIABILITY, DYNAMICS OF ADJUSTMENT, AND EXCHANGE RATE FLEXIBILITY

By

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Biography

Almukhtar Saif Mohammed Al-Abri was born in Al-Hamra, Oman in 1975. He finished his bachelor of science in economics and finance from Sultan Qaboos University, Oman in 1997. Upon earning his bachelor degree, he was appointed as a Teaching Assistant in the economics and finance department of Sultan Qaboos University, whereby he was awarded a full scholarship by the latter to pursue his graduate studies. In 1999, he earned his master of science in finance from Boston College (Boston, USA). After finishing his master’s degree, Almukhtar returned to his home university to teach before he joined the Ph.D. program at North Carolina State University’s (Raleigh, USA) department of economics in 2001. Upon submission of this dissertation, which was successfully defended in October 2005, Almukhtar will return to his home country, Oman, to join the faculty in the economics and finance department of Sultan Qaboos University as an assistant professor. Almukhtar’s broad research areas are macroeconomics, international economics, and applied econometrics.
Acknowledgments

[All the praises and thanks be to Allah, Who has guided us to this, and never could we have found guidance, were it not that Allah had guided us] The Holy Qur’an, Chapter 7, Verse 43.

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Chapter 1

Introduction

1.1 Exchange rate flexibility: theory and evidence

The emergence of the new open economy macroeconomics has enabled economists to revisit classical problems using an intertemporal micro-based perspective in a fully specified general equilibrium context. One of these classical problems that has recently been questioned by the new open economy macroeconomics is the stabilization role of exchange rate flexibility. Prior to the new open economy macroeconomics, the flexibility of the nominal exchange rate has long been perceived as a cushioning device against the effects of real shocks on aggregate activity due to the rapid relative inter-country price adjustments by the flexible exchange rate. However, this perception is not supported by the recent theoretical studies that use the framework of the new open economy macroeconomics with varieties of assumptions about export-invoicing, price/wage stickiness, policy formation, and agents’ behavior to capture some empirical regularities. Obstfeld
(2002) reviews the challenges of the arguments (based on theoretical modeling and empirical findings) against the stabilizing role of flexible exchange rates. Obstfeld summarizes these challenges in the following points: 1) the long-standing empirical findings of low price elasticities of exports and imports, thus, the trade balance is not responsive to exchange rate changes 2) the assumption of purchasing power parity in modeling international linkages, which permits prices to fully adjust precluding the allocative role for nominal exchange rates, 3) rigid real wages, which renders monetary policy ineffective in affecting the labor market, making the case for fixed exchange rates, 4) the empirical findings of low and slow pass-through from nominal exchange rates to import prices due to local currency pricing and market-segmentations by exporting firms, which undermine the expenditure switching effects of nominal exchange rate changes. These arguments and others gave rise to what is known in the literature as the “disconnect” between nominal exchange rates and economic fundamentals. The issue of a dwindling role for exchange rate flexibility motivated this research.

1.2 Three Approaches

In our attempt to revisit the issues discussed in the previous section, we evaluate the stabilizing role of exchange rate flexibility both theoretically and empirically within the framework of the new open economy macroeconomics. We follow three interrelated approaches. In the second chapter, we analyze the role of exchange rate regimes in the way the economy adjusts to real shocks when the input market, or primary goods market, is incorporated into a fully specified intertemporal general equilibrium model. By focusing on primary-commodity economies, we introduce factors of production into the picture of optimal exchange rate management. The three types of shocks that have received attention in the literature are: nominal
(demand) shocks, real (productivity) shocks, and fiscal shocks. There has been no explicit consideration of supply shocks, both theoretically and empirically, and their effects on economic fluctuations under different exchange rate regimes. We aim to answer the question: Which exchange rate regime can better insulate a primary commodity economy from different patterns of shocks, with explicit attention to oil price shocks?

We use the standard sticky-price stochastic dynamic general equilibrium model developed by Obstfeld and Rogoff (1995). We extend the model of Devereux and Engel (1998) to include three countries. The home country is an oil exporter that also has a nontraded goods sector. There are two foreign countries; each is an importer of oil and has two real sectors: traded and nontraded goods. The sources of uncertainty are random monetary (demand), productivity (real), and oil-price (supply) shocks. We also assume that agents set the nominal price of their products prior to the realization of the shocks, but after the first period, prices adjust fully. We assume two export pricing schemes, producer currency pricing and local currency pricing, for the traded consumption goods. However, for oil, we assume that the oil price is denominated in foreign country one’s currency. By making specific functional form assumptions and allowing shocks to follow log-normal distributions-following the recent literature such as Obstfeld and Rogoff (1998), Bachetta and Van Wincoop (1999), and Devereux and Engel (1998, 2003)-we are able to derive closed-form solutions for the endogenous variables where the stochastic shocks affect both the mean and the variance of these variables. This framework allows us to evaluate the optimality of exchange rate regimes from a welfare maximization standpoint.

We found that the optimal exchange rate regime for an oil-exporting country depends on pricing-schemes of its imports as well as the response of its trading-

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1 Papers are referenced in each chapter respectively.
partners to their productivity shocks and to the oil-price shocks. Under both pricing-schemes, producer currency pricing and local currency pricing, a flexible exchange regime can improve the welfare of home agents provided that the central bank in the home country (oil-exporting country) is able to predict both the shocks and the response of the foreign central banks to these shocks. This does not seem feasible given the current monetary and financial developments in such countries. In other words, the impact of monetary, productivity, and oil price shocks on the utility of agents in an oil exporting county is lower when a fixed exchange rate regime is adopted and at the same time the response of the central bank in this country is passive to these shocks compared to the response of the central bank in the country with which it fixes its currency. We also found that in the case of a fixed exchange rate regime, a basket peg is better than a unilateral peg to a single currency. As one can expect, we also found that the choice of a fixed exchange rate regime for an oil-exporting country is more appealing the more stable is the currency in which oil-price is denominated.

The purpose of the third chapter is to investigate empirically the role of alternative exchange rate regimes in the adjustment mechanism of the economy against oil price shocks in the short and medium terms using a panel of countries. The questions of interest are: In the short-run, does the exchange rate regime matter in insulating the economy from the effects of adverse oil price shocks? How might the behavior of the real exchange rate, output, and inflation be different across exchange rate regimes in the face of these shocks? Which exchange rate regime(s) achieves the necessary adjustment more rapidly?

The recent studies that attempted to test Friedman’s hypothesis that a flexible exchange rate regime can better insulate the economy from real shocks have concentrated on the effect of terms of trade shocks (see Broda (2002), and Edwards
and Levy Yeyati (2003)) on real output under alternative exchange rate regimes. In this chapter, we use oil price shocks instead of the terms of trade shocks. We argue that oil price shocks might be more robust in verifying Friedman’s hypothesis in a way that is more appropriate for exchange rate regime comparisons. This is because, in the short-run, fluctuations in the terms of trade might come from real and nominal shocks. For example, a reduction in the money supply by the Federal Reserve of the US might affect the world economy and hence the terms of trade. In this case, one cannot robustly test for the insulation property of flexible exchange rate regimes since the sources of the shock are not confidently known and the exogeneity assumption cannot be safely assumed. Furthermore, the use of terms-of-trade fluctuations to study the adjustment behavior of the economy for different exchange rate regimes is not immune from the Lucas Critique. This is because certain shocks that affect the terms-of-trade arise under one exchange rate regime might not be observable under others. On the contrary, there is no reason to believe that oil price shocks are different across exchange rate regimes. Moreover, as we have indicated earlier, there is growing support for the argument that the degree of exchange rate pass-through is not the same across different exchange rate regimes. Thus, for the same source of disturbance, the changes in the terms of trade will not be the same across different exchange rate regimes. On the other hand, as documented by a number of studies, oil prices have been the dominant factor causing persistent movements in the terms of trade (see Backus and Crucini (2000), and Amano and Van Norden (1996)).

Since the channels of influence of the oil price shocks may be many, a well-structured empirical model that robustly accounts for all channels might not be attainable. To bypass such an obstacle, we use a panel VAR technique, to test for the impact of oil price shocks on nine major OECD oil-importing countries under alternative exchange rate regimes, after controlling for other factors that might affect
the responsiveness to oil price shocks. We use quarterly observations from 1973Q1 to 2004Q2 for Japan, Germany, France, Italy, South Korea (Korea), Spain, Portugal, Sweden, and Finland.\textsuperscript{2} The endogenous variables of the panel VAR are: the real oil price shocks, the bilateral real exchange rate with the US dollar, a measure of the short-term interest rate, real output growth, and the inflation rate. We found that flexible exchange rate regimes better absorb positive oil price shocks, consistent with Friedman’s hypothesis. The necessary adjustments are made by the nominal exchange rate mostly in the same period as the oil price shocks. We found that under flexible exchange rate regimes, and in response to a one standard deviation positive oil price shocks, both the real exchange rate and output growth show faster speeds of adjustment when returning to their long-run equilibrium relative to the fixed exchange rate regimes. In addition, the inflation rate shows relatively higher contemporaneous increase due to positive oil shocks under fixed exchange regimes. Our results show that monetary policy reactions to the oil price shocks have no significant contribution to the response of the real exchange rate, output growth, and the inflation rate following oil price shocks. These findings have policy implications for emerging economies as they experience a growing industrial sector and more dependence on imported oil.

As noted in the previous section, the proposition of a stabilizing role for flexible exchange rates depends heavily on the assumption that flexible exchange rates can achieve relative price adjustments more quickly. One of the major determinants of this role is the degree of pass-through from nominal exchange rates to import prices. Early estimates of the pass-through from nominal exchange rate to import prices document low and slow pass-through, even at the industry or product level. This low pass-through has triggered rich and growing literature that attempts

\textsuperscript{2} The observations for the members of the European Union covers only the period 1973Q1-1998Q4.
to address the observed low pass-through using fully specified intertemporal general equilibrium models. The use of smooth linear regression models to estimate the degree of pass-through may overlook some of the complexity of the relationship between nominal exchange rates and import prices as suggested by the implications of the intertemporal general equilibrium models indicated above. The nonlinear relationship between changes in the nominal exchange rate and local import prices can also result from frictions such as contracts, transaction costs, menu costs, and other adjustment costs, which preclude price adjustments in the short-run. There has been a growing literature that looked at the determination of the degree of exchange rate pass-through in general equilibrium models with endogenous exchange rates. The findings of these studies suggest an equilibrium rate of pass-through (e.g. Bacchetta and Van Wicoop (2002) and Devereux, Engel, and Storgaard (2003)).

To test this hypothesis, the fourth chapter attempts to re-estimate the degree of pass-through of exchange rate changes to import prices at the aggregate as well as sectoral level by allowing for nonlinear adjustment processes. More specifically, we use a threshold vector cointegration model to account for such nonlinear relationships. By allowing for such processes, we attempt to answer the following questions: a) Can the degree of pass-through be increased when threshold nonlinearity is observed? b) Can we get more insights on the asymmetry in the speed and magnitude of adjustment in import prices to nominal exchange rate changes when threshold nonlinearity is accounted for? Our import prices data sample is that of Campa and Goldberg (2004)-updated for three more years, which consists of industry as well as aggregate level quarterly import prices in local currency for 16 OECD countries from 1975q1 to 2002q2. The data are obtained from the OECD statistical compendium for five sectors: food, energy, raw materials, manufactures, and non-manufacturing products. The nominal exchange rates and
other control variables data are obtained from the International Financial Statistics of the IMF as explained in the data section.

We document a significant threshold cointegrating relationship between the effective nominal exchange rate and import prices for the five industries considered in the sample. By allowing for such nonlinearity in estimating the degree of pass-through from the nominal exchange rates to the import prices, we find that the average degree of pass-through improves dramatically from the 50% average documented in the literature. The results of our threshold cointegration model show that import prices respond faster and by a larger extent to nominal exchange rate shocks compared to models with no threshold cointegration. The findings of this chapter support the hypothesis of an equilibrium rate of pass-through (e.g. Bacchetta and Van Wincoop (2002) and Devereux, Engel, and Storgaard (2003)). They also indicate the significance of accounting for adjustment costs in estimating the relationship between nominal exchange rates and import prices. The chapter finds that the manufacturing industry exhibits a large difference in the degree of pass-through when incorporating threshold cointegration compared to models with no thresholds.

The findings of this chapter suggest that more work needs to be done to emphasize the short-run dynamics in the way import prices respond to nominal exchange rates, possibly through the use of less aggregated data. More evidence of this kind will certainly change the view of the limited stabilizing role for exchange rate flexibility that has appeared in recent new open economy literature. Furthermore, the findings of this study have policy implications for both trade-protection strategies through competitive pricing and monetary policies directed toward inflation targeting especially for countries with relatively large imports.
Chapter 2

Economic Variability and Monetary Policy: The Optimal Exchange Rate Regime for an Oil Exporting Country

2.1 Introduction

The optimal exchange rate regime for one country or a group of countries has been a long-standing issue in the open economy literature. A large body of literature analyzes the choice of exchange rate regimes in the framework of different kinds of shocks hitting the economy. This literature assumes a short-run stabilizing role for the nominal exchange rate in the face of shocks similar to the stabilization achieved by wage-subsidies or taxes. In addition, this literature seem to be focusing on certain assumptions about price/wage rigidities, price-settings (export-invoicing), and some market imperfections (e.g. monopolistic competition), rather than
analyzing the choice of exchange rate regime for different structures of economies (e.g. developed vs. developing economies).

The purpose of this chapter is to investigate the choice of optimal exchange rate regime for a primary-commodity small open economy, a case relevant to a large number of developing countries, where a single primary-commodity dominates exports. By analyzing the transmission of different kinds of shocks under different assumptions of monetary/exchange rate arrangements, the chapter highlights the problems encountered by the central banks in these countries in designing an optimal monetary policy. In addition, by focusing on primary-commodity economies, we introduce factors of production into the picture of optimal exchange rate management. The three types of shocks that have received attention in the literature are: nominal (demand) shocks, real (productivity) shocks, and fiscal shocks. There has been no explicit consideration of supply shocks, either theoretically or empirically, and their effects on economic fluctuations under different exchange rate regimes. The chapter aims to answer the question: Which exchange rate regime can better insulate the economy from an exogenous supply shock? And if there is an adjustment role for the exchange rate; does the structure of the economy matter (i.e. being an exporter of oil as the major source of revenues or an importer of oil as a production input)? An oil-price shock is the appropriate example to study the impact of a supply shock on the economy under alternative exchange rate arrangements. The world economy is sensitive to changes in the price of this vital commodity and all countries are affected by oil-price changes.

We use the standard sticky-price stochastic dynamic general equilibrium model developed by Obstfeld and Rogoff (1995). We extend the model of Devereux and Engel (1998) to include three countries. The home country is an oil exporter that also has a nontraded goods sector. There are two foreign countries, each is an importer of oil and has two real sectors: traded and nontraded goods sectors. The
sources of uncertainty are random monetary (demand), productivity (real), and oil-price (supply) shocks. We also assume that agents set the nominal price of their products prior to the realization of the shocks, but after the first period, prices adjust fully. We assume two export pricing schemes, producer currency pricing and local currency pricing, for the traded consumption goods. However, for oil, we assume that the oil price is denominated in foreign country one’s currency. By making specific functional form assumptions and allowing shocks to follow log-normal distributions-following the recent literature such as Obstfeld and Rogoff (1998), Bachetta and Van Wincoop (1999), and Devereux and Engel (1998, 2003); we are able to derive closed form solutions for the endogenous variables where the stochastic shocks affect both the mean and the variance of these variables. This framework allowed us to evaluate the optimality of exchange rate regimes from a welfare maximization standpoint.

We found that the optimal exchange rate regime for an oil-exporting country depends on pricing-schemes of its imports as well as the response of its trading-partners to their productivity shocks and to the oil-price shocks. Under both pricing-schemes, producer currency pricing and local currency pricing, a flexible exchange regime can improve the welfare of home agents provided that the central bank in the home country (oil-exporting country) is able to predict both the shocks and the response of the foreign central banks to these shocks. This does not seem feasible given the current monetary and financial developments in such countries. In other words, the impact of monetary, productivity, and oil price shocks on the utility of agents in an oil exporting county is lower when a fixed exchange rate regime is adopted and at the same time the response of the central bank in this country is passive to these shocks compared to the response of the central bank in the country with which it fixes its currency. We also found that in the case of a fixed
exchange rate regime, a basket peg is better than a unilateral peg to a single currency. As one can expect, we also found that the choice of a fixed exchange rate regime for an oil-exporting country is more appealing the more stable is the currency in which oil-price is denominated.

The rest of the chapter is organized as follows. Section 2 reviews the previous studies that are related to this research theme. Section 3 lays out the model and its assumptions. Section 4 presents the solution of the model under different pricing schemes. Section 5 compares the welfare results under fixed and flexible exchange rate regimes. In addition, it considers the factors that affect the level of welfare under a flexible relative to a fixed exchange regime, and the relationship between central bank response to different shocks and welfare across exchange rate regimes. Some conclusions follow.
2.2 Review of Previous Studies

The literature on the response of the economy to different patterns of shocks under alternative exchange rate regimes is often referred to as “the stabilization policies in open economies”. The early contributions in this literature date back to Friedman (1953) who suggested that in the world of sticky prices the nominal exchange rate could be used to insulate the economy against real shocks, making the case for flexible exchange regimes. This idea was formally developed by the seminal work of Mundell (1961) and Fleming (1962), and the later additions by Dornbusch (1973). Since then, the Mundell-Fleming-Dornbusch (MFD) model of open economies has been the workhorse for the majority of the extensions on the issue of shocks and economic performance. However, the last decade has witnessed significant developments in the open economy literature by virtue of the microeconomic perspective or “new open economy”. The major development with respect to the literature of exchange rates is the introduction of the “two-good, two-country model of the exchange rate” by Obstfeld and Rogoff (1995), which is known as the Redux Model. We now take both the MFD and the Redux Models in turn.

2.2.1 Stabilization policy using the MFD models

The typical model in this literature is that of a small open economy that is hit by real and/or monetary domestic and/or foreign shocks. The objective is to choose the optimal monetary regime, and hence exchange rate regime, from a short-run stabilization point of view. As discussed by Marston (1985), the progress of the literature on stabilization can be classified into three categories: 1) Capital mobility. The early work on stabilization (those of Mundell and Fleming) has emphasized the

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3 In this section, we follow Genberg (1989) in his excellent review of this literature.
importance of international financial linkages. The assumption of the degree of capital mobility is crucial for the results of any open economy model. During the time when Mundell and Fleming introduced their models, international capital mobility was low or non-existent. However, there has been a dramatic change in the degree of capital mobility between then and now. 2) Wages and price flexibility. The early work of Mundell and Fleming assumed rigid wages. However, many recent studies have replaced the rigid wage assumption with various forms of wage flexibility. 3) Rational expectations. The rational expectations hypothesis has been incorporated into the literature to assess the effectiveness of stabilization policy. That is, the issue of stabilization policy has been studied with the “new classical macroeconomics” which assumes long run wage and price flexibility and develops a formal treatment of expectations.

2.2.2 Basic MFD analysis
Shocks in terms of their nature are classified as real or financial (nominal) shocks and in terms of their origin as domestic or external shocks. For domestic disturbances, the central result of MFD model is that, in a small open economy with perfect capital mobility and rigid wages, a fixed exchange regime is preferable if domestic monetary disturbances are dominant. This result is illuminated in the theoretical literature as follows: when the exchange rate is fixed, the money supply is endogenous (to keep the nominal exchange rate fixed at its parity). If there is a nominal shock to the economy, for instance, a money demand shock (or a corresponding money supply shock), then the monetary authority will instantly accommodate the shock through foreign exchange intervention. The net effect is no change in output and only a change in foreign exchange reserves (assuming a sterilized intervention). Under a flexible exchange rate regime, a monetary expansion for instance will result in a depreciation of the domestic currency and to
an increase in output. However, when shocks are real, for example, a positive domestic aggregate demand disturbance, under a flexible exchange rate regime, the nominal exchange rate will adjust to the shock leading to changes in the trade balance that will offset the initial real disturbance. The net effect is no change in total output, only a change in the composition of output. Under a fixed exchange rate regime, aggregate demand disturbances will result in higher output changes.

The above propositions were presented with no reference to any aggregate supply functions. When an aggregate supply function is added along with the assumption of wage indexation, the above propositions still hold only when there is a monetary shock. However, when there is only a real disturbance, the optimal regime is not a flexible exchange rate; the optimal regime will depend on the degree of wage indexation. A further complication is added with the development of the rational expectations hypothesis. In rational expectations models with wages temporarily fixed due to contract lags, the above propositions continue to hold provided that the disturbances are unanticipated. However, when wages are indexed to prices, then the exchange rate regimes show no difference in terms of the response of output to both the monetary and real disturbances.

2.2.3 Foreign disturbances

For foreign (external) disturbances, the traditional argument is that flexible regimes are superior in terms of insulating the economy from such disturbances. However, as discussed in the literature, this insulation feature of flexible regimes is only valid in special cases. As pointed out by Flood (1981), to analyze the impact of foreign disturbances on the domestic economy, it is necessary to trace these disturbances through the foreign economy. We should illustrate here the three key transmission

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4 This effect is called “expenditure-switching” and has been debated in the recent literature due to the export-invoicing issue. For a summary on this debate see Obstfeld and Rogoff (2000).
mechanisms, discussed in international economics textbooks, whereby macroeconomic disturbances in one country can spill over to other countries: 1) the income-expenditure channel resulting from the trade balance: this channel is more important for countries with relatively larger trade balance—the proportion of a country’s trade relative to its GNP; 2) the interest rate and capital account channel through which monetary impulses in one country may be transmitted to other countries: this channel will depend on the degree of capital mobility and the economic integration between the real and the monetary sectors; 3) the terms-of-trade channel: relative price adjustments will spill over from one country to another through movements in the terms-of-trade, this channel will depend on the degree of price flexibility and on the country’s degree of wage indexation. Thus, a decrease in money demand abroad or an increase in money supply, although it originates as a monetary disturbance, it becomes both a real and a nominal disturbance when it hits the domestic economy. In this case, the flexible exchange regime does not fully insulate the economy from such shocks.

The following exercise illustrates the analysis of foreign disturbances using the original two countries MFD model with the small country assumption. Consider an increase in the domestic money supply, under a flexible exchange rate regime; the increase in money supply will decrease the domestic interest rate. The fall in the interest rate will cause the domestic output to expand. The expansion of domestic output spills over as an expansion of foreign output through the marginal propensity to import (income channel). The higher foreign output will increase the foreign interest rate (the monetary channel).

In the literature, one case is presented in which the flexible exchange rate regime can insulate the economy from the foreign monetary disturbance, the case where the law of one price is prevailing (perfect substitutability between domestic and foreign goods) and full wage indexation is present. When the foreign
disturbance approaches the domestic economy as a real shock alone (causing movement in aggregate demand), then under a flexible exchange rate regime, currency appreciation or depreciation will cause the trade balance to adjust so that the external shock is offset. In summary, the traditional argument of the insulation feature of flexible exchange regimes cannot be generalized.

2.2.4 Extensions to the MFD model

The above analyses were also presented in the literature as extensions to the open economy case of the influential article of Poole (1970), which analyzed the choice between a monetary policy aimed at stabilizing the interest rate and one aimed at stabilizing the money supply using an IS-LM framework when the economy is disturbed by monetary and/or real shocks. In most of the literature that emerged using Poole’s model, the stochastic version is used where the information set is incomplete and the underlying shocks to both the IS and LM functions are unobservable. The objective function, in the extension of Poole’s model to the open economy, is to choose the exchange rate regime that minimizes a weighted sum of output and inflation variances. The results of such models resemble those of the MFD models. In Poole’s model, if the objective of monetary policy is to stabilize real output, then a fixed exchange rate is optimal if monetary shocks alone are present. If real shocks occur, then a flexible exchange rate is better. In other words, when the variance of the LM shock is larger relative to the variance of the IS shock, a fixed exchange rate regime is superior and in the reverse case, a flexible exchange rate regime is superior. As in the analysis of MFD models, these conclusions have to be modified somewhat when some of the restrictive assumptions underlying the model are relaxed. The adoption of Poole’s analysis has allowed researchers to consider several interesting questions. Aizenman and Frankel (1985) suggested that a pure floating exchange rate regime is always preferable over a fixed regime if wage
indexation is optimal, based on a loss function that was derived from explicit welfare criteria. Also, Genberg (1989) showed that the optimal degree of intervention in the foreign exchange market depends on the degree of wage indexation in the economy. These studies and others are based on the intuition that with wages indexed to the exchange rate, output variability can considerably be reduced because exchange rate movements can be used to induce shocks hitting the economy.

There have been many attempts to extend the original MFD model to overcome the limitations of the models, such as the formation of expectations, the aggregate supply dynamics, the role of government debt, etc. The major extensions are: the Liverpool model, which is new classical, Minford et al. (1986), and the Taylor model, which is New Keynesian, Taylor (1988). Although, these two models incorporated the rational expectations hypothesis, they supported the results of the MFD model. The seminal contribution in the study of the stabilization policy was that of Mckibbon and Sachs (1991) who developed a numerical simulation model (often referred as the McKibbon-Sachs global-MSG) that provide tractable solutions when different patterns of shocks are considered under alternative assumptions. The model includes the dynamics, expectations, and aggregate supply considerations. Surprisingly, the results of the MSG model resemble those of the MFD model given the wage settings and exchange rate regimes. The MSG model is regarded as a dynamic general equilibrium model of a multi-region world economy.

2.2.5 Stabilization policy using new open economy models

The development of the new open macroeconomy models-NOM (dynamic optimizing or intertemporal models that explicitly specify microfoundations and general equilibrium closures) allowed economists to approach the stabilization
issues from a micro-perspective. However, the new open macroeconomy models did not substantially change the insights provided by the MFD type of models. Similar to the MFD models, the predictions of NOM models depend largely on the standard parameters: the utility functions, the nature of the price adjustment process, and the characteristics of analyzed shocks. The advantage of the NOM models over the FMD models is the ability of the former to allow for an explicit welfare analysis. The FMD models use *ad hoc* criteria to evaluate the variance of output and prices when different shocks are encountered. However, due to the structure of the intertemporal models, the impacts of these shocks are traceable through intertemporal substitution in consumption, production, and investment. In addition, the intertemporal models allow the distinction among four types of shocks: transitory or persistent in duration and country-specific or common across countries.

An excellent review of the new open economy literature was provided by Lane (2000). The workhorse of most analyses of exchange rates using the new open economy models is the Redux Model developed by Obstfeld and Rogoff (1995). The Redux Model is an open-economy dynamic general equilibrium model that incorporates imperfect competition and nominal rigidity. It allows welfare analysis of different monetary policies/exchange rate regimes. As Lane (2000) put it “…allowing for nominal rigidities and market imperfections alters the transmission mechanism of shocks and also provides a more potent role for monetary policy.” One of the interesting contrasts of the Redux Model from the MFD model is the refutation of the exchange rate overshooting proposition that was attributed to unanticipated permanent increases in the domestic money supply.

In a series of papers, Devereux and Engel (1998, 1999, and 2003) sharply altered the positive and normative analysis of alternative exchange rate regimes
when they analyzed the role of price-setting (whether prices are set in the currency of producers or the currency of consumers) when the economy is subject to monetary shocks. In these papers, they differentiated between three kinds of price-setting: Producer-Currency Pricing, Local-Currency Pricing, and Pricing to Market. They found that the choice between fixed and flexible exchange rate regime depends largely on export-invoicing or price-setting. For example, they found that under flexible exchange rates and pricing to market, foreign monetary shocks do not affect domestic consumption. However, when prices are set in the producers’ currencies, the prices paid by home residents for foreign goods changes as the exchange rate changes. By focusing on monetary shocks only, the work of Devereux and Engel cannot be generalized to wider economic settings where the economy’s equilibrium is subject to different kinds of shocks (demand, real, supply shocks).

On a welfare basis, Devereux (2004) developed a model in which the feature of the flexible exchange rate regime as a shock absorber, in face of shocks to world demand for the country’s good, is not desirable. The argument is that with incomplete international financial markets, the natural rate of employment is inefficient. That is, in these circumstances, the natural rate does not respond enough to demand shocks. On the other hand, a fixed exchange regime is more desirable since it allows “…a more efficient composition of consumption between home and foreign goods”.

This glance at the stabilization literature indicates that the optimal exchange rate regime is neither a firmly fixed exchange rate nor a freely floating rate. The optimal exchange rate regime will depend crucially on the degree of capital mobility, the formation of exchange rate expectations, the nature and origin of shocks, the size and structure of the economy, and the flexibility of wages and the price level. This implies that the information requirement for choosing an exchange
regime based on the stabilization criteria is overwhelming, suggesting that there is no operationally useful rule. Genberg (1989) suggests that for stabilization purposes, the optimal exchange rate regime is a managed float monetary rule, where the money supply reacts to exchange rates, interest rates and other indicators that convey information about the shocks that hit the economy. However, the proposed optimal monetary rule depends in a very sophisticated way, again, on the nature of the shocks and the size and structure of the economy.

The above summary shows the advantage of empirical models through which we can evaluate the net effect of the three transmission channels (income, monetary, and price) discussed above. The theoretical models, such as the MFD model, can only sign the partial derivative of each of the channels on its own. For example, the income channel implies positive spillovers and the monetary channel implies negative spillovers. However, the net effect of these channels is not clearly spelled out. The empirical models can overcome this drawback by providing numerical weights for the positive and negative spillovers. To illustrate, take for example a transitory fiscal expansion in the home country, holding expectations about the future interest rates constant and assuming price rigidity, which will shift the IS curve upward, raising the level of output and hence the domestic real interest rate. In a flexible exchange regime, the rise in the interest rate must result in an appreciation of the nominal exchange rate. As a result, the trade balance will deteriorate for two reasons: the increase in output will raise imports and the appreciation of the domestic currency will hurt exports. On the other hand, under a fixed exchange rate regime, the domestic currency is not allowed to appreciate. Also, interest arbitrage will ensure equality between domestic and foreign interest rates. The increase in output will reduce the trade balance. Thus, under both regimes, the trade balance will deteriorate, but the extent is uncertain. This simple
example demonstrates the importance of the empirical analysis. As Taylor (1993) has put it “…policy evaluation results cannot be obtained from purely theoretical considerations. They depend on the empirical nature of the economic relations and on the size and correlations of the shocks to these relations”.
2.3 The Model

We follow the base models developed by Obstfeld and Rogoff (1995, 1996) and the later extensions by others (e.g. Devereux and Engel (1998, 2003), and Corsetti and Pesenti (2001)). Our model considers three countries: one home country and two foreign countries, where the home country is assumed to be small and the two foreign countries are assumed to be large. The home country produces one local non-traded composite good and exports one primary commodity, oil, and imports and consumes a traded composite good, which is produced in the two foreign countries, and its local composite nontraded good. The home country is small so that it is a price taker in both the primary commodity market and the traded composite consumption good market. Each of the two foreign countries (stands here for the rest of the world) produces two goods, a composite consumption good, which is consumed by the three countries, and a local nontraded consumption good. The two foreign countries import the primary commodity, oil, from the home country.

2.3.1 Consumers and preferences

Following the standard models developed by Obstfeld and Rogoff (1995, 1996), we assume that households in the three countries get utility by consuming the composite traded and non-traded consumption goods and holding real money balances, which provide them with liquidity services. The utility function exhibits also the disutility of efforts or labor. We assume that the home country’s money is held only by the home agents and the foreign countries’ monies only by the foreign agents. Each country has an infinitely lived representative household with identical preferences over a composite consumption good that is produced in the two foreign countries only and a composite local-nontraded consumption good that is produced
in each country for local consumption. At any particular time $t$ the home and the foreign households maximize the sum of their discounted expected one period utilities. The present discounted value of lifetime utility of a domestic resident is

$$U_t = E_t \sum_{i=0}^{\infty} \beta^t \left[ u(C_t) + \chi v \left( \frac{M_t}{P_t} \right) - \zeta(L_t) \right]$$

(2.1)

where $E_t$ is the expectation operator given the information available at the beginning of period $t$. $\beta$ is the intertemporal discount factor. $\chi$ is the weight of real balances in the agent’s utility. $M_t$ denotes the nominal money stock that the individual acquires at the beginning of period $t$ and then holds through the end of the period. $P_t$ is the consumption price index which is defined below. The same preferences are valid for the two foreign countries’ representative agent. For example, the utility function of the representative agent in the first foreign country is

$$U_{t}^{F1} = E_t \sum_{i=0}^{\infty} \beta^t \left[ u(C_t^{F1}) + \chi v \left( \frac{M_t^{F1}}{P_t^{F1}} \right) - \zeta(L_t^{F1}) \right]$$

(2.2)

The standard assumptions about the utility function are maintained (i.e. the utility function is strictly concave and twice continuously differentiable). Assume further the Inada conditions and both the consumption and real money balances are normal goods. In the following, we will use the superscripts $F1$ and $F2$ to differentiate the two foreign countries variables from their home country counterparts.

We assume that all individuals in our model are indexed by $j \in [0,1]$. The interval $j \in [0,n_1]$ consists of agents in the home country; each receives oil revenue from her government and produces a non-traded consumption good $z' \in [0,n_1]$. The intervals $j \in (n_1,n_2)$ and $j \in (n_2,1]$ consist of foreign agents in foreign country one and foreign country two respectively; each of whom produces two goods, a traded
consumption good \( z \in (n_1, n_2) \) and \( z \in (n_2, 1] \), and a non-traded consumption good \( z' \in (n_1, n_2) \) and \( z' \in (n_2, 1] \) respectively. The real consumption index for the home agent is

\[
C_t(j) = \frac{C_{T,j}(j)^\gamma C_{N,j}(j)^{1-\gamma}}{\gamma^\gamma(1-\gamma)^{1-\gamma}}
\]  

(2.3)

where \( C_{T,j}(j) \) denotes the home agent’s consumption index of traded goods and \( C_{N,j}(j) \) denotes the home agent’s consumption index of nontraded goods. The same thing is valid for the foreign agent’s consumption indexes in the two foreign countries. We assume here that agents in the three countries consume the same basket of traded and nontraded goods. We also assume that the elasticity of substitution between the composite goods of traded and nontraded goods and the elasticity of substitution between the traded goods of foreign country one and foreign country two are both unity. The consumption indexes of traded goods, and local nontraded goods are each defined as follows

\[
C_{T,j}(j) = \left[ \frac{1}{n_{F_1}} \int_{n_1}^{n_2} c_{T,F_1}^F(z)^{\phi \frac{1}{\phi-1}} dz \right]^{\frac{\phi}{\phi-1}} \\
C_{T,j}(F_1, j) = \left[ \frac{1}{n_{F_2}} \int_{n_2}^{n_1} c_{T,F_2}^F(z)^{\phi \frac{1}{\phi-1}} dz \right]^{\frac{\phi}{\phi-1}}
\]  

(2.4)

\[
C_{N,j}(j) = \left[ \frac{1}{n_H} \int_{0}^{n_1} c_{N,j}^F(z')^{\phi \frac{1}{\phi-1}} dz' \right]^{\frac{\phi}{\phi-1}}
\]  

(2.5)

\[
C_{N,j}(F_1, j) = \left[ \frac{1}{n_{F_2}} \int_{n_2}^{n_1} c_{N,F_2}^F(z')^{\phi \frac{1}{\phi-1}} dz' \right]^{\frac{\phi}{\phi-1}}
\]  

(2.6)

\[
C_{N,j}(F_1, j) = \left[ \frac{1}{n_{F_1}} \int_{n_2}^{n_1} c_{N,F_1}^F(z')^{\phi \frac{1}{\phi-1}} dz' \right]^{\frac{\phi}{\phi-1}}
\]  

(2.7)
where $c_{T,F1}(z), c_{T,F2}(z)$, and $c_{N,F}(z')$ are the home consumption of traded good $z$ produced at foreign country one and foreign country two and nontraded good $z'$ respectively. Foreign country one counterparts are defined analogously. $C_{T,j}(F1, j)$ and $C_{T,j}(F2, j)$ are the consumption of the home agent of the composite traded consumption goods produced in foreign country one and two respectively.

$\eta = \frac{n_{F1}}{n_{F1} + n_{F2}}$ is the proportion of trade consumption goods imported from foreign country one. The above consumption functions exhibit the constant-elasticity-of-substitution (CES), where $\phi$ is the price elasticity of demand faced by each monopolist and equal to the elasticity of substitution between distinct goods of a given composite good. We assume that $\phi > 1$ to ensure interior equilibrium with a positive output level. We henceforth omit the use of the index $j$ for simplicity.

Let $P_{T,F}(z), P_{T,F1}(z)$, and $P_{T,F2}(z)$ denote the home-currency and the two foreign-currencies price of the traded good $z$ produced by the two foreign countries. And let $P_{N,F}(z')$ denote the home-currency price of the local-nontraded good $z'$ produced by the home agent. Similarly, $P_{N,F1}(z')$ and $P_{N,F2}(z')$ denotes the foreign-currencies price of the local-nontraded good $z'$ produced by each of the two foreign countries. The consumption-based home and foreign price indexes are then given by

$$P_t = (P_{T,F})^\gamma (P_{N,F})^{1-\gamma}$$

$$P_t^{F1} = (P_{T,F1})^\gamma (P_{N,F1})^{1-\gamma}$$

$$P_t^{F2} = (P_{T,F2})^\gamma (P_{N,F2})^{1-\gamma}$$

(2.8)$^5$

where $P_{T,F}$ is the home-currency price of one unit of the composite consumption good and $P_{N,F}$ is the home-currency price of one unit of the local-nontraded good

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$^5$ The derivations of these price indexes are provided in Obstfeld and Rogoff (1996, Ch. 10).
produced by the home country. The price indexes for the home country are given by (the indexes for foreign country 1 and foreign country 2 follow analogously)

\[
P_{T,F}(F1) = \left( \frac{1}{n_{F1}} \right) \int_{a1}^{n1} \left[ S_{F1} P_{T,F}^{F1}(z) \right]^{-\phi} dz \right]^{1/1-\phi}, \quad P_{T,F}(F2) = \left( \frac{1}{n_{F2}} \right) \int_{a2}^{n2} \left[ S_{F2} P_{T,F}^{F2}(z) \right]^{-\phi} dz \right]^{1/1-\phi} \tag{2.9}
\]

\[
P_{N,F} = \left( \frac{1}{n_{H}} \right) \int_{0}^{n1} P_{N,F}^{(z')} (z')^{-\phi} dz' \right]^{1/1-\phi} \tag{2.10}
\]

Since we assume identical individuals who solve the same allocation problem, we can aggregate prices as \( P_{T,F}^{F1} = P_{T,F}(z) \) and \( P_{T,F}^{F2} = P_{T,F}(z) \), which allows us to define

\[
P_{T,F} = \left( S_{F1}^{F1} P_{T,F}^{F1} \right)^{\eta} \left( S_{F2}^{F2} P_{T,F}^{F2} \right)^{-\eta} \tag{2.11}
\]

Where: \( \eta = \frac{n_{F1}}{n_{F1} + n_{F2}} \) as previously defined.

The home agents’ demand for the traded consumption good \( z \) is given by\(^6\)

\[
c_{T,F}(z) = \gamma \left( \frac{P_{T,F}(z)}{P_{T,F}} \right)^{-\phi} \left( \frac{P_{T,F}}{P_{T,F}} \right) C_{t} \tag{2.12}
\]

Using the law-of-one-price condition and taking a population-weighted average of the home country’s and the two foreign countries’ demands, we find the total demand for traded good \( z \) is

\(^6\) The derivation is provided in Appendix A.
\[ y_{T,t}^d(z) = \left( \frac{P_{T,t}(z)}{P_t} \right)^\phi C_{T,t}^W \]  

(2.13)

where \( C_{T,t}^W \) is the total consumption of the traded goods in the three countries. The home agents’ demand for local nontraded good \( z' \) is given by,

\[ c_{N,t}(z') = \left( \frac{P_{N,t}(z')}{P_{N,t}} \right)^\phi \frac{P_t}{P_{N,t}} C_t \]  

(2.14)

To obtain closed-form solutions, we need to specify a functional form for the utility function. We assume that \( u(C_t) \) exhibits a constant relative risk aversion (CRRA) with degree of risk aversion \( \rho \), that is

\[ u(C_t) = \frac{C_t^{1-\rho}}{1-\rho} \]

Also, the utility of the real money balances takes the logarithmic form

\[ v(M_L) = \log\left( \frac{M_L}{P_t} \right) \]

Efforts enters the utility function in a linear form

\[ \zeta(l_t) = L_t \]

2.3.2 Production technologies

The home agent \( j \) produces only one good, the local nontraded good \( z' \in [0, n_t) \), where the only input is labor. That is,

\[ Y_{N,t}(z') = \theta_t L_{N,t}(z') \]  

(2.15)
where $\theta_t$ denotes the home country-specific productivity shock to non-traded technology. $L_N$ is the employment of labor in nontraded good production. In addition, the home agent receives her share from oil revenue, where oil is uniquely endowed in the home country. We assume first that the market for oil is perfectly competitive. In this case, the price of oil, denoted by $P^{O_F}_{0,j}$, is exogenously determined outside the home country and, we further assume that it is denominated in the currency of foreign country one. In terms of home currency, the nominal revenue of a home agent from production (oil and finished non-traded goods) is

$$R_t = S^{f_1} P^{O_F}_{0} Q^H (z) + P_{N,t} (z') Y_{N,t} (z')$$

We assume that the home country redistributes its oil revenue among its people in lump-sum payments. In the real world, the supply of any internationally traded commodity is influenced by many factors. To keep our model as simple as possible, we assume that the home country takes the price of oil as given and exports the quantity of oil that meets the foreign country’s demand for oil. For simplicity, we assume the cost of extracting oil is zero. More realistic modeling of oil supply should take into consideration the oligopolic structure of the oil market. That is, oil supply shocks can be decomposed into price and quantity shocks. The quantity of oil supplied has two separate components: a deterministic component that relates to OPEC announced production and a stochastic component that refers to non-OPEC members. In this research, we focus on price shocks and assume that quantity shocks are minimal.

The foreign agent $j$ (in each of the two foreign countries) produces two goods, a traded consumption good $z$ and a local nontraded good $z'$. For the production of
the traded consumption good, we assume for the moment that the only inputs are oil and labor and that the foreign agent has monopoly power in producing this good. To introduce price rigidity into the model, we assume that prices are set one period in advance and before information about the foreign and home countries money supplies is known. We further assume that capital stock is constant. Thus, the analyses of this study best characterize the short to medium term. The production function of traded good $z$ produced by a foreign agent takes the form

$$Y_{T,t}^{F1}(z) = \theta_t^{F1} O_t^{F1}(z) \alpha L_{T,t}^{F1}(z)^{1-\alpha} \quad 0 < \alpha < 1$$

where $O_t^{F1}(z)$ is the quantity of oil imported from home country and used for the production of good $z$. $L_{T,t}^{F1}(z)$ is labor employment in the production of traded good $z$. The demand for oil can be solved from the foreign agent’s problem (see Appendix B), which is:

$$O_t^{F1}(z) = \left( \frac{\alpha}{1-\alpha} \right)^{1-\alpha} \left( \frac{P_t^{F1}}{P_t^{0}} \right)^{\alpha} \left( \frac{C_t^{F1}}{\theta_t^{F1}} \right) \left( \frac{Y_{T,t}^{F1}(z)}{\theta_t^{F1}} \right)$$

The production of local nontraded good $z'$ is identical to that of the home agent, which takes the form

$$Y_{N,t}^{F1}(z') = \theta_t^{F1} L_{N,t}^{F1}(z')$$

Thus, in terms of foreign currency, the revenue of an agent in foreign country one is

$$R_t^{F1} = P_{T,t}^{F1}(z) Y_{T,t}^{F1}(z) + P_{N,t}^{F1}(z') Y_{N,t}^{F1}(z')$$
We can see that the home country and each of the two foreign countries are asymmetric in terms of their revenue from production activities. The resource constraints that equate the quantities demanded and supplied of each good are:

\[
Y_{N,j}(z') = \int_0^{n1} c_{N,j}^j(z')dj 
\]  
(2.21)

\[
Y_{T,j}^{F1}(z) + Y_{T,j}^{F2}(z) = \int_0^{n1} c_{T,j}^j(z) dj + \int_{n1}^{n2} c_{T,j}^j(z) dj + \int_{n2}^1 c_{T,j}^j(z) dj 
\]  
(2.22)

\[
Y_{N,j}^{F1}(z') = \int_{n1}^{n2} c_{N,j}^j(z') dj 
\]  
(2.23)

2.3.3 **Introducing price rigidity**

To introduce the simplest form of price rigidity into the model, we assume that agents choose the nominal price of their goods, traded and nontraded, one period in advance and before information about monetary, productivity, and oil-price shocks are realized. Prices fully adjust to all shocks after one period. One could justify this rigidity of prices as an institutional constraint such as menu costs. We should distinguish here between two schemes of export invoicing or price settings, producer currency pricing and local currency pricing.

**Producer currency pricing.** Under producer currency pricing, each producer sets the price of the traded good \( z \) in her own currency. In this case, the optimal price setting is (Appendix B):

\[
P_{T,j}^{F1}(z)_{PCP} = \left( \frac{\phi}{\phi - 1} \right) E_{t-1} \left[ \left( \frac{P_{o,j}^{F1}}{\theta_{o,j}^{F1} \alpha^a (1 - \alpha)^{1-a}} \right) \left( P_{o,j}^{F1} \right)^a \right] \]  
(2.24)
We can see that foreign country one does not face any exchange rate risk in pricing its traded goods since it imports oil in its own currency and exports its finished goods in its own currency too. The same thing is not true for foreign country two. It is exposed to exchange rate risk because it imports oil denominated in foreign country one’s currency.

**Local currency pricing.** However, under local currency pricing, each producer of traded good \( z \) sets the price of her good in the currency of the buyer. In this case, the optimal price setting is:

\[
P_{T,i}^F(z)_{LCP} = \left( \frac{\phi}{\phi - 1} \right) \frac{E_{t-1} \left[ \left( \frac{(P_t^F)^{1-a} (C_i^F)^{1-\alpha}}{\theta_t^F \alpha^a (1 - \alpha)^{1-a}} \right) (P_{O,t})^\alpha \right.}{E_{t-1} \left( C_i^F \right)^{-\rho}}
\]

(2.26)

We can see that producers in the two foreign countries will choose the same price to charge agents in the home country. Equation (2.26) shows that the foreign exchange risk is not included in the firms’ pricing decisions. The home country’s agent is immune to nominal exchange rate fluctuations since she buys imported goods in her own currency. Although the nominal exchange rate between the two foreign countries seems to be relevant given the fact that oil is denominated in foreign country one’s currency, it turns out that all nominal exchange rates cancel-out when prices are expressed in the home country’s currency.\(^7\)

---

\(^7\) Although we assume LCP for the consumption good, we assume the law of one price still hold for the oil price across countries since oil is denominated in foreign country one’s currency.
Finally, the choice of currency pricing is irrelevant for the price of the local nontraded good, which is optimally set by the home agent’s as (those of foreign country one and foreign country two follow analogously)

\[
P_{N,t} = P_{N,t}(z) = \left( \frac{\phi}{\phi - 1} \right) \frac{E^{-1}}{E^{-1}} \left( \frac{P_C t}{\theta} \right)
\]

\[\text{(2.27)}\]

2.3.4 The budget constraints

To simplify, we assume that there are six financial assets. Money, denominated in each currency of the three countries, and interest-bearing riskless private bonds denominated in the home country’s currency and the two foreign countries’ currencies. We assume that there are complete asset markets- agents of each country can purchase state-contingent nominal bonds for each state of the world.\(^8\) In the literature, free capital mobility is approximated by the complete asset markets assumption. We further assume that there are restrictions set forth by each country allowing residents to hold only home money. Thus, the representative individual is confined to holding her own country’s money and interest-bearing claims on home agents and foreigners denominated in the bond issuer’s currency.\(^9\) The representative consumer in the home country receives income from oil revenue distributed in lump-sum fashion by the government and from return on foreign bond holdings. He/she will pick consumption, money holdings, non-traded-good-production labor inputs, and holdings of a foreign bond to maximize utility. The individual’s financing constraint for any date \(t\) in real terms is given by

\(^8\) We omit state-contingent notations for ease of exposition.

\(^9\) Relaxing this assumption does not change the results of this chapter.
\[
\frac{B_{H,t+1}}{P_t} + \frac{S_t^{F1} B_{F1,t+1}}{P_t} + \frac{S_t^{F2} B_{F2,t+1}}{P_t} + \frac{M_t}{P_t} = (1 + r_{t}) \frac{B_{H,t}}{P_{t-1}} + (1 + r_{t}^{F1}) \frac{S_t^{F1} B_{F1,t}}{P_{t-1}} + \frac{r_{t}^{F2}}{P_{t-1}} + \frac{M_{t-1}}{P_t} + R_{t} - C_{t} - T_{t} \quad (2.28)
\]

Where \( B_{H}, B_{F1} \) and \( B_{F2} \) denote the net private holdings of bonds issued by home agents and foreign agents, respectively, and denominated in the bond issuer’s currency. \( S_{t}^{j} \) is the nominal exchange rate between the home country and foreign country \( j \) (expressed as units of the home country’s currency per units of foreign country \( j \)’s currency). \( R_{t} \) is given in (2.16). \( T_{t} \) denotes the lump-sum taxes paid to the government, \( r_{t}^{F1} \) and \( r_{t}^{F2} \) are the foreign real interest rates, and \( M_{t-1} \) is home nominal money holdings at the beginning of period \( t \). In nominal terms, the budget constraint for the home individual can be written, in terms of home currency, as\(^{10}\)

\[
B_{H,t+1} + S_t^{F1} B_{F1,t+1} + S_t^{F2} B_{F2,t+1} + M_t = (1 + i_{t}) B_{H,t} + (1 + i_{t}^{F1}) S_t^{F1} B_{F1,t} + (1 + i_{t}^{F2}) S_t^{F2} B_{F2,t} + M_{t-1} + R_{t} - P_{t} C_{t} - P_{t} T_{t} \quad (2.29)
\]

In the nominal budget constraint above, the nominal yield \( i_{t}^{j} \) is paid at the beginning of period \( t \) and is known at period \( t - 1 \). The representative agent in each of the two foreign countries will pick consumption, money holdings, bond holdings, and labor and oil inputs to maximize utility. The real budget constraint for the foreign individual can be written as

\(^{10}\) We use the notation of Obstfeld and Rogoff (1996, Ch.10). In this case, \( M_{t} \) is nominal balances accumulated during period \( t \) and carried over into period \( t + 1 \), while \( B_{F1,t} \), for example, denotes bonds accumulated during period \( t - 1 \) and carried over into period \( t \).
\begin{align*}
\frac{B_{F,1,t+1}^{F_1}}{P_t^{F_1}} + \frac{B_{H,1,t+1}^{F_1}}{S_t^{F_1}P_t^{F_1}} + \frac{B_{F,t+1}^{F_1}}{S_t^{F_2}P_t^{F_1}} + \frac{M_t^{F_1}}{P_t^{F_1}} &= (1 + r_{i_1}^{F_1}) \frac{B_{F,1,t}^{F_1}}{P_{t-1}^{F_1}} + (1 + r_t) \frac{B_{H,t}^{F_1}}{S_t^{F_1}P_t^{F_1}} \\
&+ (1 + r_{i_2}^{F_1}) \frac{B_{F,2,t}^{F_1}}{S_t^{F_2}P_t^{F_1}} + \frac{M_{t-1}^{F_1}}{P_t^{F_1}} + \frac{R_t^{F_1}}{P_t^{F_1}} - C_t^{F_1} - T_t^{F_1} \quad (2.30)
\end{align*}

In nominal terms, the budget constraint for the foreign representative agent in foreign country one can similarly be written as

\begin{align*}
\frac{B_{F,1,t+1}^{F_1}}{P_t^{F_1}} + \frac{B_{H,1,t+1}^{F_1}}{S_t^{F_1}P_t^{F_1}} + \frac{B_{F,t+1}^{F_1}}{S_t^{F_2}P_t^{F_1}} + \frac{M_t^{F_1}}{P_t^{F_1}} &= (1 + i_{1,F_1}) B_{F,1,t}^{F_1} + (1 + i_t) \frac{B_{H,t}^{F_1}}{S_t^{F_1}P_t^{F_1}} + (1 + i_{2,F_1}) \frac{B_{F,2,t}^{F_1}}{S_t^{F_2}P_t^{F_1}} \\
&+ M_{t-1}^{F_1} + R_t^{F_1} - P_t^{F_1} O_t^{H} - P_t^{F_1} C_t^{F_1} - P_t^{F_1} T_t^{F_1} \quad (2.31)
\end{align*}

The nominal interest rate for the home-currency denominated bonds on date t is defined as

\begin{equation}
(1 + i_t) = E_t \left[ \frac{P_t}{P_{t-1}} (1 + r_t) \right] \quad (2.32)
\end{equation}

with an analogous definition for each of the two foreign-currencies nominal interest rates. Also, because we assume complete asset markets, real interest rates are equal, or \( r_t = r_{i_1}^{F_1} = r_{i_2}^{F_1} \). The nominal interest rate and the exchange rate are tied together by the uncovered interest rate parity condition,

\begin{equation}
(1 + i_t) = E_t \left[ \frac{S_{t+1}^{F_1}}{S_t^{F_1}} (1 + i_{1,F_1}) \right] = E_t \left[ \frac{S_{t+1}^{F_2}}{S_t^{F_2}} (1 + i_{2,F_1}) \right] \quad (2.33)
\end{equation}

### 2.3.5 Government budget constraint

We assume that the revenue of the home government comes from taxes, seignorage, and oil revenue. However, it remits all revenue (including oil) to its people in lump-
sum fashion. Thus, its budget constraint in per capita terms is (assuming zero government purchases)

$$0 = T_t + \frac{M_t - M_{t-1}}{P_t}$$

(2.34)

The foreign government budget constraint is

$$0 = T_{t}^{f1} + \frac{M_{t}^{f1} - M_{t-1}^{f1}}{P_{t}^{f1}}$$

(2.35)

We assume that the three governments do not issue bonds. Since our main focus is on monetary policy, we assume no government expenditures to avoid any stabilization role that might be played by fiscal policy, particularly for the home country where oil revenues are collected by the government.

### 2.3.6 Effects of exchange rates on prices

The issue of export invoicing is at the center of the debate in the new open economy literature. Three price-setting mechanisms are considered in the literature, Producer-Currency Pricing (PCP), Local-Currency Pricing (LCP), and Pricing-To-Market (PTM). In PCP, producers set prices in their own currency. In this case, the price that foreigners pay for domestic goods, and the price that home residents pay for foreign goods fluctuate when the exchange rate changes. Under PCP, purchasing power parity holds at all times, since there is only one price set in producer’s currency for each good. In LCP, producers set the price in the consumers’ currency. That is, producers charge two prices-one to residents of their own country, and another to residents of the other country. In this case, prices consumers face do not respond to all to exchange rate changes. Finally, in PTM, producers segment international markets for their goods, such that they can, at least over some time horizon, charge different prices to different national markets according to these markets’ demand conditions. That is, in PTM, producers engage
in third-degree price discrimination. The difference between LCP and PTM is that in the former, producers set prices in consumers’ currencies. In addition, under LCP, producers do not engage in price discrimination. Under both the LCP and the PTM, purchasing power parity does not hold. This is because under this form of price stickiness, exchange rate changes do not lead to proportional changes in import prices, leaving short-run deviations from the law of one price. Since the import prices are pre-set in the importer’s rather than the exporter’s currency, the exchange rate pass-through to import prices is zero. As we discussed in section 1 of this chapter, the issue of the effects of price setting on the choice of the exchange rate regime was formally analyzed by Devereux and Engel (1998, 2003).

Despite the potential of PTM and LCP models to mimic a subset of business-cycle facts, they are deemed implausible by some researchers; for instance, Obstfeld and Rogoff (1999) based their criticism of PTM-LCP on a number of inconsistent assumptions and predictions of these models. We summarize Obstfeld and Rogoff’s points in the following: a) the measured deviations from the law of one price may be the result of nontradable components incorporated in consumer price indexes for supposedly tradable goods not necessarily PTM-LCP, b) price stickiness resulting from trade invoicing is shorter than the price stickiness resulting from wage stickiness, the former will thus have smaller impacts on macroeconomic interactions at business-cycle frequencies, c) empirical evidence refutes the view that exporters set prices predominantly in importers’ currencies (e.g. Obstfeld and Rogoff (1999) writes: “in 1992, ECU institute reports that the U.S. with 92 percent of exports and 80 percent of imports invoiced in dollars is an exception in that most of its imports are denominated in home currency”), d) empirical evidence could not find pass-through to export prices close to zero, contradicting the predictions of PTM-LCP.
Given the above discussion, for the composite consumption good, we compare the welfare measure of alternative exchange rate regime using the two assumptions of price-setting, PCP and LCP. However, for the price of oil, to make the model tractable and to be consistent with the empirical evidence we discussed earlier, we assume that it is denominated in the currency of foreign country 1.

2.3.7 Monetary policies/exchange rate regimes and shocks

In this part, we define the alternative exchange rate regimes and the associated monetary policies on which we base our welfare comparisons. We assume that the three economies are subject to three kinds of exogenous shocks; real oil price shocks, money supply shocks (nominal shocks), and productivity shocks (real shocks). Following Bachetta and Van Wincoop (1999), Devereux and Engel (1998, 2003), Devereux (2004), and others, we assume that all three shocks follow log-normal distributions. To allow for persistence, we assume that the log of real oil price follows an AR(1) process of the form:

\[ p_{o,t} = \phi p_{o,t-1} + \varepsilon_t \]  \hspace{1cm} (2.36)

where \( 0 \leq \phi \leq 1 \), and \( \varepsilon_t \) is mean zero i.i.d. normally distributed random variable with variance \( \sigma^2_{\varepsilon} \). The real price of oil is defined as the international price of oil denominated in foreign country one converted to local currency by the nominal exchange rate and divided by the country’s respective consumer price index. Similarly, the productivity shocks can be represented by the following form:

\[ \log \theta_t = \delta \log \theta_{t-1} + u_t \]  \hspace{1cm} (2.37)

\[ \log \theta_{t}^{F1} = \delta \log \theta_{t-1}^{F1} + u_{t}^{F1} \]  \hspace{1cm} (2.38)

\[ \log \theta_{t}^{F2} = \delta \log \theta_{t-1}^{F2} + u_{t}^{F2} \]  \hspace{1cm} (2.39)

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where $0 \leq \delta \leq 1$, and $u_i$, $u^F_{i1}$, and $u^F_{i2}$ are mean zero i.i.d. normally distributed random variables with variances $\sigma^2_u$, $\sigma^2_{u1}$, and $\sigma^2_{u2}$ respectively. We also follow Devereux and Engel (2003) in distinguishing between two alternative monetary/exchange rate arrangements, fixed exchange regime and flexible exchange regime. The log money supply for the three countries is given by:

$$m_i = m_{i-1} + \omega(s^*_i - E_{t-1}s^*_i) + a_1u_i + a_2u^F_{i1} + a_3u^F_{i2} + a_4\epsilon_i + \nu_i \tag{2.40}$$

$$m^F_{i1} = m_{i-1} + b_1u^F_{i1} + b_2u^F_{i2} + b_4\epsilon_i + \nu^F_{i1} \tag{2.41}$$

$$m^F_{i2} = m_{i-1} + \omega^f(s^F_{i1} - E_{t-1}s^F_{i1}) + c_2u^F_{i1} + c_3u^F_{i2} + c_4\epsilon_i + \nu^F_{i2} \tag{2.42}$$

Where: $s^*_i = k_1s^F_{i1} + (1-k_1)s^F_{i2}$, $0 < k < 1$. The values $k = 1$ and $k = 0$ correspond to the special cases when the home country respectively fixes its nominal exchange rate with foreign country one only or foreign country two only. $\nu_i$, $\nu^F_{i1}$, and $\nu^F_{i2}$ are mean-zero i.i.d. normally distributed random disturbances to money supply with variances $\sigma^2_\nu$, $\sigma^2_{\nu1}$, and $\sigma^2_{\nu2}$ respectively. Each money supply equation is a reaction function for the four shocks, except for the home country, which has to react to its own productivity shocks. For simplicity, we assume that the parameters of the reaction function are exogenous in this model. Quantitative estimation of these parameters should consider determining them optimally from the model (i.e., as a function of the other parameters and shocks), a step beyond the scope of this chapter.

The reaction parameters in the money supply rule are assumed to be exogenous (e.g. determined from historical records). The money supply equation for the home country and foreign country two allows the distinction between two
exchange rate regimes depending on the value of $\omega$ and $\omega^f$ respectively. When $\omega, \omega^f \to 0$, the monetary authority does not intervene in the exchange market, allowing the exchange rate to adjust freely, thus, we have a flexible exchange regime. The money supply in this case is exogenous. However, as $\omega, \omega^f \to -\infty$, there is full intervention in the exchange market by the monetary authority to maintain the exchange rate at its parity. In this case, the exchange rate is not allowed to adjust and we have a fixed exchange regime. The money supply in this case is endogenous. We also assume that the shocks in this model are not correlated. We make this assumption to ease our solution of the model and its interpretations.

The relevance of the choice of the exchange rate regime between the two foreign countries can be motivated as follows. If we think of foreign country one as the U.S., we could think of the third country as the rest of the OECD countries. Thus, $s_{t}^{F2F1}$ is the exchange rate of a weighted average of the currencies of OECD countries against the dollar. The argument for including the exchange rate policy in the money supply reaction function is partially that of Sevensson (1999). If the foreign countries adopt a flexible exchange rate regime and follows an inflation-targeting objective, then optimal monetary policy needs to respond to exchange rate movements because such movements carry information about future inflation. There is one more reason that we find compelling to include the choice of the exchange rate regime of the foreign countries, which will be clear in view of the explicit solution for the exchange rate of the home country below. Since the home agent’s share of revenue from oil exports are denominated in the currency of foreign country one, and since she consumes the traded good of the other two countries, her consumption will be affected by movements in the nominal exchange rate between the two foreign countries.
Using the three monetary policy rules above, we can obtain an explicit solution for the composite exchange rate (in logs) of the home country with the rest of the world, see Appendix B,

\[
(s_t^* - E_{t-1}s_t^*) = \left( \frac{a_1}{1 - \omega} \right)u_t + \left( \frac{a_2 - \tilde{a}_2 - \omega' (a_2 - b_2)}{(1 - \omega)(1 - \omega')} \right)u_t^{F1} + \left( \frac{a_3 - \tilde{a}_3 - \omega' (a_3 - b_3)}{(1 - \omega)(1 - \omega')} \right)u_t^{F2} \\
+ \left( \frac{a_4 - \tilde{a}_4 - \omega' (a_4 - b_4)}{(1 - \omega)(1 - \omega')} \right)\varepsilon_t + \left( \frac{1}{1 - \omega} \right)v_t + \left( \frac{(\omega' - k)v_{t-1}^{F1} - (1 - k)v_{t-1}^{F2}}{(1 - \omega)(1 - \omega')} \right)
\]

Where \( \tilde{a}_j = kb_j - (1 - k)c_j \). The solution of the composite exchange rate reveals that the home country, by fixing its exchange rate (i.e. \( \omega \to -\infty \)), it can offset the local monetary and productivity shocks only. For the foreign monetary, productivity, and oil price shocks, the home composite exchange rate will be affected by its own choice of the exchange rate regime as well as that of foreign country two. Table 2.1 summarizes the effects of a one-unit shock in each of the seven shocks on the home country’s composite exchange rate with the rest of the world, when other shocks are shut-off.

**Table 2.1: The impact of shocks on the nominal exchange rate of the home country**

<table>
<thead>
<tr>
<th>Home regime</th>
<th>Foreign country two regime</th>
<th>( v_t )</th>
<th>( v_t^{F1} )</th>
<th>( v_t^{F2} )</th>
<th>( u_t )</th>
<th>( u_t^{F1} )</th>
<th>( \varepsilon_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible ( \omega \to 0 )</td>
<td>Flexible ( \omega' \to 0 )</td>
<td>1</td>
<td>-k</td>
<td>((a_2 - \tilde{a}_2))</td>
<td>(a_1)</td>
<td>(a_4 - \tilde{a}_4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fixed ( \omega' \to -\infty )</td>
<td>1</td>
<td>0</td>
<td>(a_1)</td>
<td>(a_2 - b_2)</td>
<td>(a_4 - b_4)</td>
<td></td>
</tr>
<tr>
<td>Fixed ( \omega \to -\infty )</td>
<td>Flexible ( \omega' \to 0 )</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Fixed ( \omega' \to -\infty )</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Where $\bar{a}_j = kb_j + (1 - k)c_j$. The home country can insulate its exchange rate from all shocks by fixing it against either one of the two foreign countries or a basket of both. In other cases, we see that the choice of the nominal exchange rate between the two foreign countries matters for the effects of shocks on the nominal exchange rate of the home country. When foreign country two adopts a fixed exchange regime against foreign country one, then the former country’s monetary policy will have no impact on the home country nominal exchange rate.

2.4 Model Solution

In solving the model, we will follow the methodology presented by Obstfeld and Rogoff (1999), Corsetti and Pesenti (2001), and Devereux and Engel (1998, 2003), which solve for the endogenous variables of the model in closed-forms as a result of imposing a log-normality assumption for the distribution of the shocks hitting each economy. The equilibrium of the model for any monetary policy rule must satisfy: (a) the first order conditions for the utility maximization by home and foreign agents, (b) the risk sharing condition, (c) market clearing in inputs (labor and oil), composite consumption goods (traded and non-traded), bonds, and money, and (d) consolidated public sectors budget constraints. Detailed derivation of the optimal solution is presented in Appendix B.

The home country agent’s optimal consumption and money holdings may be described by the following familiar conditions:
\[(1 + i_{t+1}) = \frac{1}{\beta} E_{t} \left( \frac{P_{t+1} C_t^p}{P_t C_t^p} \right) \quad (2.44)\]

\[\frac{M_t}{P_t} = \chi \left( \frac{1 + i_{t+1}}{i_{t+1}} \right) C_t^p \quad (2.45)\]

Foreign country one agent’s optimal consumption, money holdings, and oil demand may similarly be described by the following conditions (those of foreign country two agent’s are similar).

\[(1 + i_{t+1}^{F_1}) = \frac{1}{\beta} E_{t} \left( \frac{P_{t+1}^{F_1} (C_{t+1}^{F1})^p}{P_t^{F1} (C_t^{F1})^p} \right) \quad (2.46)\]

\[\frac{M_t^{F_1}}{P_t^{F1}} = \chi \left( \frac{1 + i_{t+1}^{F_1}}{i_{t+1}^{F_1}} \right) (C_t^{F1})^p \quad (2.47)\]

\[O_t^{F1}(z) = \left( \frac{\alpha}{1-\alpha} \right)^{1-\alpha} \left( \frac{P_t^{F1} (C_t^{F1})^p}{P_{t\Omega}^{F1} (C_t^{F1})^p} \right)^{1-\alpha} \left( \frac{Y_t^{F1}(z)}{\theta_t^{F1}} \right) \quad (2.48)\]

Equations (2.44) and (2.46) are the familiar stochastic Euler equations, while (2.45) and (2.47) are the money market clearing conditions. Equation (2.48) is the optimal demand for oil by the foreign country’s agent. Also, from the bond holdings first order conditions, and due to the assumption of complete asset markets, we obtain the following risk-sharing condition

\[P_t C_t^p = S_i^{F1} P_t^{F1} (C_{t}^{F1})^p = S_i^{F2} P_t^{F2} (C_{t}^{F2})^p \quad (2.49)\]

Consumption is not equalized across countries since purchasing power parity (PPP) does not hold in this case due to the presence of nontraded goods. This property is discussed in detail by Corsetti and Pesenti (2001) and Devereux and Engel (2003).
2.4.1 Market clearing conditions

Both the consumption goods and the oil market clearing conditions are ensured in the derivation of the optimality conditions (see Appendix B). The money market clearing condition is ensured by assuming that each country supplies the quantity of money demanded by its agents. The bond market clearing condition results from the zero net-foreign assets assumption, or

\[
\begin{align*}
n_{F_1}B_{H,t}^{F_1} + n_{F_2}B_{H,t}^{F_2} + n_{H}B_{H,t} &= 0 \\
n_{F_1}B_{F_1,t}^{F_1} + n_{F_2}B_{F_1,t}^{F_2} + n_{H}B_{F_1,t} &= 0 \\
n_{F_1}B_{F_2,t}^{F_1} + n_{F_2}B_{F_2,t}^{F_2} + n_{H}B_{F_2,t} &= 0
\end{align*}
\] (2.50)

2.4.2 Flexible price solution

The flexible price solution will serve as a benchmark for welfare evaluations. The flexible price solution is obtained by realizing that the pricing rules are valid in every state of the world and not just in expectations. We thus have

\[
C_t = \left(\frac{\phi - 1}{\phi} \alpha^\gamma (1 - \alpha)^{1-r}\right)^{\frac{1}{\rho(\alpha - 1)}} \left(\left(\theta_t^{F_1} \right)^{\gamma} \left(\theta_t^{F_2} \right)^{(1-\gamma)} \left(\theta_t \right)^{1-\gamma}\right)^{\frac{1}{\rho(\alpha - 1)}}
\] (2.51)

\[
C_t^{F_1} = \left(\frac{\phi - 1}{\phi} \alpha^\gamma (1 - \alpha)^{1-r}\right)^{\frac{1}{\rho(\alpha - 1)}} \left(\left(\theta_t^{F_1} \right)^{\gamma} \left(\theta_t^{F_2} \right)^{(1-\gamma)} \left(\theta_t \right)^{1-\gamma}\right)^{\frac{1}{\rho(\alpha - 1)}}
\] (2.52)

The solution of foreign country two is analogous to that of foreign country one. Monetary neutrality is obtained in this case. Also, when prices are flexible, both, the
oil exporter, the home country, and the oil importers, the two foreign countries, are symmetrically affected by oil price shocks (i.e., consumption is lower with higher real oil price and higher with lower real oil price in the three countries) despite the contrasting economic structure between the home country and the two foreign countries. This result is not surprising given the identical preferences and baskets of consumption, fully flexible prices, exogeneity of the oil price, and the perfect asset market assumption. Productivity shocks are positively related to consumption. The inter-country transmission of the productivity shocks is proportional to the trade proportions.

The expected value and the variance of log consumption for the home country under flexible prices are (assuming shocks follow log-normal process)

\[
E_{t-1}(c_t) = \frac{1}{\rho(1-\alpha\gamma)} \left\{ \Phi(t-1) - \frac{(1-\gamma)\sigma_U^2}{2} - \frac{\gamma\eta\sigma_{U,F1}^2}{2} - \frac{\gamma\eta\sigma_{U,F2}^2}{2} - \frac{\alpha^2\gamma\sigma_e^2}{2} \right\} - \frac{1}{2} \sigma_e^2 + \Gamma_e
\]

(2.53)

where:

\[
\Phi(t-1) = -\alpha\gamma p_{\alpha\gamma}^t + \gamma\eta\delta \log \theta_{t-1}^{F1} + \gamma(1-\eta)\delta \log \theta_{t-1}^{F2} + (1-\gamma)\delta \log \theta_{t-1}
\]

\[
\sigma_e^2 = \frac{1}{(\rho(\alpha\gamma - 1))^2} \left\{ \alpha^2\gamma^2 \sigma_e^2 + \gamma^2\eta^2 \sigma_{U,F1}^2 + \gamma^2(1-\eta)^2 \sigma_{U,F2}^2 + (1-\gamma)^2 \sigma_U^2 \right\}
\]

(2.54)

Expected log consumption is decreasing in the volatility of consumption and in the volatility of productivity and real oil price shocks. The variance of log consumption is increasing in the volatility of real oil price and productivity shocks.

\[\text{\textsuperscript{11}}\text{This strong result is crucially dependent on the complete asset markets assumption, which we impose to obtain a closed-form solution.}\]
2.4.3 **Producer currency pricing**

Following the literature, when goods are invoiced in the producers’ currency, the degree of pass-through from nominal exchange rates to import prices is one. In this case, shocks are transmitted through the nominal exchange rate. The explicit solution for the home agent’s log consumption (see Appendix B) can be written in terms of the stochastic shocks and their variances as:

\[
c_t = E_{t-1}(c_t) + \frac{1}{\rho} \{ \Psi_1 v_t + \Psi_2 v_t^{F1} + \Psi_3 v_t^{F2} + \Psi_4 u_t + \Psi_5 u_t^{F1} + \Psi_6 u_t^{F2} + \Psi_7 e_t \}
\]

(2.55)

where:

\[
\Psi_1 = \left( \frac{1 - \gamma}{1 - \omega} \right), \quad \Psi_2 = \left( \frac{\omega \omega - \gamma \omega - \omega ((1 - \gamma)k + \gamma \eta) + \gamma \eta}{(1 - \omega)(1 - \omega')} \right)
\]

\[
\Psi_3 = \left( \frac{\omega (1 - (\gamma)k - \gamma \eta) - \gamma (1 - \eta)}{(1 - \omega)(1 - \omega')} \right), \quad \Psi_4 = \left( \frac{(1 - \gamma) \alpha_t}{1 - \omega} \right)
\]

\[
\Psi_j = \left[ \left( \frac{1 - \gamma}{1 - \omega} \right) a_j + \left( \frac{\omega \omega - \gamma \omega - \omega ((1 - \gamma)k + \gamma \eta) + \gamma \eta}{(1 - \omega)(1 - \omega')} \right) \beta_j \right] \left( \frac{(1 - \gamma)(1 - \eta)}{(1 - \omega)(1 - \omega')} \right) c_j
\]

\[
j = 5, 6, \text{ and } 7
\]

Where the expected value of the home country’s log consumption is

\[
E_{t-1}(c_t) = \frac{1}{\rho(1 - \alpha \gamma)} \left\{ \Phi(t - 1) - \frac{\gamma \eta \sigma_{s_{vert}}^2}{2} - \frac{\gamma (1 - \eta) \sigma_{s_{hor}}^2}{2} - \frac{(1 - \gamma) \sigma_{u_{vert}}^2}{2} - \frac{\gamma \eta \sigma_{u_{hor}}^2}{2} \right\}
\]

(2.56)

\[
\left\{ -\frac{\gamma \eta \sigma_{u_{vert}}^2}{2} + \frac{\alpha^2 \gamma \sigma_{s_{vert}}^2}{2} - \frac{\sigma_{s_{hor}}^2}{2} - \frac{\gamma (\rho^2 \alpha^2 + \alpha \rho^2 - \alpha \rho) \sigma_c^2}{2} - (1 - \rho - \gamma (1 - \rho (\alpha + 1))) \sigma_{mc}^{\rho \gamma (1 - \rho (\alpha + 1)) (\sigma_{s_{vert}}^2 + \sigma_{s_{hor}}^2)} + \Gamma_c \right\}
\]

where: \( \Phi(t - 1) = -\alpha \rho_{a, t-1} + \gamma \eta \delta \log \theta_{t-1} + \gamma (1 - \eta) \delta \log \theta_{t-1} + (1 - \gamma) \delta \log \theta_{t-1} \)
We can see that the expected value of log consumption for the home agent under producer currency pricing is negatively influenced by the volatility of the bilateral nominal exchange rate with each of the foreign countries weighted by the proportion of trade in consumption goods. It is also negatively influenced by the variance of home and foreign productivity shocks and oil price shocks. It is also decreasing in the variance of log consumption. For \( \rho(\gamma + 1) < 1 \), the expected value of log consumption is decreasing with the covariance between home consumption and the bilateral nominal exchange rate with each of the two foreign countries. These covariances will probably be negative since a depreciation of the home currency against each of the two foreign currencies makes foreign imported goods more expensive, hence, lowers home consumption. Thus, they may offset the negative effect of the volatilities of the bilateral nominal exchange rates on log consumption. The home country’s and foreign countries’ monetary shocks affect the expected value of consumption through their effects on the variance of log consumption, as shown below. The variance of the home country’s log consumption is:

\[
\sigma_c^2 = \Psi_1^2 \sigma_v^2 + \Psi_2^2 \sigma_{v_{f1}}^2 + \Psi_3^2 \sigma_{v_{f2}}^2 + \Psi_4^2 \sigma_{u_1}^2 + \Psi_5^2 \sigma_{u_{f1}}^2 + \Psi_6^2 \sigma_{u_{f2}}^2 + \Psi_7^2 \sigma_{\varepsilon}^2 
\]

(2.57)

Higher volatility of each of the seven shocks, leads to higher consumption variance and lower expected log consumption. Thus, the influence of both the shocks and their variances on log consumption depends largely on the choice of the exchange rate regime and the reaction of the central banks in the three countries to the shocks. Table 2.2 summarizes the influence of each shock on log consumption, assuming other shocks are absent. Productivity shocks of foreign country two and oil price shocks have analogous impact on log consumption as that of foreign country one’s productivity shocks, thus, we omit them for ease of exposition.
Table 2.2: The impact of shocks on log consumption of the home country under PCP

<table>
<thead>
<tr>
<th>Home regime</th>
<th>Foreign country two regime</th>
<th>$v_t$</th>
<th>$v_t^{F1}$</th>
<th>$v_t^{F2}$</th>
<th>$u_t$</th>
<th>$u_t^{F1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible</td>
<td>Flexible $\omega^f \to 0$</td>
<td>$1-\gamma$</td>
<td>$\gamma\eta$</td>
<td>$\gamma(1-\eta)$</td>
<td>$(1-\gamma)\kappa_1$</td>
<td>$(1-\gamma)a_2 + \gamma(\rho_b + (1-\eta)c_2)$</td>
</tr>
<tr>
<td></td>
<td>Fixed $\omega^f \to -\infty$</td>
<td>$1-\gamma$</td>
<td>$\gamma$</td>
<td>0</td>
<td>$(1-\gamma)\kappa_1$</td>
<td>$(1-\gamma)a_2 + \rho_b$</td>
</tr>
<tr>
<td>Fixed</td>
<td>Flexible $\omega^f \to 0$</td>
<td>0</td>
<td>$((1-\gamma)k + \gamma\eta)$</td>
<td>$(1-\gamma)k + (1-\gamma)\eta$</td>
<td>0</td>
<td>$((1-\gamma)k + \gamma\eta)b_2 + (1-\gamma)(k - \gamma\eta)c_2$</td>
</tr>
<tr>
<td></td>
<td>Fixed $\omega^f \to -\infty$</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>$b_2$</td>
</tr>
</tbody>
</table>

For a positive domestic monetary shock, log consumption will increase under a flexible exchange regime, and will have no effect under a fixed exchange rate regime. As we expect, under the flexible rate regime, the degree by which a domestic monetary shock affects log consumption is the proportion of nontraded goods in total consumption. This is no surprise, since domestic monetary policy can work through the local nontraded sector, the only production sector with labor/leisure choice in the home country. The impact of a positive foreign monetary shock on log consumption depends on the choice of the exchange rate regime between the two foreign countries. Foreign monetary shocks will affect the home country’s consumption through its effect on the nominal exchange rate between home and each of the two foreign countries, which will be passed on to home’s local prices. These results seem to be consistent with the literature. A positive foreign monetary shock that leads to a depreciation in the foreign currency and a higher foreign price level hurts home consumers in two ways: by decreasing their oil revenue purchasing-power and by increasing the price of imported goods when
expressed in home currency. In summary, a fixed exchange rate regime can better stabilize log consumption against monetary shocks.

A positive domestic productivity shock in the nontraded sector increases log consumption only under a flexible exchange regime by the proportion of the nontraded sector in total consumption and has no impact under a fixed exchange regime. On the other hand, a positive foreign productivity shock increases log consumption under both regimes, flexible and fixed, with varying impacts depending on the response of the central banks in the two countries, assuming central banks accommodate productivity shocks by increasing the money supply. When the home country fixes its exchange rate, the influence of foreign productivity shocks on log consumption is determined only by the response of the foreign central bank to this shock. It can influence the impact of these shocks on its log consumption by choosing the appropriate weight $k$ in the basket peg only when foreign country two adopts a flexible exchange rate regime against foreign country one. However, under a flexible exchange regime, home can influence the impact of productivity shocks by choosing optimal policy reaction coefficients $a_2, a_3,$ and $a_4$. Thus, the flexible exchange regime can better insulate log consumption from productivity shocks if the central bank of the home country is able to predict the response of the central bank in the foreign countries and act accordingly.

What has been said about foreign productivity shocks carries on to the real oil price shocks. The influence of a positive oil-price shock on log consumption will also depend on the response of the monetary authorities in the two countries to this shock and the choice of the exchange rate regime of both, the home country and foreign country two. The flexible exchange regime will better insulate log consumption against real oil-price shocks provided that the home central bank can zero the response of the foreign central banks. If the central bank of the foreign
country does not respond to oil price shocks, then the impact of oil price shocks on home log consumption vanishes.

Table 2.2 also show that when the three countries are under a fixed exchange rate regime (when the home country and foreign country two chooses to fix their nominal exchange rate) then the impact of the shocks on home’s log consumption is solely determined by the response of the independent-currency country, foreign country one.

### 2.4.4 Local currency pricing

With local currency pricing, we still have total expenditures on consumption equalized across countries due to the complete asset markets assumption. The degree of pass-through from nominal exchange rates to import prices is zero under LCP. Thus, the nominal exchange rate does not transmit shocks across countries. The log consumption of the home agent’s is

\[
c_t = E_{t-1}(c_t) + \frac{1}{\rho} \{ \Gamma_1 v_t + \Gamma_2 v_t^f + \Gamma_3 v_t^{f1} + \Gamma_4 u_t + \Gamma_5 u_t^f + \Gamma_6 u_t^{f2} + \Gamma_7 e_{1t} \}
\]

(2.58)

where: \( \Gamma_1 = \left( \frac{1}{1-\omega} \right) \), \( \Gamma_2 = \left( \frac{\omega(1-\omega)}{(1-\omega)(1-\omega_f)} \right) \), \( \Gamma_3 = \left( \frac{-\omega(1-\omega)}{(1-\omega)(1-\omega_f)} \right) \), \( \Gamma_4 = \left( \frac{a_j}{1-\omega} \right) \)

\[
\Gamma_j = \left( \frac{1}{1-\omega} \right) a_j + \left( \frac{\omega(1-\omega_f)}{(1-\omega)(1-\omega_f)} \right) b_j - \left( \frac{\omega(1-\omega)}{(1-\omega)(1-\omega_f)} \right) c_j \quad j = 5, 6, \text{and } 7
\]

The expected value of the home country’s log consumption is

\[
E_{t-1}(c_t) = \frac{1}{\rho(1-\alpha \gamma)} \left\{ \Phi(t-1) - \frac{(1-\gamma)\sigma_u^2}{2} - \frac{\gamma \eta \sigma_{\tilde{u}_{11}}^2}{2} - \frac{\gamma \eta \sigma_{\tilde{u}_{12}}^2}{2} - \frac{\alpha^2 \gamma \sigma_e^2}{2} - \frac{\gamma \sigma_y^2}{2} \right\} - \left(1 - \rho - \gamma(1 - \rho(\alpha + 1)) \right) \sigma_{mc} - \gamma \left( \rho^2 \sigma^2 + \alpha \rho^2 - \alpha \rho \right) \sigma_e^2 + \Gamma_c
\]

(2.59)
where: $\Phi(t-1) = -\alpha \gamma_{\eta,\xi-1} + \gamma \eta \delta \log \theta_{t-1}^{F1} + \gamma (1-\eta) \delta \log \theta_{t-1}^{F2} + (1-\gamma) \delta \log \theta_{t-1}^{r}$

Differently from the case of producer currency pricing, the expected value of log consumption is not affected by the variance of the bilateral nominal exchange rate with each of the two foreign countries. The variance of the home country’s log consumption is then:

$$\sigma_{c}^{2} = \Gamma_{1}^{2} \sigma_{r}^{2} + \Gamma_{2}^{2} \sigma_{v_{1}}^{2} + \Gamma_{3}^{2} \sigma_{v_{2}}^{2} + \Gamma_{4}^{2} \sigma_{u_{1}}^{2} + \Gamma_{5}^{2} \sigma_{u_{2}}^{2} + \Gamma_{6}^{2} \sigma_{v_{1}}^{2} + \Gamma_{7}^{2} \sigma_{c}^{2}$$

To compare the two pricing schemes, the impact of a one unit shock in each of the shocks, shutting-off other shocks, on log consumption can similarly be summarized in Table 2.3.

**Table 2.3: The impact of shocks on log consumption of the home country under LCP**

<table>
<thead>
<tr>
<th>Home regime</th>
<th>Foreign country two regime</th>
<th>$v_{t}$</th>
<th>$v_{t}^{F1}$</th>
<th>$v_{t}^{F2}$</th>
<th>$u_{t}$</th>
<th>$u_{t}^{F1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible $\omega \rightarrow 0$</td>
<td>Flexible $\omega \rightarrow 0$</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>$a_{1}$</td>
<td>$a_{2}$</td>
</tr>
<tr>
<td>Flexible $\omega \rightarrow 0$</td>
<td>Fixed $\omega \rightarrow -\infty$</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>$a_{1}$</td>
<td>$a_{2}$</td>
</tr>
<tr>
<td>Fixed $\omega \rightarrow -\infty$</td>
<td>Flexible $\omega \rightarrow 0$</td>
<td>0</td>
<td>$k$</td>
<td>$1-k$</td>
<td>0</td>
<td>$kb_{2} + (1-k)c_{2}$</td>
</tr>
<tr>
<td>Fixed $\omega \rightarrow -\infty$</td>
<td>Fixed $\omega \rightarrow -\infty$</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>$b_{2}$</td>
</tr>
</tbody>
</table>

As noted above, with local currency pricing, the degree of pass-through from nominal exchange rate to local prices is zero, since prices are already set in local currency. We can see that the impact of local monetary shock is higher under local currency pricing when the home country adopts a flexible exchange rate regime.
Foreign monetary shocks have no impact on log consumption when the home country allows its nominal exchange rate to be fully flexible. For the foreign productivity shocks and real oil price shocks, the impact is solely determined by the response of the home central bank to these shocks if the latter allows the nominal exchange rate to be fully flexible. Given a freely flexible exchange rate between the two foreign countries, if the home country fixes its nominal exchange rate then the effect of foreign monetary shocks is determined by the weights of the composite nominal exchange rate against the two foreign countries. Similar analyses are valid for the foreign productivity and oil shocks. In summary, when consumption goods are priced in the home country’s currency, the effects of monetary, productivity, and oil shocks on log consumption are generally lower and more controllable than when they are priced in the currency of the producers.

Under flexible exchange rate regime, the implications of local currency pricing on monetary policy are substantial. This is because changes in nominal exchange rates will not affect relative prices between domestic and imported goods. As noted by Devereux and Engel (2003), LCP is consistent with fixed exchange rate regimes when only traded goods are considered. However, recently Duarte (2004) show that a flexible exchange rate regime might still be advantageous in case of distinctive nontraded productivity shocks (specific country shocks). As shown in Table 2.3, the impact of foreign real shocks (productivity and oil price shocks) depends solely on the reaction of the home country’s central bank when the latter adopts a flexible a flexible exchange rate regime. However, when it chooses a fixed exchange rate regime, the reactions of the foreign central banks will affect the log consumption of the home country. The home country’s central bank cannot offset these reactions since money supply is endogenous under a fixed exchange rate regime.
Empirical literature supports producer currency pricing for the developed countries. For example, Obstfeld and Rogoff (1999) recite the ECU Institute’s report taken in 1992 of currency invoicing. According to that report, the following are countries along with the percentage of their exports denominated in own currency: US 92%, Japan 40%, Germany 77%, France 55%, and United Kingdom 62%, Italy 40%, and Netherlands 43%.

\section{2.5 Welfare Evaluations}

Our welfare criterion for choosing the optimal exchange rate regime under different assumptions about shocks is the conditional expected utility level, which depends on expected level of consumption, variance of consumption, and expected disutility of efforts. Following the literature, we ignore the utility from holdings of real money balances (assume $\chi \to 0$). This is because real money balances enter the utility function as a means to generate a demand for money. Since there are other ways to derive a demand for real balances (e.g. Cash-In-Advance method) it is safe to ignore utility from real balances in comparing welfare. Our welfare criterion is then:

\begin{equation}
EU_t = E \left( \frac{C_t^{1-\rho}}{1-\rho} \right) - E(L_t)
\end{equation}

We assume that utility is the same each period (stationary). This is due to the complete markets assumption (free capital mobility) and the one period ahead pricing policies by agents (see Obstfeld and Rogoff (1998)).

Since we assume that the shocks follow log-normal distributions, the solution of the endogenous variables should follow log-normal distributions as well. Thus,
we can express expected utility of consumption in terms of the mean of log
consumption and the variance of log consumption

\( E(C^{1-\rho}) = \exp(1 - \rho)[E(c) + ((1 - \rho)/2)\sigma_c^2] \).

To complete our welfare evaluation, we need to find the expected level of
employment. For the home agent (see Appendix B),

\[ E(L_{N,t}) = \frac{(1 - \gamma)(\phi - 1)}{\phi} E(C^{1-\rho}) \]  

Equation (2.62) shows that the expected level of efforts is a linear function of
\( E(C^{1-\rho}) \). Thus, we can base our welfare analysis on utility from consumption. The
welfare measure can then be reduced to

\[ EU_t = \left( \frac{\phi - (1 - \rho)(1 - \gamma)(\phi - 1)}{\phi(1 - \rho)} \right) \exp(1 - \rho) \left( Ec + \frac{(1 - \rho)}{2} \sigma_c^2 \right) \]  

Using (2.63), we can compare alternative monetary policy/exchange rate regime
choice for the two pricing schemes (PCP and LCP). We can write equation (2.63) in
terms of the variances of the shocks and the covariances once we substitute for the
expected value and the variance of log consumption. The expected utility is
increasing in the variance of log consumption for any values of the risk aversion
coefficient, \( \rho \). The variance of log consumption is generally lower under LCP since
the volatility of the nominal exchange rate is absent. In terms of expected log
consumption, it is not clear which pricing-scheme dominates. This is because for
producer currency pricing, the positive impact on expected consumption of the
covariances between consumption and nominal exchange rates might offset the
negative effects of nominal exchange rate volatility. Thus, it is unclear whether
expected utility is higher under producer currency pricing. The question that needs to be addressed then is given the export-pricing scheme, what is the optimal exchange rate regime that maximizes the home agent’s utility. We can observe that the home agents are better off under producer currency pricing adopting a flexible exchange rate regime. This is due to the standard argument in favor of a flexible exchange rate regime of active monetary policy. The central bank in the home country will have a free-hand to respond to the shocks. This is also true under local currency pricing, practically if the real foreign shocks are dominant.

However, given the information requirement to conduct optimal monetary policy, we should consider the choice of a fixed exchange rate regime for the home country as a second-best alternative. In this case, the home country is faced with the choice between fixing its exchange rate to one of the foreign countries or a basket of both. The relevant case to consider is when the two foreign countries are in a flexible exchange rate regime against each other.

Under producer currency pricing, the optimal weight \( k \) to fix the exchange rate against foreign country one is

\[
k_{PCP} = \frac{\left( \frac{\gamma^2 \eta}{1-\gamma} \right) \sigma_{V_1}^2 + \left( \frac{\gamma (1-\gamma \eta)}{1-\gamma} \right) \sigma_{V_2}^2 - \sum_{j=2}^{4} (b_j - c_j) \gamma \eta b_j + (1-\gamma \eta) c_j}{\gamma (\sigma_{V_1}^2 + \sigma_{V_2}^2) + \sum_{j=2}^{4} (b_j - c_j)^2 \sigma_j^2}
\]

(2.64)

Where \( j = 2, 3, \text{and} 4, \) \( \sigma_2^2 = \sigma_{V_1}^2, \) \( \sigma_3^2 = \sigma_{V_2}^2, \) and \( \sigma_4^2 = \sigma_x^2. \) The optimal weight is a complicated function of foreign monetary, productivity, and real oil price shock variances as well as the response functions of the foreign central banks to theses shocks. If the two foreign countries follow a random walk money supply rule (i.e. when the monetary rule does not respond to productivity or real oil price shocks) or
if they respond equally to these shocks, then the optimal weight for the basket peg will merely reflect the relative variance of uncontrollable money supply shocks.

On the other hand, when we assume local currency pricing, the optimal weight to fix the exchange rate against foreign country one is

\[
k_{LCP} = \frac{\sigma_{y_{z2}}^2 - \sum_{j=2}^{4} c_j (b_j - c_j)}{\sigma_{y_{z1}}^2 + \sigma_{y_{z2}}^2 + \sum_{j=2}^{4} (b_j - c_j)^2 \sigma_j^2}
\]

(2.65)

Again, if we assume that the two foreign central banks will respond to own and foreign productivity shocks and oil shocks equally, or if they allow their money supply to follow a random walk process (i.e. they set their reaction parameters equal to zero), then the optimal weight to fix against foreign country one is the proportion of foreign country two’s monetary shocks in the two foreign countries’ monetary shocks. That is, the home country should put more weight to the country with less monetary disturbances. The determination of the optimal currency basket weight demands overwhelming information about the variance of the shocks and the expected response of foreign central banks. Thus, from (2.64) and (2.65), we conclude that in the case of a fixed exchange rate regime, a basket peg is better than a unilateral peg to the currency of one of the two foreign countries.

The choice of the monetary rule reaction coefficients depends on the exchange rate regime being adopted by the home country, on price-setting of imports (PCP vs. LCP), and on the reaction coefficients of the two foreign countries. In the case of a fixed exchange rate regime, the monetary policy will be directed toward maintaining the exchange rate at its parity. However, only under a flexible exchange rate regime will the home country have the freedom to respond to
productivity and oil price shocks. Here, we solve for the optimal reaction coefficients for the home country’s monetary rule. We assume that the three countries will be under a flexible exchange rate regime. The home country chooses its optimal reaction coefficients given the reaction coefficients of the other two countries.

\[ a_{1}^{PCP} = 0, \quad a_{1}^{LCP} = 0 \]  
\[ a_{j}^{PCP} = -\gamma (\eta b_2 + (1-\eta)k_2) \frac{1}{1-\gamma}, \quad a_{j}^{LCP} = 0, \quad j = 2, 3, \text{and} \ 4 \]  

(2.66) 
(2.67)

For a positive home productivity shock that affects the nontraded sector, expected nontraded consumption will increase and expected prices will decrease, boosting the nominal interest rate. However, since the home country has no traded sector, the optimal response of the central bank is zero change in money supply. This is because an increase or a decrease in money supply will affect the nominal exchange rate with the two foreign countries. This in turn affects home country’s consumption of traded goods. For a positive foreign productivity or oil price shock, the response of the home country’s central bank will depend on the response of the two foreign countries to these shocks. For example, a higher oil price that is expected to be permanent will increase the home country’s expected consumption due to higher revenue, but it will increase expected future prices due to the higher input costs in the foreign country. Since we assume prices are set one period in advance, consumption will increase this period leading to higher nominal interest rate. If we assume that the two foreign countries will respond positively to this shock, then the optimal response of the home country’s central bank is to reduce the
money supply.\footnote{Devereux and Engel (2000) show that increasing the money supply is the optimal response of the central bank to a positive productivity shock (domestic or foreign) in a two-country model.} We can see from (2.66) and (2.67) that a passive monetary policy (with respect to real shocks) is consistent with LCP. As noted above, allowing the nominal exchange rate to be flexible dominants a fixed exchange rate policy in terms of welfare. More specifically, a flexible exchange rate regime results in a lower variance of consumption under LCP, given the assumption of active monetary policies for the two foreign countries.

2.5.1 Caveats
The results of this chapter crucially depend on two assumptions that may not be realistic. The first assumption is the complete asset markets. This assumption allows us to arrive at a simple closed-form solution that is both tractable and can be used to study the transmission of shocks in general equilibrium. The cost of such simplification is the unappealing symmetric effects of oil price shocks on the three countries’ consumption despite the different economic structures. The second assumption is the exogeneity of the oil price to the three countries in the model. This assumption also allows us to arrive at a simple closed-form solution by bypassing the complexity of the international oil market. To sum up, proper modeling should relax these two assumptions, which entails, of course, giving up the simple closed-form solution.

2.6 Conclusions
In this chapter, we attempt to analyze the optimal choice of exchange rate regime for developing countries that depend largely on the export of primary commodities, such as oil. We follow the methodology presented by Devereux and Engel (2003) to
solve a three-country, the home country and two foreign countries, stochastic general equilibrium model of Obstfeld and Rogoff (1995) with sticky final-good prices and monopolistic competition. The sources of uncertainty are random monetary (demand), productivity (real), and oil-price (supply) shocks, which we assume follow a log-normal process. There is only one composite traded good produced by the foreign country. The home country is the producer of a primary commodity, oil, used in the production of the composite traded good. Each country has its local nontraded composite good. We allow for complete asset markets.

We found that the optimal exchange rate regime for an oil-exporting country depends on pricing-schemes of its imports as well as the response of its trading-partners to their productivity shocks and to the oil-price shocks. Under both pricing-schemes, producer currency pricing and local currency pricing, a flexible exchange regime can improve the welfare of home agents provided that the central bank in the home country (oil-exporting country) is able to predict both the shocks and the response of the foreign central banks to these shocks. This does not seem feasible given the current monetary and financial developments in such countries. In other words, the impact of monetary, productivity, and oil price shocks on the utility of agents in an oil exporting country is lower when a fixed exchange rate regime is adopted and at the same time the response of the central bank in this country is passive to these shocks compared to the response of the central bank in the country with which it fixes its currency. We also found that in the case of a fixed exchange rate regime, a basket peg is better than a unilateral peg to a single currency. As one can expect, we also found that the choice of a fixed exchange rate regime for an oil-exporting country is more appealing the more stable is the currency in which oil-price is denominated.
APPENDICES A & B
2.7 APPENDIX A

2.7.1 Derivations of individual demand functions

Following Obstfeld and Rogoff (1996, pp. 664), to obtain the home individual demand for traded good \( z \), we solve the problem

\[
\max_{c(z)} \left[ \int_{n_1}^{1} c(z) \frac{\phi-1}{\phi} dz \right]^{\frac{\phi}{\phi-1}} \tag{A1}
\]

subject to

\[
\int_{n_1}^{1} P(z)c(z)dz = Z \tag{A2}
\]

where \( Z \) is any fixed total nominal expenditure on traded good \( z \in (n_1,1] \). From the first order conditions, we can show that for any two goods \( z \) and \( z' \)

\[
c(z) = c(z') \left( \frac{P(z)}{P(z')} \right)^{\phi}
\]

If we plug this expression into the budget constraint

\[
\int_{n_1}^{1} p(z)c(z') \left( \frac{P(z)}{P(z')} \right)^{-\phi} dz = Z
\]

rearrange

\[
c(z')p(z')^\phi \int_{n_1}^{1} P(z)^{1-\phi} dz = Z
\]

\[
\left[ c(z')P(z')^\phi \right] \left[ \int_{n_1}^{1} P(z)^{1-\phi} dz \right]^{\frac{1}{1-\phi}} = Z^{\frac{1}{1-\phi}}
\]
but $P_T = \left[ \int_{\eta_1}^{\eta} P(z)^{1-\phi} dz \right]^{\frac{1}{1-\phi}}$, rearrange

$$c(z') = \left( \frac{Z}{P_T} \right) \left( \frac{P(z')}{P_T} \right)^{-\phi}$$

but $Z$ is total nominal expenditures of home agent $j$ on all varieties $z$ in the composite traded good which means $(Z/P_T) = C_T$ and the above equation is valid for any traded good $z \in (\eta, 1]$. We obtain the demand of home agent for traded good $z$

$$c(z) = \left[ \frac{P(z)}{P_T} \right]^{-\phi} C_T$$  \hspace{1cm} (A3)

The demand for the local nontraded good $z'$ by the home agent can be obtained using similar derivation, which yields

$$c_{N,j}(z') = \left[ \frac{P(z')}{P_N} \right]^{-\phi} C_N$$  \hspace{1cm} (A4)

We can also derive the demand of home agent for the composite traded and nontraded goods as follows:

$$\max_{c_T, c_N} \frac{C_T^\gamma C_N^{1-\gamma}}{\gamma(1-\gamma)}$$  \hspace{1cm} (A5)

subject to

$$P_T C_T + P_N C_N = Z$$  \hspace{1cm} (A6)

From the two first-order conditions, we obtain

$$\gamma P_N C_N = (1-\gamma) P_T C_T$$  \hspace{1cm} (A7)

If we substitute back in the budget constraint, we find the demand for the composite traded and nontraded goods
\[ C_T = \gamma \left( \frac{P}{P_T} \right) C \]  \hspace{1cm} (A8)

\[ C_N = (1 - \gamma) \left( \frac{P}{P_N} \right) C \]  \hspace{1cm} (A9)

Using the above two demand equations, we can finally arrive at the demand for traded good \( z \) presented in the text

\[ c_{T,j}(z) = \gamma \left[ \frac{P(z)}{P_T} \right]^{-\phi} \left( \frac{P}{P_T} \right) C \]  \hspace{1cm} (A10)

Similarly, for the nontraded good,

\[ c_{N,j}(z') = (1 - \gamma) \left[ \frac{P(z')}{P_N} \right]^{-\phi} \left( \frac{P}{P_N} \right) C \]  \hspace{1cm} (A11)
2.8  APPENDIX B

2.8.1  The home agent’s problem

The home agent’s problem is the following:

\[
\begin{align*}
\max_{c_t, b_{H,t}, b_{F1,t}, b_{F2,t}} & \quad E_t \sum_{t} \beta^t \left[ \frac{C_t^{1-\rho}}{1-\rho} + \chi \log \left( \frac{M_t}{P_t} \right) - L_{N,t} \right] \\
\text{subject to} & \quad B_{H,t+1} + S_{t}^{F1} B_{F1,t+1} + S_{t}^{F2} B_{F2,t+1} + M_t = (1 + i_t) B_{H,t} + (1 + i_t^{F1}) S_{t}^{F1} B_{F1,t} \\
& \quad + (1 + i_t^{F2}) S_{t}^{F2} B_{F2,t} + M_{t-1} + R_i - P_t C_t - P_t T_t
\end{align*}
\]

where

\[
R_i = S_i^{F1} P_i^{F1} O_i^H (z) + P_{N,i} (z') Y_{N,i} (z')
\]

and

\[
\begin{align*}
\text{Nontraded goods market clearing:} & \quad Y_{N,i} (z') = \int_0^{n_1} c_{N,i}^j (z') dj \\
\text{Nontraded good production function:} & \quad Y_{N,i} (z') = \theta_i L_{N,i} (z') \\
\text{Demand for nontraded good:} & \quad c_{N,i} (z') = \left[ \frac{P_N (z')}{{P_N}} \right]^{\phi} C_N \\
\text{Demand for oil:} & \quad O_i^H (z) = O_i^{F1} (z) + O_i^{F2} (z)
\end{align*}
\]

\[ B_t \]

\[ \text{subject to} \]

\[ B_{H,t+1} + S_{t}^{F1} B_{F1,t+1} + S_{t}^{F2} B_{F2,t+1} + M_t = (1 + i_t) B_{H,t} + (1 + i_t^{F1}) S_{t}^{F1} B_{F1,t} \\
+ (1 + i_t^{F2}) S_{t}^{F2} B_{F2,t} + M_{t-1} + R_i - P_t C_t - P_t T_t \]

\[ R_i = S_i^{F1} P_i^{F1} O_i^H (z) + P_{N,i} (z') Y_{N,i} (z') \]

\[ \text{and} \]

\[ \text{Nontraded goods market clearing:} \]

\[ Y_{N,i} (z') = \int_0^{n_1} c_{N,i}^j (z') dj \]

\[ \text{Nontraded good production function:} \]

\[ Y_{N,i} (z') = \theta_i L_{N,i} (z') \]

\[ \text{Demand for nontraded good:} \]

\[ c_{N,i} (z') = \left[ \frac{P_N (z')}{{P_N}} \right]^{\phi} C_N \]

\[ \text{Demand for oil:} \]

\[ O_i^H (z) = O_i^{F1} (z) + O_i^{F2} (z) \]
Solve for $L_{x,t}$ from (B4), (B5), and (B6) and substitute in (B1). Substitute (B3) in (B2), we then get the first order conditions:

$$\frac{\partial (\text{ })}{\partial C_t} = 0 \Rightarrow B' \frac{1}{C_t^\rho} = \beta' \lambda_t P_t \quad (B8)$$

$$\frac{\partial (\text{ })}{\partial M_t} = 0 \Rightarrow \beta' \frac{X}{M_t} + \beta^{i+1} E_t \lambda_{t+1} = \beta' \lambda_t \quad (B9)$$

$$\frac{\partial (\text{ })}{\partial B_{H,t+1}} = 0 \Rightarrow \lambda_t = \beta E_t \lambda_{t+1} (1 + i_{t+1}) \quad (B10)$$

$$\frac{\partial (\text{ })}{\partial B_{F1,t+1}} = 0 \Rightarrow S_{t}^{F1} \lambda_t = \beta E_t \lambda_{t+1} (1 + i_{t+1}) \quad (B11)$$

$$\frac{\partial (\text{ })}{\partial B_{F2,t+1}} = 0 \Rightarrow S_{t}^{F2} \lambda_t = \beta E_t \lambda_{t+1} (1 + i_{t+1}) \quad (B12)$$

The transversality condition is

$$\lim_{T \to \infty} E_t \left((1 + r_{j,T}^j) \left(B_{j,t+T+1} + \frac{M_{t+T}}{P_{t+T}}\right)\right) = 0, \ j = F1, F2$$

Using (B8), (A8), and (A9), we can derive the stochastic Euler equation

$$(1 + i_{t+1}) = \frac{1}{\beta} E_t \left(\frac{P_{t+T} C_{t+1}^\rho}{P_t C_t^\rho}\right) \quad (B13)$$

Also, using (B10) and (B11), we arrive at the money demand equation

$$\frac{M_t}{P_t} = \chi \left(\frac{1 + i_{t+1}}{i_{t+1}}\right) C_t^\rho \quad (B13)$$

### 2.8.2 Optimal price setting

We assume that agents set the price of their product before the realization of period $t$ shocks. Thus, the home agent maximizes the Lagrangian, (B1), with respect to
$p_{N,J}(z')$. The currency of invoicing (producer currency pricing vs. local currency pricing) is irrelevant for the nontraded goods.

$$
\frac{\partial(\ )}{\partial P_{N,J}(z')} = 0 \Rightarrow \nonumber
E_{t-1} \left[ -\beta^t - \phi \left( \frac{P_{N,J}(z')}{P_{N,J}} \right)^{\phi-1} \frac{1}{P_{N,J}} C_{N,J} - \beta^t \lambda_t (1 - \phi) \left( \frac{P_{N,J}(z')}{P_{N,J}} \right)^{\phi} \frac{1}{P_{N,J}} C_{N,J} \right] = 0 \quad (B14)
$$

Using (A9), (A11), substituting for the marginal utility of consumption, $\lambda_t = \left( 1 / P_t C_t^\rho \right)$, and realizing that prices are set in period $t-1$, we obtain

$$
P_{N,J} = P_{N,J}(z) = \left( \frac{\phi}{\phi - 1} \right) \frac{E_{t-1} \left( P_C \right)}{E_{t-1} \left( C_t^{\rho} \right)} \quad (B15)
$$

### 2.8.3 Foreign agent’s problem

Similarly, an agent’s problem in either of the two foreign countries is the following (we take foreign country one as an example)

$$
\max_{C_{F,1}, M_{F,1}, B_{F,2,1}, B_{F,2,1}, B_{F,2,1}} \quad E \sum_t \beta^t \left[ \left( C_t^{F_1} \right)^{1-\rho} + \chi \log \left( \frac{M_{t-1}^{F_1}}{P_t^{F_1}} \right) - L_t^{F_1} \right] \quad (B16)
$$

Subject to

$$
B_{F,1+t}^{F_1} + B_{H,1+t}^{F_1} + B_{F,2+t}^{F_1} + M_t^{F_1} = (1 + i_t^{F_1}) B_{F,1,t} + (1 + i_t^{F_1}) \frac{B_{H,t}}{S_t^{F_1}} + (1 + i_t^{F_1}) \frac{B_{F,2,t}}{S_t^{F_2 F_1}} \nonumber
+ M_{t-1}^{F_1} + R_t^{F_1} - P_{O}^{F_1} O_t^H - P_t^{F_1} C_t^{F_1} - P_t^{F_1} T_t^{F_1} \quad (B17)
$$

where

$$
R_t^{F_1} = P_{T,t}^{F_1}(z) Y_{T,t}^{F_1}(z) + P_{N,t}^{F_1}(z') Y_{N,t}^{F_1}(z') \quad (B18)
$$

and
Traded goods market clearing:

\[ Y_{T,i}^{F_1}(z) = \int_0^{n_1} c_{T,j}^j(z) dj + \int_{n_1}^{n_2} c_{T,J}^{F_1}(z) dj + \int_{n_2}^{n} c_{T,j}^{F_2}(z) dj \]  

\[ \text{(B19)} \]

Nontraded goods market clearing:

\[ Y_{N,i}^{F_1}(z') = \int_{n_1}^{n_2} c_{N,j}^{F_1}(z') dj \]  

\[ \text{(B20)} \]

Labor supply resource constraint

\[ L_i^{F_1} = L_{T,i}^{F_1} + L_{N,i}^{F_1} \]  

\[ \text{(B21)} \]

Production function of traded good:

\[ Y_{T,i}^{F_1}(z) = \theta_i^{F_1} O_i^{F_1}(z) \alpha L_{T,i}^{F_1}(z)^{1-\alpha} \]  

\[ \text{(B22)} \]

Production function of nontraded good:

\[ Y_{N,i}^{F_1}(z') = \theta_i^{F_1} L_{N,i}^{F_1}(z') \]  

\[ \text{(B23)} \]

Demand for traded good by the home agent:

\[ c_{T,i}^j(z) = \gamma \left[ \frac{P_{T,i}^{F_1}(z)}{P_{T,i}} \right]^{-\phi} C_{T,i} \]  

\[ \text{(B24)} \]

Demand for traded good by Foreign 1:

\[ c_{T,i}^{F_1}(z) = \gamma \left[ \frac{P_{T,i}^{F_1}(z)}{P_{T,i}^{F_1}} \right]^{-\phi} C_{T,i}^{F_1} \]  

\[ \text{(B25)} \]

Demand for traded good by Foreign 2:

\[ c_{T,i}^{F_2}(z) = \gamma \left[ \frac{P_{T,i}^{F_2}(z)}{P_{T,i}^{F_2}} \right]^{-\phi} C_{T,i}^{F_2} \]  

\[ \text{(B26)} \]

Demand for nontraded good:

\[ c_{N,i}^{F_1}(z') = (1-\gamma) \left[ \frac{P_{N,i}^{F_1}(z')}{P_{N,i}} \right]^{-\phi} C_{N,i}^{F_1} \]  

\[ \text{(B27)} \]

The first-order conditions of the above problem are similar to those of the home agent. Accordingly, the stochastic Euler equation and the money demand equation follow as in the home agent’s first order conditions.

2.8.4 Demand for oil

To obtain the demand for oil by the foreign agent producing good z, we maximize the Lagrangian, (B1), with respect to \( O_i^{F_1}(z') \).
\[ \frac{\partial ( \_ )}{\partial O_{t}^{F_{1}}(z)} = 0 \Rightarrow \]

\[ E_{t-1}
\begin{bmatrix}
B^{i} \left( \frac{1}{1 - \alpha} \right)
\left( \frac{1}{\theta_{t}^{F_{1}}(O_{t}^{F_{1}}(z))^{\alpha}} \right)
\left( \frac{\alpha}{\theta_{t}^{F_{1}}(O_{t}^{F_{1}}(z))^{\alpha + 1}} \right)
Y_{t,t}(z)
- B^{i} \lambda_{t}^{F_{1}} P_{O}^{r} = 0
\end{bmatrix}
\]

rearrange, and using \( \lambda_{t}^{F_{1}} = \left( 1 / P_{t}^{F_{1}}(C_{t}^{F_{1}})^{\rho} \right) \), we find

\[ O_{t}^{F_{1}}(z) = \left( \frac{\alpha}{1 - \alpha} \right)
E_{t-1}
\begin{bmatrix}
P_{t}^{F_{1}}
\left( \frac{1}{P_{O,t}^{F_{1}}(C_{t}^{F_{1}})^{\rho}} \right)
\frac{Y_{t,t}(z)}{\theta_{t}^{F_{1}}}
\end{bmatrix}
\]

(B28)

2.8.5  **Optimal price setting.**

Similar to the nontraded case of home agent, a foreign agent sets the price of the nontraded good \( z' \) before information about period \( t \) shocks are known. The first-order condition is

\[ \frac{\partial ( \_ )}{\partial P_{N,j}^{F_{1}}(z')} = 0 \Rightarrow \]

\[ E_{t-1}
\begin{bmatrix}
- \beta' \phi
\left( \frac{P_{N,j}^{F_{1}}(z')}{P_{N,j}^{F_{1}}(z)} \right)^{-\phi}
\frac{1}{P_{N,j}^{F_{1}}(z)}
C_{N,j}^{F_{1}}
- \beta' \lambda_{t}^{F_{1}}(\phi - 1)
\left( \frac{P_{N,j}^{F_{1}}(z')}{P_{N,j}^{F_{1}}} \right)^{-\phi}
\left( C_{N,j}^{F_{1}} \right)
\end{bmatrix}
= 0
\]

(B29)

rearranging, we arrive at

\[ P_{N,j}^{F_{1}} = P_{N,j}^{F_{1}}(z') = \left( \frac{\phi}{\phi - 1} \right)
E_{t-1}
\begin{bmatrix}
P_{t}^{F_{1}} C_{t}^{F_{1}}
\theta_{t}^{F_{1}}
\end{bmatrix}
\]

(B30)

Assuming producer currency pricing for the traded consumption goods, the first-order condition with respect to the price of the traded good \( z \) is:
\[
\frac{\partial(\quad)}{\partial P_{T,j}^{F_1}(z)} = 0 \Rightarrow
\]
\[
E_{t-1} \left[ \beta^t \frac{1}{1-\alpha} \left( \frac{1}{\theta_{t}^{F_1}(O_{t}^{F_1})} Y_{T,j}^{F_1}(z) \right)^{\frac{\alpha}{1-\alpha}} \left( \frac{1}{\theta_{t}^{F_1}(O_{t}^{F_1})} \phi \left( \frac{P_{T,j}^{F_1}(z)}{P_{T,j}^{F_1}} \right)^{-\phi} \right) C_{T,j}^{F_1} \right] = 0
\]
\[
(B31)
\]
Rearranging (B31), and making use of the equality \( \lambda_{t}^{F_1} = \left(1 / P_{t}^{F_1}(C_{t}^{F_1})^{\rho} \right) \), we obtain
\[
P_{T,j}^{F_1}(z) = \left( \frac{\phi}{\phi - 1} \right) \frac{E_{t-1} \left[ \left( P_{t}^{F_1} C_{t}^{F_1} \right)^{\frac{1}{1-\alpha}} \left( Y_{T,j}^{F_1}(z) \right)^{\frac{\alpha}{1-\alpha}} \right]}{E_{t-1}(C_{t}^{F_1})^{1-\rho}}
\]
\[
(B32)
\]
Substitute the demand for oil, (B28) in (B32), we obtain
\[
P_{T,j}^{F_1}(z)_{PCP} = \left( \frac{\phi}{\phi - 1} \right) \frac{E_{t-1} \left[ \left( P_{t}^{F_1} C_{t}^{F_1} \right)^{\frac{1-\alpha}{\alpha}} \left( \theta_{t}^{F_1} \alpha^a (1 - \alpha)^{-a} \right) \right]}{E_{t-1}(C_{t}^{F_1})^{1-\rho}}
\]
\[
(B33)
\]
Under local currency pricing, firms in the two foreign countries set the price of their traded goods in the currency of the home agent, therefore the first order condition becomes
\[
\frac{\partial}{\partial P_{T,t}^F(z)} = 0 \Rightarrow
\]
\[
E_{t-1} \left[ \beta^t \frac{1}{1-\alpha} \left( \frac{1}{\theta^F(O_{t}^F)} \right)^{\alpha} \left( \frac{1}{\theta^F(O_{t}^F)} \right)^{\alpha} \left( \frac{P_{T,t}(z)}{P_{T,t}^F} \right)^{-\phi} C_{T,t} \right] = 0 \quad (B34)
\]

Rearrange and substitute for the demand of oil as in the producer currency pricing, the price of traded good \( z \) set by an agent in foreign country one is
\[
P_{T,t}(z)_{LCP,F1} = \left( \frac{\phi}{\phi - 1} \right) \frac{E_{t-1} \left[ \left( \frac{P_t}{\theta^F} \right)^{1-\alpha} \left( \frac{C_t}{\alpha (1-\alpha)^{1-\alpha}} \right) \left( P_{O,t}^{F} \right)^{\alpha} \right]}{E_{t-1} \left[ C_t \right]^{1-\rho}} \quad (B35)
\]

### 2.8.6 Solving the model

We start by defining the composite log nominal exchange rate of the home country against the two foreign countries, \( s_t^* = k s_t^{F1} + (1-k) s_t^{F2} \), which is a weighted average of the bilateral exchange rate with each foreign country. We can do the same for the price index \( (p_t^*) \) and nominal money balances \( (m_t^*) \). We proceed by subtracting the log of a weighted average of foreign countries’ money market clearing condition from the home condition (using the same weights as those of the composite nominal exchange rate), and using the risk sharing result, from the nominal bonds first order conditions, that \( P_t C_t^\rho = S_t^{F1} P_t^{F1} (C_t^{F1})^\rho = S_t^{F2} P_t^{F2} (C_t^{F2})^\rho \), and, recognizing that
\( i_t = i_t^{F1} = i_t^{F2} \) in equilibrium, we can derive the solution to the exchange rates given by

\[
\begin{align*}
  s_t^* &= m_t - m_t^* \\
  s_t^{F2F1} &= m_t^{F2} - m_t^{F1}
\end{align*}
\]  

(B36)  

(B37)

Now, we can derive a solution of the composite exchange rate in terms of the shocks by substituting for \( m_t \) and \( m_t^* = km_t^{F1} + (1-k)m_t^{F2} \) from (2.40), (2.41), and (2.42) respectively. The solution is given in (2.43).

The home country money market clearing condition (B13) can be written in logs as

\[
\rho c_t = m_t - p_t + \log \left( \frac{1 + i}{i} \right)
\]  

(B38)

In the long-run equilibrium, the nominal interest rate is constant. Following Devereux and Engel (2003), we impose the fact that the solution for consumption will be log normal since the shocks follow log normal distributions. Also, assuming identical agents in both countries and taking log of price indexes gives:

\[
p_t = \eta p_{T,t} + (1-\gamma)p_{N,t}
\]  

(B39)

\[
p_{T,t} = \eta \left( s_t^{F1} + p_{T,t}^{F1} \right) + (1-\eta) \left( s_t^{F2} + p_{T,t}^{F2} \right)
\]  

(B40)

Taking logs of the optimal prices, using the relationship that if \( X \) follows a normal distribution, then

\[
E(X) = \exp \left( E(x) + \frac{\sigma^2_x}{2} \right), \quad \text{or} \quad \log E(X) = E(x) + \frac{\sigma^2_x}{2},
\]

where \( x = \log X \) after substituting for the price level from the money market clearing condition. We can then obtain the solution for log consumption by substituting for the money supply process (2.40) and the price index (2.45).
2.8.7 Evaluating welfare

The welfare measure we have used for comparing the two exchange regimes, fixed and flexible, is

\[ U_t = E\left( \frac{C_t^{1-\rho}}{1-\rho} \right) - E(L_t) \]  \hspace{1cm} (B41)

For the home agent

\[ L_t = L_{N,t} = \frac{C_{N,t}}{\theta_t} \]

but \( C_{N,t} = (1-\gamma) \left( \frac{P_t}{P_{N,t}} \right) C_t \), and \( P_{N,t} = P_{N,t}(\varepsilon') = \left( \frac{\phi}{\phi-1} \right) E_{t-1} \left( \frac{P_t C_t}{\theta_t} \right) \), thus

\[ E(L_{N,t}) = \frac{(1-\gamma)(\phi-1)}{\phi} E(C_t^{1-\rho}) \]

Combining the two terms, we get

\[ EU_t = \frac{\phi - (1-\rho)(1-\gamma)(\phi-1)}{\phi(1-\rho)} E(C_t^{1-\rho}) \]

Using the properties of the lognormal distribution

\[ EU_t = \frac{\phi - (1-\rho)(1-\gamma)(\phi-1)}{\phi(1-\rho)} \exp \left\{ (1-\rho) \left[ Ec_t + \frac{(1-\rho)}{2} \sigma^2 \right] \right\} \]  \hspace{1cm} (B42)
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Chapter 3

Oil-Price Shocks and the Short/Medium Term Dynamic Macroeconomic Adjustments: The Role of Exchange Rate Regimes

3.1 Introduction

One of the main arguments in favor of flexible exchange rate regimes has been the ability of flexible regimes to insulate the economy from real external shocks that require adjustment in relative prices among countries. This argument dates back to Friedman (1953). The argument stands on the following reasoning: if prices and wages are sticky (or move slowly), and in the face of a real shock that requires the adjustment of the real exchange rate among countries, then it is better to move the nominal exchange rate to make the necessary adjustment in the real exchange rate instead of waiting for prolonged adjustment through excess demand in the goods
and labor markets to push the prices and wages to the new equilibrium. With the above argument in mind, an important question, which was raised following the series of economic storms caused by oil price hikes that have shaken the world economy since 1973, is whether fixed exchange rate regimes can survive in this environment. Right after the collapse of the Bretton Woods system in March 1973, a group called “the committee of twenty” had been assigned the job of designing a new system of fixed exchange rates that would overcome the drawbacks of the Bretton Woods system.13 However, the strong oil price shock that hit the world at that time made a return to a fixed exchange rate regime unfavorable.

Although the above proposition that flexible exchange rate regimes cushion the economy against external real shocks had been given a rigorous theoretical foundation by both Keynesian and new open economy macroeconomics, the stabilizing role of flexible exchange rate regimes has recently received less support empirically. First, the empirical evidence shows that the nominal exchange rates react very little to shocks in macroeconomic fundamentals. In addition, due to their extensive fluctuations, nominal exchange rates show a “disconnect” from these fundamentals, which show relatively little fluctuations (e.g. Mussa (1986); and Obstfeld and Rogoff (1998)). Second, the recent evidence found little support for the “expenditure switching” mechanism through which flexible exchange rate regimes insulate real output from adverse real effects. More specifically, the empirical evidence shows a low pass-through from nominal exchange rates to domestic prices, Engel (2002, 2000, 1999), Engel and Rogers (1996, 2001), and many other contributions.14 The evidence adds to the growing notion that the role of a flexible exchange rate regime in cushioning the economy against adverse real shocks is

13 Krugman and Obstfeld (2003)
14 For the recent theoretical and empirical developments in this literature see Engel (2002)
overstated since changes in the nominal exchange rate do not largely translate into
differences in relative prices of goods among countries.

Some of the most visualized and recurring shocks that hit all economies in the
world since World War II have been the oil price shocks. Economists have
extensively analyzed, theoretically and empirically, the role of price shocks on
macroeconomic variables, although most of the studies have concentrated on the US
economy. The world has witnessed many adverse and severe oil price shocks: 1973,
price shocks, what monetary and exchange rate systems might facilitate the
absorption of these shocks? This question along with our previous discussions
motivated the work in this chapter.

The purpose of this chapter is to investigate empirically the role of alternative
exchange rate regimes in the adjustment mechanism of the economy against oil price
shocks in the short and medium terms in a panel of countries. The questions of
interest are: In the short-run, does the exchange rate regime matter in insulating the
economy from the effects of adverse oil price shocks? How might the behavior of
real exchange rate, output, and inflation be different across exchange rate regimes in
face of these shocks? Which exchange rate regime(s) achieves the necessary
adjustment more rapidly?

The recent studies that attempted to test Friedman’s hypothesis that a flexible
exchange rate regime can better insulate the economy from real shocks have
concentrated on the effect of terms of trade shocks (see Broda (2004), and Edwards
and Levy Yeyati (2003)) on real output under alternative exchange rate regimes. In
this chapter, we use oil price shocks instead of the terms of trade shocks. We argue
that oil price shocks might be more robust in verifying Friedman’s hypothesis in a
way that is more appropriate for exchange rate regime comparisons. This is
because, in the short-run, fluctuations in the terms of trade might come from real
and nominal shocks. For example, a reduction in the money supply by the Federal Reserve of the US might affect the world economy and hence the terms of trade. In this case, one cannot robustly test for the insulation property of flexible exchange rate regimes since the sources of the shock are not confidently known and the exogeneity assumption cannot be safely assumed. Furthermore, the use of terms-of-trade fluctuations to study the adjustment behavior of the economy for different exchange rate regimes is not immune from the Lucas Critique. This is because certain shocks that affect the terms-of-trade arise under one exchange rate regime and might not be observable under others. On the contrary, there is no reason to believe that oil price shocks are different across exchange rate regimes. Moreover, as we have indicated earlier, there is growing support for the argument that the degree of exchange rate pass-through is not the same across different exchange rate regimes. Thus, for the same source of disturbance, the changes in the terms of trade will not be the same across different exchange rate regimes. On the other hand, as documented by a number of studies, oil prices have been the dominant factor causing persistent movements in the terms of trade (see Backus and Crucini (2000), and Amano and Van Norden (1996)).

Since the channels of influence of the oil price shocks may be many, a well-structured empirical model that robustly accounts for all channels might not be attainable. To bypass such an obstacle, we use a panel VAR technique, with minimal restrictions, to test for the impact of oil price shocks on nine major OECD oil-importing countries under alternative exchange rate regimes, after controlling for other factors that might affect the responsiveness to oil price shocks. We use quarterly observations from 1973Q1 to 2004Q2 for Japan, Germany, France, Italy, South Korea (Korea), Spain, Portugal, Sweden, and Finland. The endogenous

15 The observations for the members of the European Union covers only the period 1973Q1-1998Q4.
variables of the panel VAR are: the real oil price shocks, the bilateral real exchange rate with the US, a measure of monetary policy, real output growth, and the inflation rate.

We found that flexible exchange rate regimes better absorb positive oil price shocks, consistent with Friedman’s hypothesis. The necessary adjustments are borne-up by the nominal exchange rate mostly in the same period of the oil price shocks. We found that under flexible exchange rate regimes, and in response to one standard deviation positive oil price shocks, both the real exchange rate and output growth show faster speeds of adjustment when returning to their long-run equilibrium relative to the fixed exchange rate regimes. In addition, the inflation rate shows relatively higher contemporaneous increase due to positive oil shocks under fixed exchange regimes. Our results show that monetary policy reactions to the oil price shocks make no significant contribution to the response of the real exchange rate, output growth, and the inflation rate following oil price shocks. These findings have policy implications for emerging economies as they experience a growing industrial sector and more dependence on imported oil.

The rest of this chapter is organized as follows: Section 2 reviews the relevant literatures. Section 3 discusses the role of the exchange rate regime in the oil price shocks-macroeconomy relationship. Section 4 discusses the issues surrounding the two important inputs of the econometric model, the exchange rate regime classification and the measurement of oil price shocks. Section 5 presents the econometric techniques. Section 6 discusses the results and robustness. Finally, some conclusions follow.
3.2 Review of Previous Studies

In this section, we review the empirical literature on the ability of exchange rate regimes to insulate the economy against real shocks. In addition, we briefly review the literature on the channels and impacts of oil price shocks on the economy.

3.2.1 Exogenous real shocks and the exchange rate regime

The literature on the choice of exchange rate regimes in face of different kinds of shocks dates back to Friedman (1953) with his famous case for flexible exchange rate regimes as a shock absorber. Friedman argues that in the face of a negative real shock that requires an adjustment in the real exchange rate, currency depreciation is both quicker and less costly to achieve the needed adjustment than a prolonged adjustment through wages and prices. This proposition was formally developed using the famous Mundell-Flemming-Dornbouch (MFD) model and the New-Open-Economy (NOE) models (see Genberg (1989) for a survey of the MFD literature and Lane (2000) for a survey of the NOE literature).

Despite the long and extensive theoretical developments of the stabilization policy literature (see chapter two), there has been very little empirical work on the relationship between exchange rate regimes and the effect of different kind of shocks on different measures of economic performance. The studies that attempted to examine this relationship empirically have ignored the role of the exchange rate regime in the transmission process. Only a few studies have focused on the significance of the choice of the exchange regime on measures of macroeconomic stability, such as aggregate output, inflation, real exchange rates, etc. We discuss these studies below.

One empirical finding that has received wide support is that flexible exchange regimes induce higher volatility of real exchange rates. Recent examples
are Flood and Rose (1995) and Broda (2004). Bayoumi and Eichengreen (1994) examined the impact of aggregate demand shocks on inflation and output under the Bretton Woods system and the flexible exchange rate regimes using a sample of the G-7. They found that the two systems responded differently to those shocks with the fixed exchange rate regime being more affected by aggregate demand shocks. Their findings suggest that the post-1971 shift from fixed to floating rates was associated with a gradual increase in positive demand disturbances as well as an increase in the dispersion of the disturbances. Like some others, they attribute the breakdown of the Bretton Woods system to demand side factors.

Broda (2004) investigated the response of real GDP, real exchange rates, and prices to terms-of-trade shocks across different exchange regimes using a sample of 75 developing countries for the period 1973-96 and the de facto regime classification of Ghosh et al. (1997). Broda used a sample of only developing countries to avoid the problem of endogenous terms-of-trade shocks. Using a semi-structural panel vector autoregression methodology, Broda found a significant difference across regimes with the flexible regimes being able to buffer the shocks better than those with fixed regimes, as argued by Friedman (1953). The interesting finding of Broda is that the differences in responses across regimes are mostly driven by the response to negative shocks. Broda also found the real exchange rate adjustment to be more persistent in flexible regimes than in fixed regimes when negative shocks hit and no significant difference when positive shocks hit. However, the impulse responses of consumer price indexes across regimes due to terms-of-trade shocks do not provide any plausible explanation.

Concentrating only on output growth, Edwards and Levy-Yeyati (2003) also examined the impact of the terms-of-trade shocks under alternative exchange rate regimes. Using a sample of annual observations of 100 countries (both developed and developing) over the period 1974-2000 and the de facto regime classification of
Levy Yeyati and Sturzenegger (2002) they were able to assert Friedman’s theoretical proposition that “countries with flexible exchange rates are able to better accommodate real external shocks”. In addition, they also found evidence of an asymmetric response to terms-of-trade shocks under fixed exchange regimes, negative shocks having greater impact on output. The authors attributed this asymmetry to downward nominal inflexibility.

The empirical studies that attempted to evaluate the performance of alternative exchange rate arrangements have concentrated on one specific shock (the terms-of-trade shock). Thus, they don’t provide good evidence of the performance of alternative exchange rate regimes because, in the short-run, fluctuations in the terms of trade might come from real and nominal shocks as well as from internal and external shocks to some economic variables when the sample includes both large and small countries. In this case, one cannot robustly test for the insulation property of flexible exchange rate regimes since the sources of the shock are not confidently known and the exogeneity assumption cannot be safely applied. Furthermore, the use of terms-of-trade fluctuations to study the adjustment behavior of the economy for different exchange rate regimes is not immune from Lucas Critique. In other words, as many theoretical models assert, fluctuations in the terms-of-trade are more pronounced under fixed regimes than under flexible regimes. On the contrary, there is no reason to believe that oil price shocks are different across exchange rate regimes. Moreover, there is growing support for the argument that the degree of exchange rate pass-through is not the same across different exchange rate regimes. Thus, for the same source of disturbance, the changes in the terms of trade will not be the same across different exchange rate regimes.
3.2.2 Oil price shocks and the macroeconomy

The relationship between oil price fluctuations and the performance of the economy has received continuous attention from economists, most of whom have concentrated on the US economy. An early influential contribution on the relationship between oil price shocks and the macroeconomy was by Hamilton (1983). Hamilton demonstrated that all recessions, except that of 1960, in the US economy after World War II were preceded by oil price hikes, and ever since this literature has been fertile. As discussed by Jones, Leiby, and Paik (2004) in their extensive review, this literature has emerged in four strands: a) the microeconomic channels and the resource reallocations of oil price shocks; b) the portions of the recessions that are explained by either oil price shocks and/or by monetary policy that responds to these shocks; c) the nature and stability of the relationship between oil price shocks and GDP; and finally d) the estimation of the magnitude of effect of an oil price shock on GDP. In this brief review, we do not attempt to cover all aspects of the literature; rather we will concentrate on the first and second strands.

There are many theoretical propositions for the channels through which an oil price shock affects the economy. Examples of these theoretical propositions are: variable mark-up responses to oil price shocks by producers (e.g., Rotemberg and Woodford (1996)), variations in the utilization rates for productive capital (e.g., Finn (2000)), and sectoral shifts models (e.g., Hamilton (1988)).

Another issue in the recent oil price shocks-macroeconomy literature is whether recessions that follow oil price hikes are caused by oil price shocks themselves or by the monetary authority’s reaction to the shocks by tightening interest rates in fear of inflation. The difficult part in separating the effects of each is

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16 An excellent review of this literature is provided by Jones, Leiby, and Paik (2004)
the control of monetary policy in studying the impact of oil price shocks on the economy. Most of the empirical investigations used either money supply or interest rate variables in regressions of output on oil prices to overcome the endogeneity problem of monetary policy to oil price shocks. Examples of studies that advocate a substantial role for monetary policy in causing recessions as opposed to oil price shocks are Hooker (1999a, 1999b) and Bernanke, Gertler, and Watson (1997, BGW). Unlike the previous empirical literature, BGW used counterfactual VAR simulations of oil price shocks with alternative monetary policy. They counterfactually allowed the Federal Reserve to maintain the federal funds rate at a constant level rather than raising it. Using the resulting Impulse Response Functions, they concluded that most of the reductions in GDP following the 1973, 1979, and 1990 oil price shocks were caused by monetary policy. Although innovative, the results of BGW were not appealing to many economists. One of the criticisms of BGW is that it is not immune from the Lucas Critique since they hold the federal funds rate constant. Specifically, Hamilton and Herrera (2001, H&H) used the same data as BGW but reached opposite conclusions about the relative contributions of monetary policy and oil price shocks to the observed recessions. H&H attributed the results obtained by BGW to two factors: a) H&H question the ability of the Fed to accomplish the monetary policy needed to eliminate the output losses from oil shocks; b) they also questioned the use of 7 lags by BGW when they have found that full impact period requires longer lags.

As pointed out earlier, the studies that concentrated on cross-country analysis of the oil price shocks-macroeconomy relationship are few. Examples of these studies are Mork, Olsen, and Mysen (1994, MOM) and Cunado and Perez de Gracia (2003, C&PG). Using data for 14 European countries and a VAR consists of industrial production, oil prices, and inflation rates, both studies found varying
effects of oil price shocks on industrial production and inflation across the countries included in their sample. They found that the effects on industrial production are larger when oil prices are denominated in national currencies rather than US dollars. There are other studies that concentrated on a single country, example Papapetrou (2001) on Greece, and Miguel, Manzano, and Martin-Moreno (2003) on Spain.
3.2.3 **How might exchange rate regimes play a role in the effects of oil price shocks?**

In an open economy, we can think of three inter-related (not clearly distinctive) channels through which the exchange rate regime plays a role in the effects of oil-price shocks. The first channel is the direct channel, in which oil price shocks affect the nominal exchange rate of a country with the US dollar. This channel is relevant for countries with flexible exchange rate regimes. The country will be directly affected by oil-price shocks through the domestic currency prices of imported oil. Given that oil sales are denominated in US dollars, there is no clear theory that explains the effect of oil price shocks on the bilateral nominal exchange rates with the US dollar.

Figure 3.1 and Figure 3.2 depict the movements of the domestic-currency real oil price, the nominal exchange rate, and the real exchange rate both with the US dollar for two floating currencies, the Japanese Yen and the German Mark. We can see that, in general, there seems to be an association between movements in the real oil price and the nominal and real exchange rates.

Figure 3.3 and Figure 3.4 depict the same picture for two intermediate regime countries, Sweden and Korea. Although, the nominal exchange rate is not allowed to float freely, we can see that casual associations between domestic-currency oil prices and the nominal and real exchange rate with the US dollar exist too. One argument that attempts to explain this casual observation assumes that the exchange rate of the dollar vis-à-vis other major currencies might have influenced OPEC’s price decisions, Terzian (1985). This is because the dollar depreciation against European or Japanese currencies makes goods denominated in those currencies more expensive, triggering OPEC to increase the price of oil in dollar terms to make up for the more expensive imports of OPEC members.
A second argument is that of the monetary policy reaction to oil price shocks, Bernanke, Gertler, and Watson (BGW, 1997). Focusing only on the US economy, BGW argue that monetary policy could be used to reduce any recessionary consequences of oil price shocks. Thus, in the open economy context, holding other things constant, one can argue that a tightening of monetary policy (through an increase in the equivalence of the US federal funds rate) could result in currency appreciation against the US dollar, which will mitigate the adversary effects of oil price shocks. In summary, this channel concentrates the effects of oil price shocks on the total US dollar bill paid by agents in a given country for oil imports.

The second channel, the indirect channel, in which oil price shocks affect the relative price between domestic and foreign goods, which in turn affects demand for domestically produced goods and the domestic aggregate demand as well. Since there is no reason to believe that the oil-price shocks are larger for fixed exchange rate regime countries than for flexible exchange rate regime countries, after controlling for the relevant factors, the difference will reflect the behavior of the real exchange rate under the two regimes. Given our discussion of the first direct channel, theoretical propositions suggest that countries with more flexible exchange rate regimes are better able to adjust their real exchange rate in a way that helps reduce adjustment costs in terms of output. For fixed exchange rate regimes, the adjustment will be through prolonged movements in excess demand and labor markets that will eventually push nominal prices to equilibrium. This channel operates after the work of the first channel. When the nominal exchange rate changes, so does the real exchange rate, and hence, relative prices across countries. In summary, this channel focuses on the adjustment in a country’s comparative advantage (or real exchange rate) as a result of oil price shocks.
Finally, the third channel that is worth discussing is the role of expectations. Producers in fixed exchange regime countries, particularly those with fixed regimes against the US dollar, such as currency board, dollarization, or conventional pegs to the US dollar, will set prices differently from their counterparts in flexible exchange rate regime countries. Producers in flexible exchange rate countries are worried of possible appreciations or depreciations of their currency against the dollar beside expected oil price hikes. This argument has received good support in recent general equilibrium new open economy models. For example, Devereux and Engel (1998, 2003) show that that changes in the mark-up charged by a firm, due to monetary or productivity shocks, will differ across exchange rate regimes. With no clear and sound theoretical foundation, the above three channels might be reinforcing or offsetting each other. This makes the investigation of the role of the exchange rate regime in the transmission of oil price shocks rather an empirical question, which is the thesis of this chapter.

3.3 Two Inputs of the Econometric Model

In this section we address the two important inputs to our empirical estimations: the classification of the exchange rate regimes and the proxy for oil price shocks.

3.3.1 Classifying countries into exchange rate regimes

In this section we address the choice of exchange rate regimes. In practice, classifying a particular country as belonging to a certain exchange rate regime is rather difficult. This is due to the practice of the monetary authorities that try to move from the two polar cases in order to acquire as much as possible of what is referred in the literature as the “trinity”-independent monetary policy, free capital mobility, and a purely fixed exchange rate. The behavior of the countries to purse such a trinity gives rise to different classifications of exchange rate regimes.
Exchange rate systems can be classified in this respect into two groups: *de facto* and *de jure* regimes. *De jure regimes* are based on the publicly stated and reported commitment of the authorities in the country. This *de jure* classification distinguishes between three broad categories: pegged regimes, regimes with limited flexibility (within a band or cooperative arrangements), and more flexible arrangements (managed and free floats). We should emphasize here that the task of drawing the lines between fixed, intermediate, and flexible regime has been subject to a wide debate. It is important to separate this system from the *de facto* system in order to study the effect of future policy intentions on expectations especially the private sector expectations. *De facto regimes* are implied by the observed behavior of the nominal exchange rates. One way to imply the actual exchange rate regime used by a country is by observing the behavior of the instruments of monetary policy of that country.

The *de jure-de facto* classification identifies the monetary authorities that meet their commitment from the ones that act differently from their stated policies. For example, if one country reports that it follows a free-float exchange rate but intervenes substantially in the foreign exchange market due to some fear of floating, then, its exchange rate system moves from being free-float to being managed-float. The *de facto-de jure* classification poses a problem for empirical work since identifying the actual regime used by a country is not simple and the actual regime being adopted is what actually matters for empirical tests. Partial attempts to correct for this problem are provided by, among others, Quirk (1994), Frankel (1999), Ghosh, Gulde, Ostry, and Wolf (1997), Levy-Yeyati and Sturzenegger (2002), and most recently by Reinhart and Rogoff (2004). In the following, we highlight here three of these attempts.

One important contribution was that of Levy-Yeyati and Sturzenegger (2002), henceforth LYS, who constructed a *de facto* classification for all countries for the
period 1990-99 that has received good attention in the empirical literature. The classification of LYS was based on the behavior of three variables: the behavior of foreign exchange reserves, the base money, and the nominal exchange rate. The idea underlying the LYS algorithm is that the behavior of these three variables can allow the identification of the exchange regime that a country is actually following. For example, a flexible exchange regime is characterized by little intervention in the exchange rate market together with high volatility of exchange rates. On the other hand, a fixed exchange rate regime is characterized by little volatility in the nominal exchange rate and substantial fluctuations in foreign reserves. For the intermediate regimes, the three variables are expected to show relatively high variability.

Another important contribution was that of Ghosh et al. (1997) who combine the \textit{de jure} and \textit{de facto} approaches. In their algorithm, they start with the IMF classification (\textit{de jure}) and further divide fixed regimes into frequent and infrequent adjusters based on the number of adjustments per year. They also distinguished between heavily managed flexible regimes and other types of flexible regimes.

Although more informative than the \textit{de jure} classifications, the attempts mentioned above are not entirely satisfactory to many researchers. These \textit{de facto} classifications are criticized on several dimensions: (a) the algorithms used in these attempts were not able to distinguish between stable nominal exchange rates resulting from the absence of shocks and stability that results from policy actions offsetting shocks; (b) as pointed out by Calvo and Reinhart (2002), using reserves has serious limitations, for example, the change in reserves reported by the IMF sometimes underestimates the interventions by authorities to stabilize the exchange rate. Calvo and Reinhart give the example of Brazil, and many more other countries, where foreign exchange intervention is frequently done through trading in domestic dollar-linked debt, which is not reflected in the IMF reported changes in reserve data. Also, due to higher financial integration, many countries have been
increasingly using the interest rate as a means to stabilize the exchange rate instead of direct foreign exchange intervention. Finally, the foreign reserves will change, although less than the above factors, due to fluctuations in valuations and the accrual of interest earnings; (c) as pointed out by Rogoff, Husain, Mody, Brooks, and Oomes (2003), proper classification should identify longer-term regimes rather than shorter-term “spells” within a regime. The short horizon algorithms can mistakenly record a large number of regime changes that are in fact related to short periods of disturbances and do not involve a change in the regime itself. For example, countries experiencing episodes of macroeconomic instability often have very high inflation and this will be reflected in high and frequent exchange rate depreciations. These reasons make use of foreign exchange reserves and the actual exchange rates to infer that actual exchange rate regimes are less informative.

To overcome some of the previous drawbacks of exchange regime classifications, Reinhart and Rogoff (2004) have developed a new de facto algorithm for classifying exchange rate regimes using monthly observations. The algorithm used in their classification was based on the market-determined parallel exchange rates going back to 1946 for 153 countries. In their approach, the dual or parallel exchange markets (legal or otherwise) have an explicit role in inferring the exchange rate regimes.\(^\text{17}\) They argue that a proper classification algorithm should distinguish between unified rate systems (with one official exchange rate and no significant “black” or parallel market) and all other systems. They provide empirical evidence that the multiple exchange rates (dual or parallel rates) systems are far better indicators of monetary policy than the official exchange rate and more economically meaningful. They found that market-determined exchange rate (dual or parallel exchange rates) systematically predicts realignments in the official rate. They

\(^{17}\) In footnote 2, Reinhart and Rogoff note that dual markets are legal, whereas parallel markets may or may not be legal.
identified a separate category of “freely falling” regime that is characterized by high inflation and weak macroeconomic management. Reinhart and Rogoff also provide evidence that exchange classification can be blamed for the mixed empirical findings on the exchange regime-economic performance link.

The point that we want to raise here is whether the dual or parallel exchange rates are subject to the same forces as the official exchange rates, that is, do changes in former rates reflect changes in economic fundamentals? Casual observation suggests that the dual or parallel markets are subject to speculations (non-fundamental driven changes) more than the official markets (especially the illegal markets). This observation casts some doubt on the accuracy of this new classification.

Up to the time of writing this essay, and to our knowledge, there have been no real tests of the accuracy of the Reinhart and Rogoff classification. If proved to be well representative of actual exchange rate regimes, we expect this new classification to give a new momentum to the empirical investigation due to the construction of a chronological de facto classification for 153 countries for 1946-2001, an empirical input that past research was lacking.

For the most part, the mismatch between the IMF (de jure) classification and each of the de facto classifications is significant and leads to substantial misleading empirical results. For example, Levy-Yeyati and Sturzenegger (2002) have found that money growth and inflation are higher under fixed exchange rate regimes when using the IMF (de jure) classification in their empirical estimation. However, under LYS (de facto) classification, they found the opposite is true. The same argument was also raised by Calvo and Reinhart (2002). The above empirical frustration came as no surprise in view of the fact, reported in the empirical literature, that the proposed

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18 Reinhart and Rogoff (2004) have shown that the IMF classification is close to random!
de facto classifications are uncorrelated with each other and each has low correlation with the IMF (de jure) classification.

### 3.3.2 Oil price shocks

The important question that arises when analyzing oil price shocks in cross-country context is what proxy for these shocks is more robust? Previous studies that analyzed oil price shocks used the real price of oil (the US dollar price converted into the respective country’s currency and deflated by the GDP deflator or the CPI). For our sample, we use the average spot oil price of Brent, Texas, and Dubai in US dollars converted to local currencies using the nominal exchange rate with the US dollar, and then deflated using the respective country’s CPI. To construct a proxy of oil price shocks, the literature provides multiple measures. In the following, we briefly discuss the different measures proposed along with our preferences. We use all of the proxies below to check for robustness.

#### A. Oil Price Change (OPC)

\[
OPC = po_t - po_{t-1}
\]

where \( po_t \) is the log quarterly price of oil measured in US dollars, converted to local currency for each country using the nominal exchange rate with the US dollar and deflated using the consumer price index of the respective country. This symmetric measure assumes a smooth linear relationship between oil price fluctuations and the economic variables under consideration. In other words, this measure assumes that both increases and decreases in oil price will have the same impact on the economy.
B. Net Oil Price Increase (NOPI):

\[ NOPI_t = \max\left[0, \left( p_{o_t} - \max\left( p_{o_{t-1}}, p_{o_{t-2}}, p_{o_{t-3}}, p_{o_{t-4}}\right) \right) \right] \]  \hspace{1cm} (3.2)

where \( p_{o_t} \) is as defined above. This measure was first proposed by Hamilton (1983) and defined as the quarterly percentage change in real oil price from the past 4 quarters. Here, we take only positive oil price shocks. The idea behind this measure is to capture the behavior of consumers and investors as they compare the price of oil this quarter to those in previous quarters. In our robustness check we extend this measure of shocks to include 8 quarters (2 years).

C. Unexpected Oil Price Increase (UOPI):

\[ UOPI = \max\left[0, p_{o_t} - p_{f,t-2}^O \right] \]  \hspace{1cm} (3.3)

where \( p_{o,t} \) is as defined above and \( p_{f,t-2}^O \) is the six-month log real price of oil in the forward market. To the best of our knowledge, this measure has not been used before. Using this measure, we can detect the unexpected increases in oil prices that are perceived as a shock to oil market participants.

D. Stable Oil Price Increase (SOPI)

\[ SOPI_t = \max\left(0, \hat{\varepsilon}_t / \sqrt{h_t} \right) \]  \hspace{1cm} (3.4)

where \( h_t = \gamma_0 + \gamma_1 \hat{\varepsilon}_{t-1}^2 + \gamma_2 h_{t-1}, \Delta p_{o_t} = \alpha + \sum_{j=1}^{k} \beta \Delta p_{o,t-j}^O + \varepsilon_t, \varepsilon_t / I_t \approx N(0, h_t) \)

This measure was proposed by Lee et al. (1995) using a GARCH (1,1) to model the volatility of oil prices. This measure gives more weight to oil price increases in stable periods than those in more volatile ones.
3.4 The Econometric Techniques

In this section, we describe the econometric techniques and the methodology we follow. We use a panel Vector Autoregression (panel VAR) model to study the impact of oil price shocks on the real exchange rate, the discount rate of the central bank, real output growth, and the inflation rate under alternative exchange rate regimes. We use quarterly observations from 1973Q1 to 2004Q2 for nine oil-importing countries: Japan, Germany, France, Italy, South Korea (Korea), Spain, Portugal, Sweden, and Finland and we adopt the Reinhart and Rogoff (2004) exchange rate classification.

The variables included in the panel VAR model are: the real oil price shocks \( (OPC, NOPI, etc.) \), the bilateral real exchange rate index with the US \( (rer_i) \), a measure of short-term interest rate \( (f_i) \), the real output \( (y_i) \), and the consumer price index \( (cpi_i) \). To control for other factors (other than the exchange rate regime) that might affect the impact of oil price shocks on the economy, we include a set of conditioning (control) variables, which are: the industrial production \( (ip_i) \), expressed as an index, the degree of openness \( (OPENN_i) \) expressed as total exports and imports as a percentage of GDP in real terms, and government spending \( (G_i) \) as a percentage of GDP in real terms. All of the above variables are in logs except for \( OPENN_i \) and \( G_i \).

The central bank’s discount rate is included in the VAR to control for the reaction of monetary policy due to oil price shocks (see section 2). That is, we study the influence of oil price shocks on the macroeconomic variables when the effects of monetary policy are accounted for. Industrial production is included as a measure of economic activity (business cycle). The degree of openness is a proxy of the
proportion of traded goods and services in the economy, which might influence the
degree of price adjustment. To control for fiscal policy, we include government
expenditures. The sources and definitions of all variables are provided in the
Appendix.

3.4.1 Unit roots, cointegrations, and the choice of lags

The first step is to establish stationarity for the variables to be included in our VAR
analysis. We first implement the augmented Dickey-Fuller (ADF) tests for the levels
and first differences of the variables in logs of each country separately. That is, for
each country, we estimate the equation

\[ x_t = \gamma + \delta t + \alpha x_{t-1} + \sum_{j=1}^{k} \theta_j \Delta x_{t-j} + e_t \]

using the appropriate lag length. The results of these tests (shown in Table 3.3 and
Table 3.4) indicate that only the log oil price shock is stationary in level. However,
the log real exchange rate, the log discount rate, the log real output, the log
consumer price index, the log industrial production, the degree of openness, and the
government expenditures are stationary in first difference only. Following the
literature and to solve for the low power problem of individual unit root tests, we
perform a panel unit root test based on the methodology proposed by Levin and Lin
(LL, 1993). The LL unit root test is based on a test of

\[ H_0 : \rho_1 = \rho_2 = \cdots = \rho_N = \rho = 1 \quad \text{vs.} \quad H_1 : \rho_1 = \rho_2 = \cdots = \rho_N = \rho < 1 \]

when estimating the panel data equation

\[ x_{it} = \rho x_{i,t-1} + e_{it} \quad \text{for } i = 1,2,\ldots,N \text{ countries.} \]
Results of this test are shown in Table 3.5 and Table 3.6. The results mostly support the individual ADF tests. However, as indicated in the literature, we found that the Levin-Lin panel unit root test is sensitive to the lag length.

The second step is to test for the presence of cointegrating vectors to account for a possible long-run relationship between the variables. To this end, we use the methodology of Pedroni (1995) and Kao (1999). We performed pair-wise Kao cointegration tests and could not reject the null hypothesis of no cointegration, Table 3.7. We, thus, estimate the model in first difference. We follow both standard statistical procedures and economic intuition (Hamilton et al (2004)) in selecting the lag length, which we set at 4 lags.

### 3.4.2 Causality and exogeneity

The literature on oil price shocks and the macroeconomy has long treated these shocks as exogenous, largely driven by political events. Recently, Barsky and Kilian (2004) demonstrated that the idea of treating oil price shocks as purely exogenous is not robust, as it long seemed. They show that a number of oil price shocks had not been preceded by any political turmoil. To formally address this controversy, we perform Granger causality tests on the endogenous variables in our panel VAR model. Results show (Table 3.2) that both the real exchange rate and the consumer price index Granger cause real oil price shocks (using the NOPI definition). In addition, the results show that it is not safe to assume that the vector of the four endogenous variables, the real exchange rate index, the discount rate, real output growth, and the inflation rate, does not Granger cause the oil price shocks. On the other hand, the results show that real oil price shocks Granger causes the real exchange rate, the real output growth, and the inflation rate at the 1% level of significance.
3.4.3 Econometric model

Given our earlier discussion, the econometric model takes the following form

\[ A_0 Y_{i,t} = A(L)Y_{i,t} + B(L)X_{i,t} + u_{i,t} \]  

(3.5)

\[ Y_{i,t} = \begin{bmatrix} OPC \\ NOPI \end{bmatrix}, \Delta r e i_{y_t}, \Delta f_{u_t}, \Delta y_{u_t}, \Delta cpi_{u_t} \], \quad X_{i,t} = [\Delta r e i_{y_t}, \Delta OPENN_{u_t}, \Delta G_{u_t}],

\[ u_{i,t} = \begin{bmatrix} \Delta p_{o_t}, \Delta cpi_{o_t}, u_{i,t}^{r_y}, v_{i,t}^{cpi}, \Delta y_{u_t}, u_{i,t}^{y} \end{bmatrix} \] is the vector error term with zero mean and finite variance.

\( A(L) \) and \( B(L) \) are \( n \times n \) matrixes of polynomials in the backward-shift operator \( L \).

To investigate whether oil price shocks have different effects under alternative exchange rate regimes, we can use two alternative methods to detect the influence or the role of the exchange rate regime. The first method is to include dummies that interact with the \( A(L) \) and \( B(L) \) parameters. To this end, we include three dummy variables: 1) \( D\text{Fix} \), that takes the value of one if the exchange rate regime followed by a country in a particular period is currency union, dollarization, currency boards, or any conventional pegs. 2) \( D\text{Flex} \), that takes the value of one if the exchange rate regime followed by a country is free float. 2) \( D\text{INT} \), that takes the value of one if the exchange rate regime followed by a country is an intermediate regime, such as crawling peg, crawling band, and managed float. The second method is to split the sample into three sub-samples corresponding to fixed, intermediate, and flexible exchange rate regimes and estimate the above model for each subsample with no dummies for the exchange rate regime. The disadvantage of this method is the uneven distribution of observations across the resulting subsamples. Due to the degrees of freedom constraint, we use the second method.
Using a panel VAR as opposed to individual VARs imposes the constraint that the structure of the response of economies to oil price shocks is homogenous. In other words, we impose the assumption that the adjustment process is the same across the countries in our sample. To overcome any possible heterogeneity in the estimated parameters, beside the exogenous control set in (3.5), we relax the homogeneity of coefficients constraint using two methods. First, we account for heterogeneity by including country fixed effects in the model. Second, we allow the variance of the error \( u \) to vary with “\( i \)”, the country. In other words, we allow for cross-sectional heteroscedasticity.

### 3.5 Results and Discussions

#### 3.5.1 Main results

We first allow for a symmetric one period 10% oil price shock using the difference in the log price of oil as an oil price shock. We use this definition of an oil price shock due to the clear symmetry in accounting for both oil price increases and oil price decreases. The impulse responses of the real exchange rate, the discount rate, the real output growth, and the inflation rate are shown in Figure-3. The impulse responses show that after a symmetric oil price shock, the real exchange rate depreciates instantaneously under flexible regimes with little but prolonged adjustment in fixed regimes. The adjustments in the real exchange rate under flexible regimes are mostly driven by depreciation in the nominal exchange rate, at least for the quarter contemporaneous to the oil price shock when prices and wages are sluggish. After the contemporaneous depreciation, the real exchange rate returns to its long-run equilibrium faster than its counterpart under a fixed exchange rate. The response of the real exchange rate under fixed regimes show a slight depreciation for the quarter contemporaneous to the oil price shock followed by
periods of appreciations and deprecations settling at its long-run equilibrium around the fifth quarter following the shock. To analyze the behavior of the nominal exchange rate with the US dollar when allowed to float when there is an oil price shock, we estimate the following panel relationship for the flexible exchange rate regime countries

\[
\Delta neri_{it} = \text{constant}_i + \sum_{i=0}^{4} \left\{ OPC_{i,t-j} \right\} + \sum_{j=1}^{4} \Delta neri_{i,t-j} + error_{i,t}.
\]

The results are shown in Table 3.8. The impulse response of the nominal exchange rate for countries adopting flexible exchange rate regimes to a 10% oil price shock using OPC and NOPI are shown in Figure 3.6. Using either definition of the oil price shocks, the symmetric OPC or the NOPI, the results are almost identical. The nominal exchange rate depreciates in the same period of the shock and then returns rapidly to its long-run equilibrium. The impulse response of the nominal exchange rate resembles that of the real exchange rate, allowing us to conclude that the adjustment seen in the impulse response of the real exchange rate of countries under flexible exchange rate regimes are largely driven by depreciations in the nominal exchange rate, consistent with Friedman’s hypothesis.

The inflation impulse responses show that fixed regimes suffer slightly higher inflation, due to oil price shocks, compared to flexible regimes. The response of monetary policy (represented by the central bank’s discount rate) seems consistent across the regimes with more pronounced reaction under flexible regimes. For output growth, the symmetric oil price shocks do not show clear contrast in the response of countries adopting fixed or flexible exchange rate regimes. However, the empirical evidence in the literature suggests that oil price shocks are not
symmetric, with oil price increases having significant effects on the economy and no effects from oil price decreases (e.g. Hamilton (1996, 2000), and Lee et al. (1995) for the US case and Mork (1994) for some OCED countries). Given this, one should expect a sharper distinction in the response of the four aggregate variables, the real exchange rate, the discount rate, the real output growth, and the inflation rate to positive oil shocks when the latter are considered exclusively. Thus, we now turn to examine the effect of oil price increases and decreases separately.

3.5.2 **Asymmetric oil price shocks**

Figure 3.4 shows the impulse responses to a 10% positive oil price shock. The shock definition used to generate the impulse responses is Hamilton’s NOPI defined above. As we pointed out in the previous paragraph, the response of the endogenous variables under different exchange regimes are more distinguishable when using oil price increases only. For the real exchange rate, although the initial response resembles that of symmetric oil price shocks, Figure 3.4 shows that the real exchange rate under fixed regimes seems to suffer prolonged periods of appreciation and depreciation to return to its long-run equilibrium compared to the real exchange rate response under flexible regimes. This finding is consistent with Friedman’s hypothesis that adjustments in the real exchange rate under flexible regimes should be smoother. Adjustment in the real exchange rate can be achieved by either changes in the nominal exchange rate or changes in relative prices when expressed in local currency. The response of the real exchange rate due to an oil price increase under fixed exchange rate regimes is driven merely by the adjustments in relative prices and wages since the nominal exchange rate is fixed.

The responses of real output growth under fixed and flexible exchange rate regimes reinforce the previous finding of real exchange rate. Under flexible regimes, real GDP growth shows a negative change of 50 basis points after a 10% increase in
the oil price and returns to its long-run equilibrium by the third quarter following the shock. However, although the initial response of the GDP growth rate under fixed regimes is lower than that of flexible regimes, output growth undergoes periods of output decline followed by output growth and decline again till it returns to its long-run equilibrium by the fifth quarter.

The response of the inflation rate resembles that of symmetric oil price shocks discussed in the previous section. Although the impact of a positive oil price shock is higher under fixed regimes in the quarter contemporaneous to the shock, the inflation rate does not distinguish between fixed and flexible exchange rate regimes when it comes to the speed of adjustment (i.e. the inflation rate returns to its long-run equilibrium in the same quarter under fixed and flexible exchange regime).

As expected, the role of monetary policy seems to be different when considering positive oil price shocks only. Surprisingly, the reaction of monetary policy to a positive oil price shock is more pronounced under fixed exchange rate regimes. This comes as a surprise since monetary policy is less potent under fixed regimes, where the task of monetary policy is to maintain the parity of the nominal exchange rate. In general, the monetary authorities in the sample under consideration seem to tighten monetary policy following positive oil price shocks. Although the reaction is slightly higher under a flexible regime in the first period following the shock, the discount rate takes a sharp hike after the second quarter under fixed regimes. One possible explanation for this is to keep the exchange rate constant under a fixed exchange rate regime.

To test the statistical significance of the effects of oil price shocks on the endogenous variables in the panel VAR model under different exchange rate regimes, we conduct standard testing procedures (Table 3.9 and Table 3.10). We can see that oil price shocks are statistically significant only in affecting the real
exchange rate across all exchange rate regimes. The difference between the exchange rate regimes in reacting to an oil price shock is also statistically significant only for the real exchange rate across the three regimes.

We also attempted to analyze negative oil price shocks, we use a definition similar to that of Hamilton’s NOPI, which can be defined as

\[
NOPD_t = \min[0, \min(p_{t-1}, p_{t-2}, p_{t-3}, p_{t-4})].
\]

Surprisingly, the response of the real exchange rate, the discount rate, the real output growth, and the inflation rate under fixed regimes resembles those of positive oil price shocks. However, under flexible regimes the responses are not significant at 10% level.

3.5.3 Variance decomposition

How important are oil price shocks in explaining short-term variations in the endogenous variables of our empirical VAR model? To answer this question we perform standard variance decomposition exercises based on the four quarters ahead forecast shown in Table 3.11. When using the symmetric definition of oil price shocks, they explain more than one third of the variations in the real exchange rate and the inflation rate for both fixed and flexible exchange rate regimes. This is consistent with previous studies. However, when using the NOPI measure of shocks, the oil price shocks do not seem to explain any significant variations in any of the endogenous variables in the system. Backus and Crucini (2000) found that oil prices account for much of the variations in the terms of trade for eight developed OECD countries. Amano and Norden (1996) found that the domestic-currency real
oil prices seem to capture significant long-run movements in the real effective exchange rates for Germany, Japan, and the United States.

### 3.5.4 Caveats and robustness check

How robust are the findings of our estimations in this chapter? We will answer this question by addressing the following caveats. The first important caveat is that the varying responses to the oil price shocks might come from the different economic structures in the countries included in the sample and not necessarily from the exchange rate regime adopted by the group of countries. We can partly relax this caveat first by the fact that the sample we choose is that of nine oil-importing OECD countries in which the importance of oil is proportional to the size of the economy. In addition, the set of control variables (industrial production, degree of openness and government expenditures) reduces the effects of those other factors other than the exchange rate regime.

The second caveat is the choice of the exchange rate regime classification. Although our estimations are based on the *de facto* exchange rate regime classification of Reinhart and Rogoff (2004), for the countries included in our sample, this classification is highly correlated with the *de facto* classification of Levy-Yeyati and Sturzenegger (2002). The Reinhart and Rogoff classification is empirically more appealing due the fact that countries less frequently switch among regimes in this classification compared to that of Levy-Yeyati and Sturzenegger. The correlation of the Reinhart and Rogoff classification with the *de jure* classification of the IMF is very low. In this case, validating our results with the IMF classification will not be meaningful.\(^{19}\)

The third caveat is the choice of the proxy for oil price shocks. We found that using the NOPI measure gives more significant results compared to the positive

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\(^{19}\) Reinhart and Rogoff (2004) argue that the IMF *de jure* classification is close to random.
changes of OPC measure. We also extended NOPI to include 8 lags (2 years), and the results were qualitatively similar to those of 4 lags (one year), but less significant.

A fourth caveat is the stability of the relationship between the measure of the oil price shocks and the economic variable under consideration. In the empirical literature, the relationship between the oil price shocks and real GDP was found to be less stable across the last three decades (e.g., Hamilton 2000). The major argument in the literature to support such instability is the collapse of OPEC around 1986 when it failed to act as a cartel. However, in this study, the degrees of freedom is the major restriction in validating the results of the estimations across different time periods. Nonetheless, we argue that using the NOPI measure (extended to longer lags) will reduce any instability in the parameters, given the nonlinearity of this measure. However, our objective is to analyze the role of the exchange rate regimes in the adjustments to oil price shocks, which take effect in the short-to-medium term, rather than focusing on possible long-run stable relationships between the oil price and the macroeconomic variables.

3.5.5 Monetary policy and oil price shocks

In this section, we revisit the point we have briefly introduced in this chapter regarding the debate on whether only oil price shocks should be blamed for the recession usually found after these shocks or whether the contractionary monetary policy reacting to the high oil prices contributes to the recession. We address this issue formally by re-estimating the empirical model without accounting for the monetary policy variable (the discount rate) to see if the responses of the endogenous variables are any different than if monetary policy is accounted for. Figure 3.5 shows the impulse response of the real exchange rate, the output growth rate, and the inflation rate to a 10% positive oil price shock using NOPI measure of shocks. The responses are almost the same as when the discount rate is accounted
for. This allows us to conclude that the response of monetary policy is not very instrumental in the behavior of any of the three variables, the real exchange rate, the output growth rate, and the inflation rate, after a positive oil price shock when the sample is pooled.

### 3.6 Conclusions

The recurring oil price shocks that hit all economies in the world provide an opportunity to empirically test Friedman’s hypothesis that flexible regimes better absorb real external shocks. The uncertainty associated with the size and timing of these shocks has certainly contributed, directly and indirectly, to the search, choice, and design of robust monetary and exchange rate systems that might facilitate the absorption of these shocks. For example, after the collapse of the Bretton Woods system in March 1973, a group called “the committee of twenty” had been assigned the job of designing a new system of fixed exchange rates that would overcome the drawbacks of the previous system, the Bretton Woods. However, the strong oil price shock that hit the world at that time made a return to a system of fixed exchange regime unfavorable.

In this chapter, we empirically tackle the issue of the role of exchange rate regimes in affecting the responses of some key economic variables to oil price shocks. Since the channels of influence of the oil price shocks may be many, a well-structured empirical model that robustly accounts for all channels might not be attainable. To bypass such an obstacle, we use a panel VAR technique, with minimal restrictions, to test for the impact of oil price shocks on nine major OECD oil-importing countries under alternative exchange rate regimes using Reinhart and Rogoff classification scheme, after controlling for other factors that might affect the

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20 Krugman and Obstfeld (2003)
responsiveness to oil price shocks. We use quarterly observations from 1973Q1 to 2004Q2 for Japan, Germany, France, Italy, South Korea (Korea), Spain, Portugal, Sweden, and Finland. The endogenous variables of the panel VAR are: the real oil price shocks, the bilateral real exchange rate with the US, the discount rate of the central bank, real output growth, and the inflation rate.

We found that flexible exchange rate regimes better absorb positive oil price shocks, consistent with Friedman’s hypothesis. The necessary adjustments are made by the nominal exchange rate mostly in the same period of the oil price shocks. We found that under flexible exchange rate regimes, and in response to one standard deviation positive oil price shock, both the real exchange rate and output growth show faster speeds of adjustment when returning to their long-run equilibrium relative to the fixed exchange rate regimes. In addition, the inflation rate shows relatively higher contemporaneous increase due to positive oil shocks under fixed exchange regimes. Our results show that monetary policy reactions to the oil price shocks have no significant contribution to the response of the real exchange rate, output growth, and the inflation rate following oil price shocks. These findings have policy implications for emerging economies as they experience a growing industrial sector and more dependence on imported oil.

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21 The observations for the members of the European Union covers only the period 1973Q1-1998Q4.
APPENDIX C
3.7 Appendix C

3.7.1 Data sources and definitions

The data includes quarterly observations from 1973Q1 to 2004Q2 except for the members of the European Union, where the data ends in 1998Q4. All data are obtained from International Financial Statistics CD-ROM November 2004, published by the International Monetary Fund. The countries included in the sample are: Finland, France, Germany, Italy, Japan, Korea, Portugal, Spain, and Sweden. For each series that is not seasonally adjusted, we use the X11 procedure to take any seasonality effects.

Table 3.1: Data sources and definitions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real oil price ($po_t$)</td>
<td>The average spot oil price of Brent, Taxes, and Dubai in US dollars converted to local currencies using the nominal exchange rate with the US dollar, and then deflated with the respective country’s CPI.</td>
</tr>
<tr>
<td>Bilateral real exchange rate with the US dollar ($reri_{it}$)</td>
<td>Calculated as the bilateral nominal exchange rate with the US dollar adjusted by the relative consumer price indices, expressed as an index, not seasonally adjusted.</td>
</tr>
<tr>
<td>Real output ($y_{it}$)</td>
<td>Nominal GDP in respective currencies divided by GDP deflator, expressed as an index, not seasonally adjusted.</td>
</tr>
<tr>
<td>Consumer price index ($cpi_{it}$)</td>
<td>Published by the IMF, not seasonally adjusted.</td>
</tr>
<tr>
<td>The central bank’s discount rate ($f_{it}$)</td>
<td>The discount rate under the direct control of monetary authorities (the name may vary from country to country). not seasonally adjusted.</td>
</tr>
<tr>
<td>Industrial Production ($ip_{it}$)</td>
<td>Published by the IMF, seasonally adjusted.</td>
</tr>
<tr>
<td>Degree of openness ($OPENN_{it}$)</td>
<td>Real imports plus real exports divided by real GDP, not seasonally adjusted.</td>
</tr>
<tr>
<td>Government spending ($G_{it}$)</td>
<td>Total government expenditures in local currency divided by GDP, not seasonally adjusted.</td>
</tr>
</tbody>
</table>
### 3.7.2 Tables and figures

Table 3.2: Granger Causality Test between oil price shocks and other variables in the VAR system based on p=4 lags

<table>
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<th>Causality Hypothesis $^b$</th>
<th>p-value $^a$</th>
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<tr>
<td>Real exchange rate $Gr \rightarrow$ oil price shocks</td>
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</tr>
<tr>
<td>Discount rate $Gr \rightarrow$ oil price shocks</td>
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<td>Real output growth $Gr \rightarrow$ oil price shocks</td>
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<td>Inflation $Gr \rightarrow$ oil price shocks</td>
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<tr>
<td>All four variables $Gr \rightarrow$ oil price shocks</td>
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</tr>
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<td>Oil price shocks $Gr \rightarrow$ All four variables</td>
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</tr>
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</table>

$^a$ the lowest significant level at which we can reject the null hypothesis

$^b$ note that the null hypothesis assumes no Granger causality between the variables on both sides
Table 3.3: Augmented Dickey-Fuller tests for the variables in levels for individual countries

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<th>po</th>
<th>reri</th>
<th>y</th>
<th>cpi</th>
<th>f</th>
<th>ip</th>
<th>OPENN</th>
<th>G</th>
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(i) refers to zero mean, (ii) a single mean, and (iii) a trend

* **, and *** refers to 1%, 5%, and 10% levels of significance respectively.
Table 3.4: Augmented Dickey-Fuller tests for the variables in first differences for individual countries

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<th>y</th>
<th>cpi</th>
<th>f</th>
<th>ip</th>
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(i) refers to zero mean, (ii) a single mean, and (iii) a trend
*, **, and *** refers to 1%, 5%, and 10% levels of significance respectively.
Table 3.5: Levin-Lin panel unit root test for the variables in levels

<table>
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<th>variable</th>
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<td>(i)</td>
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<td>25.981</td>
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<tr>
<td>y</td>
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<tr>
<td>(ii)</td>
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<td>-1.731 **</td>
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<tr>
<td>(iii)</td>
<td>-0.078</td>
<td>5.605</td>
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</tr>
<tr>
<td>(ii)</td>
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<td>-7.989 *</td>
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<td>(iii)</td>
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<td>-0.3956</td>
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<tr>
<td>reri</td>
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</tr>
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<td>-1.648 **</td>
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(i) with no constant, (ii) with a constant, (iii) with a constant and a trend

*, ** refers to 1% and 5% levels of significance
Table 3.6: Levin-Lin panel unit root test for the variables in first differences

<table>
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<tr>
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<td>-1.840</td>
<td>-22.174*</td>
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<tr>
<td></td>
<td>-1.845</td>
<td>-26.421*</td>
</tr>
<tr>
<td>$cpi$</td>
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<td>-6.898*</td>
</tr>
<tr>
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<td>-0.314</td>
<td>-5.500*</td>
</tr>
<tr>
<td></td>
<td>-0.458</td>
<td>-8.917*</td>
</tr>
<tr>
<td>$reri$</td>
<td>-0.839</td>
<td>-18.710*</td>
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<td>-0.842</td>
<td>-15.845*</td>
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<td>-19.366*</td>
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<td>$f$</td>
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<td>-1.387</td>
<td>-28.834*</td>
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(i) with no constant, (ii) with a constant, (iii) with a constant and a trend
* refers to 1% levels of significance

Table 3.7: Kao’s Dickey Fuller test of the bilateral cointegration

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<th>Real oil price</th>
<th>Real exchange rate</th>
<th>Short-term interest rate</th>
<th>Output growth</th>
</tr>
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<tr>
<td>Real exchange rate</td>
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<tr>
<td>Short-term interest rate</td>
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<td>Output growth</td>
<td>-3.92</td>
<td>0.87</td>
<td>-0.11</td>
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</tr>
<tr>
<td>Inflation rate</td>
<td>-4.03</td>
<td>-2.07</td>
<td>-1.09</td>
<td>-0.11</td>
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Notes: the values are the DF statistics of testing the null of no cointegration
Table 3.8: The impact of oil shocks on the nominal exchange rate for countries under flexible exchange rate regimes

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<th>Using OPC</th>
<th>Using NOPI</th>
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<td>Oil shock at the same quarter</td>
<td>0.148</td>
<td>0.176</td>
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<tr>
<td></td>
<td>(0.026)</td>
<td>(0.061)</td>
</tr>
<tr>
<td>Oil shock lagged one quarter</td>
<td>-0.052</td>
<td>-0.092</td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(0.051)</td>
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<tr>
<td>Oil shock lagged two quarter</td>
<td>0.074</td>
<td>0.078</td>
</tr>
<tr>
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<td>(0.026)</td>
<td>(0.051)</td>
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<tr>
<td>Oil shock lagged three quarter</td>
<td>-0.033</td>
<td>-0.038</td>
</tr>
<tr>
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<td>(0.025)</td>
<td>(0.050)</td>
</tr>
<tr>
<td>Oil shock lagged four quarter</td>
<td>0.032</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.045)</td>
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<tr>
<td>$\Delta neri_{i,t-1}$</td>
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<td>0.330</td>
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<tr>
<td></td>
<td>(0.065)</td>
<td>(0.065)</td>
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<td>$\Delta neri_{i,t-2}$</td>
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<td>-0.185</td>
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<tr>
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<td>$\Delta neri_{i,t-3}$</td>
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<td>0.193</td>
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<td>(0.067)</td>
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<td>$\Delta neri_{i,t-4}$</td>
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<td>(0.065)</td>
</tr>
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<td>R-squared</td>
<td>0.255</td>
<td>0.170</td>
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Note: standard errors are in parenthesis
Table 3.9: Hypothesis testing of the significance of oil price shocks across different regimes

<table>
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<th>Variable</th>
<th>Fixed</th>
<th>Flexible</th>
<th>Intermediate</th>
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</thead>
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<td>Real exchange rate</td>
<td>3.92**</td>
<td>2.33*</td>
<td>4.38**</td>
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<tr>
<td>Discount rate</td>
<td>0.21</td>
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<td>0.58</td>
</tr>
<tr>
<td>Real output growth</td>
<td>0.27</td>
<td>0.59</td>
<td>0.86</td>
</tr>
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<td>Inflation rate</td>
<td>0.88</td>
<td>1.08</td>
<td>3.06**</td>
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</table>

Notes: (1) values are the F-value of testing the hypothesis that coefficients are zero at all lags. (2) +, *, and ** refer to 10%, 5%, and 1% level of significance respectively.

Table 3.10: Hypothesis testing of the difference across regimes to oil price shocks

<table>
<thead>
<tr>
<th>Variable</th>
<th>Fixed=Flexible</th>
<th>Fixed=Intermediate</th>
<th>Flexible=Intermediate</th>
<th>All three equal</th>
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</thead>
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<td>Real exchange rate</td>
<td>2.83+</td>
<td>6.49**</td>
<td>0.50</td>
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<tr>
<td>Discount rate</td>
<td>5.35*</td>
<td>1.44</td>
<td>3.59*</td>
<td>2.96*</td>
</tr>
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<td>Real output growth</td>
<td>0.76</td>
<td>1.19</td>
<td>0.01</td>
<td>0.60</td>
</tr>
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<td>Inflation rate</td>
<td>1.90</td>
<td>6.64**</td>
<td>1.42</td>
<td>3.62*</td>
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</table>

Notes: (1) values are the F-value of testing the hypothesis that coefficients are equal. (2) +, *, and ** refer to 10%, 5%, and 1% level of significance respectively.
Table 3.11: Variance Decomposition: Proportion of variance explained by the oil price shocks (%)

<table>
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<tr>
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<th>Real exchange rate</th>
<th>Discount Rate</th>
<th>Output Growth</th>
<th>Inflation Rate</th>
</tr>
</thead>
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<td>Symmetric Oil Price shocks</td>
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<td>33</td>
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<td>1</td>
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<td>1</td>
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Note: the above variance decomposition is based on 4 quarters ahead forecast.
Figure 3.1: The domestic-currency real price of oil, the nominal exchange rate, and the real exchange rate for flexible exchange rate regime countries.
Figure 3.2: The domestic-currency real price of oil, the nominal exchange rate, and the real exchange rate for intermediate exchange rate regime countries
Figure 3.3: The impulse responses to a 10% symmetric oil price shock (using OPC)
Figure 3.4: The impulse responses to a 10% positive oil price shock (using NOPI)
Figure 3.5: The impulse responses to a 10% oil price shock (using NOPI) without controlling for monetary policy
Figure 3.6: The impulse response of the nominal exchange rate to 10% oil price shocks for flexible regime countries

Note: dotted lines are two standard deviations confidence interval
3.8 References


Chapter 4

Re-Examining the Exchange Rate Pass-Through Into Import Prices Using Non-Linear Estimation Techniques: Threshold Cointegration

4.1 Introduction

As we have previously indicated, the stabilizing role, or expenditure switching, of flexible exchange rates rests on the assumption that import prices respond to changes in nominal exchange rates. The empirical evidence, so far, using aggregate as well as sectoral cross section and time series samples, on exchange rates and import prices is not supportive of complete pass-through. Since the issue of pass-through is crucial for the optimal monetary policy and the choice of optimal exchange rate regimes, the low pass-through finding triggered development of a
theoretical literature that attempted to explain the empirical evidence of low exchange rate pass-through using new open economy macroeconomics. The literature has progressed in several interrelated strands. One strand of literature focuses on the implication of currency denomination of produced goods and services for monetary and exchange rate policy. It analyzes the industrial structure and the role of goods market segmentations and price discrimination. Depending on the degree of price discrimination and on the currency in which the good is sold, there have been three assumptions about price setting: a) Producer Currency Pricing, b) Consumer Currency Pricing, and c) Local Currency Pricing. Another strand of literature attempted to allow for nontraded transaction costs that are embedded in the traded goods, which might account for the low pass-through. In other work, imported goods are treated as intermediate inputs that are used to produce final consumption goods. In this case, producers will behave differently in setting the prices of their products as their costs of production are affected by movements in the nominal exchange rates. In the same vein, a number of theoretical studies link the degree of pass-through to macroeconomic variables, such as inflation and the status of the business cycle, arguing that the degree of pass-through is endogenous.

The papers that attempted to estimate the degree of pass-through of exchange rates to import prices have in general found low pass-through using cross-country and time series samples. Most of the studies focused on aggregate prices as opposed to industry level or sectoral level prices. The merit of using sectoral level samples is obvious in that they give more insights on the characteristics of the industries that account for the varying degree of pass-through. Also, sectoral level prices overcome nontraded goods problems that are sometimes hard to isolate when using aggregate data. In addition, the empirical studies that used aggregate or sectoral level cross-section and time series samples assumed linear smooth relationships between
changes in the nominal exchange rates and import prices. The fertile theoretical literature, which we have succinctly addressed above, indicates that the nominal exchange rate pass-through into import prices relationship might not be appropriately approximated by the usual smooth linear regressions, suggesting a potential for nonlinear estimation. For example, exporting firms which use local currency pricing (LCP) might find it optimal to change their prices (and hence prices to the importers) as an adjustment to substantial changes in the nominal exchange rate or cost of production, although under LCP the degree of pass-through should be zero, i.e. prices should be insulated from nominal exchange rate changes.

The nonlinear relationship between changes in the nominal exchange rate and local import prices can also result from frictions such as contracts, transaction costs, menu costs, and other adjustment costs, which preclude price adjustments in the short-run. As a result, we expect the degree of pass-through from nominal exchange rate changes to import prices to be higher in the long-run. More formally, there has been a growing literature that looked at the determination of the degree of exchange rate pass-through in general equilibrium models with endogenous exchange rates. The findings of these studies suggest an equilibrium rate of pass-through (e.g. Bacchetta and Van Wincoop (2002) and Devereux, Engel, and Storgaard (2003)). To test this hypothesis, this chapter attempts to re-estimate the degree of pass-through of exchange rate changes to import prices at the aggregate as well as sectoral level by allowing for nonlinear adjustment processes. More specifically, we use a threshold vector cointegration model to account for such nonlinear relationships. By allowing for such processes, we attempt to answer the following questions: a) Can the degree of pass-through be increased when threshold nonlinearity is observed? b) Can we get more insights into asymmetry in the speed and magnitude of adjustment in import prices to nominal exchange rate changes when threshold nonlinearity is accounted for? Our import prices data sample is that of Campa and Goldberg
(2004)-updated with three more years, which consists of industry as well as aggregate level quarterly import prices in local currency for 16 OECD countries from 1975q1 to 2002q2. The data are obtained from the OECD statistical compendium for five sectors: food, energy, raw materials, manufactures, and non-manufacturing products. The nominal exchange rates and other control variables data are obtained from the International Financial Statistics of the IMF as explained in the data section.

We document a significant threshold cointegrating relationship between the effective nominal exchange rate and import prices for the five industries considered in the sample. By allowing for such nonlinearity in estimating the degree of pass-through from the nominal exchange rates to the import prices, we find that the average degree of pass-through improves dramatically from the 50% average documented in the literature. The results of our threshold cointegration model show that import prices respond faster and by a larger extent to nominal exchange rate shocks compared to models with no threshold cointegration. The findings of this chapter support the hypothesis of an equilibrium rate of pass-through (e.g. Bacchetta and Van Wincoop (2002) and Devereux, Engel, and Storgaard (2003)). They also indicate the significance of accounting for adjustment costs in estimating the relationship between nominal exchange rates and import prices. The chapter finds that the manufacturing industry exhibits a large difference in the degree of pass-through when incorporating threshold cointegration compared to models with no thresholds.

The findings of this chapter suggest that more work needs to be done to emphasize the short-run dynamics in the way import prices respond to nominal exchange rates, possibly through the use of less aggregated data. More evidence of this kind will certainly change the view of the limited stabilizing role for exchange rate flexibility that has appeared in recent new open economy literature. Further more, the findings of this study have policy implications for both trade-protection
strategies through competitive pricing and monetary policies directed toward inflation targeting especially for countries with relatively large imports.

We proceed as follows. Section 2 reviews the relevant studies. Section 3 discusses the theoretical framework. Section 4 presents the econometric model. Section 5 discusses the results and the caveats. Some conclusions follow.
4.2 Summary of Literature

4.2.1 Exchange rate pass-through in theory

The main mechanism through which the exchange rate can have a role in the economic adjustment toward a new equilibrium is through the “expenditure switching effect”. The main argument in favor of flexible exchange rate regimes relies entirely on their ability to provide a vital expenditure switching effect. The early contribution on this issue was by Friedman (1953). Friedman’s hypothesis assumes that flexible exchange rates facilitate smoother and faster relative price adjustments across countries. Theoretically, the Keynesian and the new open economy models supported this argument. However, the above argument is dependent on two assumptions: a) goods and services are denominated in the currency of the producers, and b) there is a one-to-one relationship between the nominal exchange rate and import prices when expressed in the currency of the buyer (complete pass through). Thus, if consumer prices are not responsive to exchange rates, then the expenditure switching effect is impotent and the stabilizing role of the nominal exchange rate is questionable. The recent empirical evidence is not supportive of the second assumption (see Mussa (1986) for an early contribution, Engel (1993, 1999, 2000), and Engel and Rogers (1996, 2001)). Recently, the theoretical literature has taken more than one approach to address this empirical evidence of incomplete pass-through to import prices. The recent theoretical literature in open-economy macroeconomics that addressed the empirical evidence on the effects of exchange rates on prices was surveyed by Engel (2002). In the following we briefly summarize the different strands that address the pass-through issue.
Using the Redux-Model, introduced by Obstfeld and Rogoff (1995), which assumes goods are invoiced in the currency of the producers, a number of studies analyzed the impact of assuming alternative export invoicing on the conduct of monetary policy and the optimal choice of exchange rate regimes (Betts and Devereux (1996, 2000), Chari, Kehoe, and McGrattan (2000), and others). Three price-settings structures are considered in this literature, Producer-Currency Pricing (PCP), Local-Currency Pricing (LCP), and Pricing-To-Market (PTM). In PCP, producers set prices in their own currency. In this case, the price that foreigners pay for domestic goods and the price that home residents pay for foreign goods fluctuate when the exchange rate changes. Under PCP, purchasing power parity holds at all times, since there is only one price set in the producer’s currency for each good. In LCP, producers set the price in the consumers’ currency. That is, producers charge two prices—one to residents of their own country, and another to residents of the other country. In this case, the prices that consumers face do not respond at all to exchange rate changes. Finally, in PTM, producers segment international markets for their goods, such that they can, at least over some time horizon, charge different prices to different national markets according to these markets’ demand conditions. That is, in PTM, producers engage in third-degree price discrimination. The difference between LCP and PTM is that in the former, producers set prices in consumers’ currencies. In addition, under LCP, producers do not engage in price discrimination. Under both the LCP and the PTM, purchasing power parity does not hold. This is because, under this form of price stickiness, exchange rate changes do not lead to proportional changes in import prices, leaving short-run deviations from the law of one price. Since the import prices are pre-set in the importer’s rather than the exporter’s currency, the exchange rate pass-through to import prices is zero. Despite the potential of PTM and LCP models to mimic a subset of business-cycle facts, they are deemed implausible by some researchers; for instance, Obstfeld and
Rogoff (2000a) based their criticism of PTM-LCP on a number of inconsistent assumptions and predictions of these models. We summarize Obstfeld and Rogoff’s points in the following: a) the measured deviations from the law of one price may be the result of nontradable components incorporated in consumer price indexes for supposedly tradable goods not necessarily PTM-LCP, b) price stickiness resulting from trade invoicing is shorter than the price stickiness resulting from wage stickiness, the former will thus have smaller impacts on macroeconomic interactions at business-cycle frequencies, c) empirical evidence refutes the view that exporters set prices predominantly in importers’ currencies (e.g. Obstfeld and Rogoff (2000a) writes: “in 1992, the ECU Institute reports that the U.S., with 92 percent of exports and 80 percent of imports invoiced in dollars, is an exception in that most of its imports are denominated in home currency”), d) empirical evidence could not find pass-through to export prices close to zero, contradicting the predictions of PTM-LCP.

Another strand of literature, which attempts to address the empirical evidence of low pass-through, focuses on market frictions, such as distribution costs and transportation costs embedded with traded goods. Such costs might allow market segmentation across countries (Obstfeld and Rogoff (2000b), McCallum and Nelson (1999), and Corsetti and Dedola (2001)). This argument is illustrated by the following example: consider two goods, domestic and imported, that are close substitutes for each other. Changes in the exchange rate will not be completely reflected in a higher price of the imported good due to the large nontraded transaction and distribution costs associated with the imported good, which are not affected by the exchange rate. However, this argument is valid only when we consider the pass-through to consumer prices as opposed to the import prices (prices paid by importers). It is the final consumption good that should be
embedded with transaction and distribution costs by the time it reaches the consumer.

Another approach contrasts the degree of pass-through and the degree of substitutability between domestic and imported goods (Devereux, Engel, and Tille (1999)). In the same vein, some studies modeled imported goods as intermediate inputs that are used along with domestic inputs to produce final goods. In this literature, the foreign and domestic inputs are highly substitutable, thus, the importer can switch between the two when the exchange rate changes, thus, affecting the degree of pass-through.

A number of theoretical models attempt to nest the assumptions of general equilibrium open economy macroeconomics, such as price and wage stickiness, with an endogenous pass-through in contrast to the literature which assumed exogenously that firms set prices either in their own currency or in that of the importer (see Devereux, Engel, and Storgaard (2003) and Bacchetta and Van Wincoop (2002)). In these models, the pass-through and the exchange rate are simultaneously determined, and interact with one another. Devereux, Engel, and Storgaard (2003) suggest that treating the exchange rate pass-through as endogenously determined in new open economy macroeconomic models matters for international transmission of shocks, the optimal monetary policy, and the international coordination of monetary policy. In their model, producers will choose the price setting currency (export-invoicing) based on several endogenous factors, such as the variance of the exchange rate, the correlation between marginal cost of their production and the exchange rate as well as the stability of monetary policy. Bacchetta and van Wincoop (2002) model the determinants of the export-invoicing strategy of firms. They suggest that producers with higher market share and more differentiated goods will price in their own currency (PCP). They found
other factors such as the country size and the cyclicality of real wages to be less important empirically.

A recent paper by Choudhri, Faruquee and Hakura (2003) attempts to reconcile the empirical evidence of the low pass-through with the implications of a typical open economy macroeconomic model that nests LCP, PCP, and a number of different specifications if wage-price dynamics along with international price discriminations based on distribution costs. Using a broad set of domestic and international prices for non-US G7 countries, they found that hybrid models that combine LCP and PCP improve the fit of their open economy model to the data when compared with the evidence based on VAR models.

4.2.2 Empirical evidence on pass-through
Empirically, the evidence on the exchange rate pass-through to import prices indicates, in general, a low pass-through using aggregate as well as industry level for both cross sections of countries and time series data samples. Most studies that used aggregated import prices found pass-through estimates of 60 percent or less (see Goldberg and Knetter (1997)) despite the upward trend of trade and economic integration among developed countries as well as developing countries, although less so with the latter countries. The estimated pass-through at the industry level is even lower (see recent evidence by Pollard and Coughlin (2003) and Olivei (2002)). The empirical literature also documents a downward trend in the degree of pass-through over time, Campa and Goldberg (2004). Campa and Goldberg (2004) attempt to explain the varying degree of pass-through both across countries and over time using micro and macroeconomic variables. Across countries, they found that higher inflation and nominal exchange rate volatility are weakly associated with higher pass-through. At the industry level, Campa and Goldberg found that energy and raw material imports have higher pass-through compared to manufacturing
and food products. Over time, they found that microeconomic factors, such as industry composition of a country’s import bundle, moving towards more manufacturing products, better explain changes in pass-through, in contrast to others’ attribution of lower inflation rates in the world that reduce pass-through. Campa and Goldberg conclude that microeconomic factors such as the one mentioned above and the strategic pricing in segmented markets better explain changes in pass-through than macroeconomic policy variables, such as the money growth rate and inflation rate.

A group of studies focused on the direction of change in the exchange rate (exchange rate depreciation vs. exchange rate appreciation) in estimating the pass-through, i.e. an asymmetric pass-through into import prices. Using aggregate data, Mann (1986) found evidence of asymmetry in pass-through using US aggregate data and Webber (2000) found evidence from five Asian countries. Using only one US industry and a single country, Kadiyali (1997) and Goldberg (1995) found evidence of asymmetry in exchange rate pass-through.

The only paper that has addressed the size effect of changes in the nominal exchange rate is that of Pollard and Coughlin (2004). They use US import prices in the manufacturing sector as well as 9 two-digit and 20 three-digit level manufacturing industries to ask whether the size of the change in the exchange rate affects the pass-through issue. They found, in general, a positive association between the size of the change in the exchange rate and the level of pass-through to import prices. The authors attributed the size effect in the degree of pass-through to the menu cost argument of price adjustments. In their estimation procedures, the authors interacted the pass-through coefficients with dummies for the size of changes in the exchange rate in an “ad hoc” manner.
This chapter adds to the empirical exchange rate pass-through literature by explicitly accounting for the nonlinear adjustments in estimating the degree of pass-through of exchange rates to import prices at both the aggregate and the sectoral level. We attempt to test the hypothesis that the observed pass-through reflects adjustments toward a long-run equilibrium pass-through. To that end, we use a threshold vector cointegration regression technique that takes into account, among other factors, the size of changes in nominal exchange rates, that might affect the long-run equilibrium relationships between import prices and nominal exchange rates. For the same sample we use in this chapter, but using classical linear regressions, Campa and Goldberg (2004) found the average pass-through into import prices across countries to be 0.61 in the short-run and 0.77 in the long-run, but with large cross-country differences. Our approach differs from that of Campa and Goldberg (2004) in that we use an error correction model that accounts for the cointegration among the variables to separate short-run adjustments from long-run equilibrium pass-through. Campa and Goldberg treat the contemporaneous coefficients as the short-run pass-through and the sum of all coefficients up to certain lags as the long-run pass-through. This approach does not assume any equilibrium pass-through that import prices revert to. In this study, we first estimate a long-run equilibrium relationship between the non-stationary variables, the import prices and the nominal effective exchange rates, controlling for other relevant factors that might influence that relationship. We then estimate a two-variable vector error correction model allowing for three regimes based on the size of deviations from the long-run equilibrium.
4.3 Theoretical Framework

One of the applications of threshold cointegration models has been in empirical studies of purchasing power parity and the law of one price\textsuperscript{22}. The empirical evidence on purchasing power parity and the law of one price, using linear models, support the proposition that these parities hold in the long-run only, when using long time series samples of a century or more in length, with a slow speed of convergence (on the order of 4 to 5 years). The threshold cointegration models (e.g. Obstfeld and Taylor (1997) for the univariate approach and Lo and Zivot (1999) for the multivariate approach) attempt to account for the observation that transport costs and other trade barriers limit price convergence across markets. The thresholds or “commodity-points” are identified as those points above which intermarket price differentials exceed the costs of transport or other trade barriers. In this case, as proposed by these models, price differentials exhibit no central tendency within the threshold points. However, outside the threshold points price differentials are arbitraged away in a faster decay rate than when no commodity-points are considered (the linear smooth case).

Why should a similar formulation work in estimating the pass-through from nominal exchange rates to import prices? To answer this question, we should start first by identifying the major factors that affect such pass-through. The literature, succinctly summarized in the previous section, identifies two of these factors: the currency denomination of imports and the market share of the exporting firm. We have seen that when imports are denominated in the currency of the exporter, we expect the pass-through to be close to one. On the other hand, if the imports are denominated in the currency of the importer (be it as local market pricing or local currency pricing), we expect the degree of pass-through to be close to zero. Also,

\textsuperscript{22} For a theoretical review of the threshold cointegration models, see Blake and Fomby (1997).
pass-through is greater when exporting firms have a high degree of market power, Feenstra, Gagnon, and Knetter (1996), and Bacchetta and Van Wincoop (2002). This is because the higher the market share of an exporting firm in an industry, the more likely it will set the price in its own currency. In all cases, we can assume that the relationship between nominal exchange rates and import prices is stable in the long-run, given other factors that affect such relationships.

More formally, there has been a growing literature that looked at the determination of the degree of exchange rate pass-through in general equilibrium models with endogenous exchange rates. The findings of these studies suggest an equilibrium rate of pass-through (e.g. Bacchetta and Van Wincoop (2002) and Devereux, Engel, and Storgaard (2003)). Devereux, Engel, and Storgaard (2003) model both the exchange rates and the pass-through as simultaneously determined and interacting with one another. They assume that pass-through is endogenous because firms choose the currency in which they set their export prices. Hence, the rate of pass-through is determined by that decision given the presence of nominal price stickiness. Since, by the construction of their model, they assume that the price-setting decision is also determined by the volatility of the nominal exchange rate, they find that there is a two-way interaction between exchange rate pass-through and exchange rate volatility. This type of modeling produces a unique equilibrium rate of pass-through. Devereux, Engel, and Storgaard find the pricing decisions depend on the variance of the nominal exchange rate and the covariance of the exchange rate with marginal costs, with no dependence on market demand and the prices of all other firms.

This having been said, we then can argue that the degree of pass-through from nominal exchange rates to import prices might be independent (no central tendency) of its determinants, currency of denomination, nominal exchange rate volatility, and the covariance between nominal exchange rate and marginal costs
within some critical points, and revert to its long-run equilibrium outside these points. In this case, a threshold cointegration model will better capture such behavior in the exchange rate pass-through compared to one regime standard linear models.

### 4.4 Econometric Techniques

Previous studies that analyze the exchange rate pass-through to import prices, both at the aggregate level and the industry or even individual good level, start, respectively, from the purchasing power parity relationship or the law of one price, which entails (in logs):

\[ p_t^H = s_t + p_t^F \]  \hspace{1cm} (4.1)

where \( p_t^H \) is the price of imported good in the home currency, \( s_t \) is the spot nominal exchange rate (units of home currency per unit of foreign currency), \( p_t^F \) is the price of the imported good in the foreign currency. The empirical estimation of the degree of pass-through concentrated on the response of the import price \( p_t^H \) to changes in the nominal exchange rate \( s_t \). It is different from the purchasing power parity empirical literature, where the latter concentrated on studying the tendency of the two sides of equation (4.1) to revolve around equilibrium. The difficult part in estimating the exchange rate pass-through to import prices is the choice of the control variables, factors that affect the import prices other than changes in the nominal exchange rate between the importing and the exporting countries. For example, Pollard and Coughlin (2004) included two proxy variables as the control set, the price of a substitute good and the foreign marginal cost of production, which were the producer price indexes for home and for the exporting country.
respectively. They did not include a measure of income due to the less certain relationship between the expenditure (income) measure and the import price. Campa and Goldberg (2004) used factors that affect the mark-up of the exporting producers as their control variables. These factors are: 1) a proxy for the shifting relative costs of a country’s trading partners, which they constructed as the nominal exchange rate multiplied by the importing country’s price index divided by the real exchange rate, 2) real GDP as a proxy for the import market income level.

Since our emphasis on this chapter is on the long-run equilibrium (cointegrating) relationship between the nominal exchange rate and the import prices, we should include variables that might affect the adjustment to this equilibrium. Following the literature, we choose three control variables: a) a weighted average of the real wage rate in the exporting countries as a proxy for the marginal cost of producers, b) the real wage rate in the importing country to account for the prices of local substitute goods, c) real GDP of the importing country to control for total expenditures. The first variable is intended to control for the supply side while the latter two variables are intended to control for the demand side.

4.4.1 Data
We use the same data set of import prices (updated with the last three years) used by Campa and Goldberg (2004), which consists of five categories of quarterly import price indexes for 16 OECD countries from 1975Q1 to 2002Q2 as well as the aggregate of all goods price index. The categories included are Food and Agricultural, Energy, Raw Materials, Manufacturing, Non-manufacturing, and All-goods. We choose trade prices as opposed to retail prices in line with several observations in the literature that pass-through to trade import prices should be higher due to less add-in costs. We also utilize the quarterly real wage rates published by the OECD. For the nominal exchange rate (NEER), we use the IMF effective nominal exchange rate
quarterly series. These rates represent a weighted average of the respective country’s bilateral nominal exchange rate against 17 other currencies. The nominal effective exchange rate and real GDP are obtained from the International Financial Statistics of the IMF.

4.4.2 Threshold cointegration model

The threshold cointegration regression technique allows for the possibility that the degree of exchange rate pass-through to import prices moves towards equilibrium in a nonlinear behavior defined by critical point(s) or thresholds. These thresholds might be associated with the size changes in the nominal exchange rates or any other factor that introduces adjustment costs to changes in the import prices. Given our earlier discussion about the presence of adjustment costs and other factors, the movement toward equilibrium need not occur in every period. For example, a symmetric critical threshold will divide the pass-through relationship between the nominal exchange rate and the import prices paid by importers into two ranges: one range with no cointegrating relationship between these two variables and another range with a cointegrating relationship. The range of no cointegrating relationship might correspond, for example, to the case of small changes in the nominal exchange rate that result in minimal pass-through, whereas the second range might be characterized by the maximal pass-through when the import prices and the nominal exchange rate are in long-run equilibrium. Thus, estimating the degree of pass-through into import prices using smooth linear models will overlook such nonlinearity in the relationship between these two variables, resulting in low estimated pass-through. Following the methodology presented by Blake and Fomby (1997), we estimate the following Equilibrium-threshold cointegration model (EQ-TAR) for the non-stationary variables:
\[ p_t = \alpha + \beta s_t + \gamma w_t + \epsilon_t \quad (4.2) \]

\[ \epsilon_t = \begin{cases} 
\rho_1 \epsilon_{t-1} + \eta_{t-1}^{\text{out}} & \text{if } \epsilon_{t-1} \leq \theta_1 \\
\rho_3 \epsilon_{t-1} + \eta_{t-1}^{\text{in}} & \text{if } \theta_1 < \epsilon_{t-1} < \theta_2 \\
\rho_2 \epsilon_{t-1} + \eta_{t-1}^{\text{out}} & \text{if } \epsilon_{t-1} \geq \theta_2 
\end{cases} \quad (4.3) \]

where \( p_t \) is the log import price of a given sector of imports in local currency, \( s_t \) is the log nominal effective exchange rate (defined as a weighted average of the reciprocal of the units of the local importing country’s currency per units of the exporting countries’ currency), \( w_t = [w_{t-1}, w_t, gdp_t] \) is a vector of control variables which include, respectively, the weighted average real wage as a proxy for the marginal cost of exporters, the real wage for the importing country as a proxy for the price of substitute goods, and the real GDP of the importing country as a proxy for income (expenditure) of importer. Equation (4.2) is the cointegration relationship where the residuals, \( \epsilon_t \), are the deviations from the long-run equilibrium. \( \theta_1 \) and \( \theta_2 \) is the critical thresholds. \( \eta_t \) is i.i.d. random variable with mean zero and variance \( \sigma_{\eta_t}^2 \). We expect the degree of pass-through to return to a single long-run equilibrium beyond the critical threshold. Once the critical thresholds are identified using procedures outlined below, we estimate the following reduced-form vector error correction model with three regimes (two thresholds)\(^{23}\):

\[ \Delta y_t = \sum_{j=1}^{3} \delta_j \left( \sum_{j=1}^{k} b_{ij} \Delta y_{t-j} + \sum_{j=1}^{k} c_{ij} \Delta w_{t-j} + d_{ij} \epsilon_{t-j} \right) + v_t \quad (4.4) \]

\(^{23}\) The resulting variance-covariance matrix of equation (4.4) shows low association between the residuals of the two endogenous variables. We, thus, estimate (4.4) without imposing any structure on the shocks.
Where: \( \mathbf{y}_t = [p, s_t] \) is the endogenous vector of variables, \( \mathbf{w} = [\mathit{ew}_t, \mathit{iw}_t, \mathit{gdp}_t] \) is the exogenous vector of variables, \( \delta_t \) is an indicator parameter, which equals one if the deviation from equilibrium is within each of the two thresholds and zero otherwise, \( d_t \) is the error correction coefficient of the previous period deviation \( (\varepsilon_{t-1}) \) from the long-run equilibrium, and \( \nu_t \) is the error term. The import price, the nominal effective exchange rate, and the control variables are all in first differences, as explained in the forthcoming section. We are interested in the difference in the coefficients of \( b_j^i \) across the three regimes. The thresholds are determined by the errors or deviations from the long-run equilibrium. By the construction of the model, the two regimes away from the two thresholds correspond to higher pass-through, since higher deviation (error) from the equilibrium triggers higher changes in the import prices, hence higher pass-through.

### 4.4.3 Unit root and cointegration

We first perform standard Dickey-Fuller unit root tests for all variables in our empirical model. Results show that the log level of all variables is not stationary. Thus, to estimate equation (4.4) we take the first difference of all variables.

Following Balke and Fomby (1997), we test for the cointegrating relationship (4.2) using the procedures of Engle and Granger (1987), which tests for the residuals using standard unit root tests such as Dickey-Fuller or Phillips-Perron. As discussed by Balke and Fomby and supported by their Monte Carlo simulations, standard time series analyses for unit root testing in \( \varepsilon_t \) of (4.2) will be valid asymptotically for threshold cointegration.\(^{24}\) Their simulation exercise also shows that the Phillips-Perron test has more power in this context due to its nonparametric nature. Table

\(^{24}\) In their paper, Balke and Fomby (1997) cite Pippeneger and Goering (1993) who found similar conclusion about the power of Dickey-Fuller test against stationary equilibrium threshold autoregression (EQ-TAR).
4.4 reports the Phillips-Perron unit root test statistics for the residuals in equation (4.2). For most cases we can reject the null hypothesis of a unit root in the residuals against the alternative of stationarity at the 5% level of significance. Thus, we can confidently assume that a cointegrating relationship is present.

Based on individual evaluation of the Schwartz-Bayesian Information Criterion (SBC) and standard diagnostic checks of the residuals, we estimate equation (4.4) using either one or two lags.

### 4.4.4 Long-run equilibrium pass-through

Table 4.6 shows the estimated long-run equilibrium pass-through, the parameter $\beta$ in equation (4.2). We can see that for the 95 cases considered, the average long-run equilibrium pass-through is between 55% and 161%. As we explain below, the energy sector has the highest degree of pass-through, followed by non-manufacturing and raw materials. One important caveat here is that the regressions are estimated using the full sample, in which the degree of pass-through might not be constant across time. We address this issue in the robustness check section of the chapter.

### 4.4.5 Estimation and testing for the adequacy of a threshold cointegrating

Given that the variables in (4.2) are cointegrated, we next search for the critical thresholds using grid search after dividing the deviations from the equilibrium relationship into regular intervals. The estimated threshold parameters, $\hat{\theta}_1$ and $\hat{\theta}_2$, are chosen based on the estimated maximum grid search of the joint log likelihood ratio, which amounts to an OLS estimation of the log determinant of the variance-covariance matrix of residuals. The test statistics in this case follow a nonstandard distribution since some parameters are present under the alternative hypothesis that
are not present under the null of no threshold integration, or what is referred to in
the literature as nuisance parameters.

In order to test the null hypothesis of no threshold cointegration against the
alternative of threshold cointegration, we use the sup-LR test statistic suggested by
Lo and Zivot (1999), which extends Hansen (1996)’s univariate sup-Wald to the
multivariate case,

\[
LR_{1m} = T \left( \ln \left| \hat{\Sigma} \right| - \ln \left| \hat{\Sigma}_m \right| \right)
\]

where \( \hat{\Sigma} \) and \( \hat{\Sigma}_m \) denote the estimated residual variance-covariance matrices from
the linear cointegration VECM and the \( m \)-regime threshold cointegration TVECM
respectively. \( T \) is the number of observations. Since this test is subject to the
nuisance parameters problem as indicated above, we follow Hansen’s bootstrapping
procedure to compute the \( p \)-values.

We should point out here that our choice of a three-regime model is
suggested by the adjustment cost theory, where the degree of pass-through from
nominal exchange rate to import prices will be different depending on how far, in
both sides positive and negative, the current deviation is from the long-run
equilibrium. In addition, we allow for asymmetric thresholds to allow for the
possibility that the adjustment to the long-run equilibrium depends not only on the
distance from the equilibrium, but also on the sign of the deviation.
4.5 Main Results

Figure 4.1 through Figure 4.16 show the resulting impulse responses of the import prices to a one standard deviation shock, both positive and negative shocks, in the nominal effective exchange rates. In each of these figures, we compare the impulses resulting from a standard VEC (Vector Error Correction) model to those of a three-regime TVEC (Threshold Vector Error Correction) model for each of the five industry-level prices and for all-goods prices. We are interested in the difference in terms of speed and magnitude of changes in the import prices under the two models. In general, the impulses of the TVEC model show both larger reactions in import prices and faster adjustments as a result of a one standard deviation shock in the nominal effective exchange rate compared to their counterparts using the standard VEC model. In addition, the majority of the impulses of the TVEC model settles at a higher long-run equilibrium compared to those of the standard VEC model due to the aforementioned shock. The majority of the impulses under the two models behaves as expected, with positive shocks causing import prices to decrease since an increase in the nominal effective exchange rate (expressed as units of foreign currency per unit of domestic currency) makes foreign imported goods less expensive. The opposite is also true. We can also observe that, by construction, the effects of positive and negative shocks in the nominal exchange rate affect import price symmetrically under the standard VEC model. However, in most of the cases, this is not carried over to the TVEC model. Under that model, negative shocks to the nominal exchange rates have larger effects on import prices than positive shocks in terms of both immediate reaction and long-run equilibrium.

To reinforce the findings of the impulse responses, Table 4.6 shows the estimated one-lag coefficients associated with the nominal exchange rate in the
import price equation (4.4) for four cases: the case with no threshold but with the error correction component included, the case when the equilibrium errors exceed the positive threshold (C+ column), the case when the equilibrium errors are less than the negative threshold (C- column), and the case when the equilibrium errors are within the two thresholds (C column). The table shows a total of 95 cross country-cross industry cases (six import prices and 16 countries). The statistically significant (at the 10% level) one-lag pass-through coefficients came, as expected, with negative signs since an increase in the nominal effective exchange rate (expressed as units of foreign currency per unit of domestic currency) makes foreign imported goods less expensive as previously explained. The error correction coefficients are significant at the 10% level for most of the cases. The coefficients on the majority of the other variables in equation (4.4) were statistically significant at the 10% level (not reported).

For most of the cases, we observe the degree of pass through increases dramatically for the two regimes outside the two thresholds (C- and C+ columns in the table) compared to the linear case, as reported in the average row of Table 4.6. We can clearly see that the average pass-through when threshold cointegration is taken into consideration exceeds the 50% average that has been documented by the majority of the empirical literature. The unweighted average of the one-period lagged pass-through with no thresholds is approximately 22%, while that of the regimes above the negative and positive thresholds are 35% and 50% respectively. We notice that for the majority of import prices, the regime above the positive threshold (positive deviation from the long-run equilibrium) features higher pass-through. Also, going back to the impulse responses, we can see that when allowing for thresholds, and especially for negative shocks, import prices over-react to nominal exchange rate shocks before going back to their long-run equilibrium.
To test the significance of these findings, Table 4.7 reports the critical values of the Lo and Zivot (1999)’s test described earlier and the p-values obtained via simulation procedures. We can see that out of the 94 cross-country import prices, we can reject the null hypothesis of no threshold cointegration against the alternative hypotheses of three-regime threshold cointegration for 45 cases at the 10% level of significance. The raw materials and the manufacturing sectors have relatively more significant test statistics across countries when compared to the other sectors.

4.5.1 Pass-through across industries

When allowing for threshold cointegration, on average we find that the three sectors, energy, raw materials, and food and agricultural products, have the highest degree of pass-through, while the manufacturing sector has the lowest pass-through. This is consistent with the empirical literature on pass-through. Energy and raw materials are largely homogenous products and mostly denominated in US dollars in international markets. Given the highly integrated commodity markets in the world and price information availability, the local prices of products within each of these industries can promptly and less expensively be adjusted to changes in the quoted international prices. Thus, we expect the difference in pass-through between VEC models and TVEC models for energy and raw materials to be less than that of other industries, which entails higher costs of adjustment, such as the manufacturing sector.

This finding confirms the adjustment costs story for an equilibrium relationship between the nominal exchange rate and the local currency import prices. One possible theory to explain this is as follows. For less durable goods with fewer substitutes, we expect some transaction costs to be lower (e.g. warranties and setup costs). This allows firms to pass changes in the nominal exchange rates to
good prices, as opposed to absorbing these changes into adjustments to the mark-up.

Optimal thresholds are plotted in Figure 4.17. The thresholds are the deviations from the equilibrium relationship established by the cointegrating vector. As we have proposed earlier, the extent of pass-through is larger outside the two thresholds. Thus, larger thresholds entail larger deviations from the equilibrium pass-through relationship, hence, higher pass-through. The energy sector has the largest thresholds, followed by the non-manufacturing sector and by the raw materials respectively. The smallest thresholds are those of the manufacturing sector and the food and agricultural sector respectively. The fact that the manufacturing sector has the smallest thresholds reinforces the finding that the latter exhibits a large differences in pass-through between the model with threshold cointegration and the one without as evidenced by Table 4.7. Explained differently, since critical thresholds are smaller, any deviation from the equilibrium relationship (between nominal exchange rates and import prices) in the manufacturing sector is more likely to induce higher changes in import prices due to nominal exchange rate shocks. Figure 4.17 also shows a tendency toward asymmetry in the thresholds across sectors. Apart from the energy and raw materials, the positive thresholds are larger than the negative thresholds for the other three industries for most of the countries. These findings reinforce our initial specification of two possibly asymmetric thresholds as opposed to one symmetric threshold. This suggests that import prices respond differently to deviations from the long-run relationship with nominal exchange rates based on the direction of such deviations.
4.5.2 Pass-through across countries

There are also significant cross-country differences in terms of the degree of pass-through into import prices. The countries with high pass-through are Denmark, France, Japan, and Netherlands. On the other hand, countries with low pass-through are USA, UK, and Italy. As discussed in the literature, factors such as the nominal exchange rate regime, the currency of invoicing (Local Currency Pricing (LCP) versus Producer Currency Pricing), and size of import demand account for the wide variations in the degree of pass-through across countries. Previous studies attempted to test for the assumption of currency invoicing by testing the null hypothesis of zero pass-through for LCP and unity for PCP. The main drawback of such an approach is that the omission of other factors that might account for the observed degree of pass-through other than the currency of invoicing factor. To be more specific, in our estimates we can see that the degree of pass-through is not significantly different from zero (supporting LCP) for USA, UK, Italy, Spain, and Austria. While this is consistent with other studies that document that approximately 75% of US imports are denominated in US dollar, this might not be the case for countries such as Spain and Austria.

Having determined the significance of the cointegrating relationship between the import prices and the nominal effective exchange rates, a question of interest is how might the volatility of the nominal exchange rate be associated with the rate of pass-through. Table 4.9 reports the mean and the variance of the nominal effective exchange rate. We can see that countries such as Italy, UK, and USA, with low rate of pass-through have relatively higher variance of the nominal exchange rate. This suggests that the proposition that higher nominal exchange rate volatility results in higher rates of pass-through is not warranted by the data.

We also attempted to explain the strange behavior of some import prices due to exchange rate shocks, particularly, in the energy sector, which shows higher
import prices for positive nominal exchange rate shocks. We assume that such behavior might result from the dominance of crude oil to the energy sector. The currency of denomination of crude oil is the US dollar. Thus, high negative correlation between a country’s bilateral nominal exchange rate with the US dollar and its Nominal Effective Exchange Rate (NEER) might explain such strange behavior. However, as reported in Table 4.8, such correlation is positive. This means that the bilateral nominal exchange rate with the US dollar and the NEER for most of the countries in the sample move together.

4.5.3 Robustness check

As a first robustness check, we divide the sample into two sections: pre-1990 and post-1990. Our choice to divide the sample into two sections only is largely dictated by the available number of observations. Results (not reported) show that the impulses are mainly the same as those of Figure 4.1 through Figure 4.16. We also examine the sensitivity of our findings to the empirical model’s specifications, mostly the lag length. Due to the constraint of the degrees of freedom, we found that the results are largely insignificant when more than two lags are included. Despite that, and for most import prices, the identification of the thresholds is not significantly influenced by the model’s specification.

We also check the behavior of import prices when nominal exchange rates are shocked by more than one standard deviation. As we have indicated earlier, this might arise due to regime-switching behavior of the import-prices when threshold cointegration is accounted for. The results show more distinctive difference between the TVEC model and the standard VEC model when more than one standard deviation shocks are experimented.
4.6 Conclusions

Using a sample of 16 OECD quarterly import prices for five industries, as well as an aggregate goods price index, we document a significant threshold cointegrating relationship between the effective nominal exchange rate and the import prices. The five industries are: food and agricultural, energy, manufacturing, non-manufacturing, raw materials. By allowing for such nonlinearity in estimating the degree of pass-through from nominal exchange rates to import prices, we find that the average degree of pass-through improves dramatically from the 50% average documented in the literature. The results of our threshold cointegration model show that import prices respond faster and by a larger extent to nominal exchange rate shocks compared to models with no threshold cointegration. The findings of this chapter support the hypothesis of an equilibrium rate of pass-through (e.g. Bacchetta and Van Wincoop (2002) and Devereux, Engel, and Storgaard (2003)). They also asset the significance of accounting for adjustment costs in estimating the relationship between nominal exchange rates and import prices. The chapter finds that the manufacturing industry exhibits the distinctive difference in the degree of pass-through when incorporating threshold cointegration compared to models with no thresholds.

The findings of this chapter suggest that more work needs to be done to emphasize the short-run dynamics in the way import prices respond to nominal exchange rates, possibly through the use of less aggregated data. More evidence of this kind will certainly change the view of limited stabilizing role for exchange rate flexibility that have appeared in recent new open economy literature. Further more, the findings of this study have policy implications for both trade-protection strategies through competitive pricing and monetary policies directed toward inflation targeting especially for countries with relatively large imports.
APPENDIX D
### 4.7 Appendix D

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Table 4.2: Augmented Dickey-Fuller unit root tests for the variables in log levels

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Notes: (1) the appropriate lag length for the ADF test is found to be four lags. (2) i, ii, and iii corresponds to zero mean, constant, constant and a trend. (3) * refers to the rejection of the null of unit root at the 5% level of significance.
Table 4.2 (Continued): Augmented Dickey-Fuller unit root tests for the variables in log levels

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Notes: (1) the appropriate lag length for the ADF test is found to be four lags. (2) i, ii, and iii corresponds to zero mean, constant, constant and a trend. (3) * refers to the rejection of the null of unit root at the 5% level of significance.
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</table>

Notes: (1) the appropriate lag length for the ADF test is found to be four lags. (2) i, ii, and iii corresponds to zero mean, constant, constant and a trend. (3) * refers to the rejection of the null of unit root at the 5% level of significance.
Table 4.4: Engle-Granger single equation approach for testing cointegration using Phillips-Perron test for unit root in residuals

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<th>Non-manufacturing</th>
<th>Raw materials</th>
<th>All goods</th>
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Notes: (1) values are the Phillips-Perron test statistics for the residuals from the regression equation (2), assuming zero mean and no trend. (2) * refers to the rejection of null hypothesis of unit root at the 5% levels of significance.
Table 4.5: The long-run estimated pass-through using estimated cointegration vector

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<th>Manufacturing</th>
<th>Non-manufacturing</th>
<th>Raw materials</th>
<th>All goods</th>
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</tbody>
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Notes: (1) values are the $\beta$ estimates in $p_t = \alpha + \beta s_t + \gamma w_t + \epsilon_t$. (2) values in parentheses are standard errors. (3) * refers to significance at the 5% level.
<table>
<thead>
<tr>
<th>Country</th>
<th>Food and Agricultural</th>
<th>Energy</th>
<th>Manufacturing</th>
<th>Non-manufacturing</th>
<th>Raw materials</th>
<th>All goods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NT C- C+ C</td>
<td>NT C- C+ C</td>
<td>NT C- C+ C</td>
<td>NT C- C+ C</td>
<td>NT C- C+ C</td>
<td>NT C- C+ C</td>
</tr>
<tr>
<td>Australia</td>
<td>-0.18* -0.15 -0.37* -0.12*</td>
<td>0.18 -0.11 -0.14 1.14*</td>
<td>-0.42* -0.11 -0.32 -0.13*</td>
<td>-0.01 -0.30 0.07 -0.09</td>
<td>-0.10 -0.27 0.29* -0.28</td>
<td>0.00 -0.11 0.16 0.01</td>
</tr>
<tr>
<td>Austria</td>
<td>-0.99* -1.75* -3.24* -1.09*</td>
<td>-0.67 0.23 -1.64 0.20</td>
<td>-0.01 0.45 0.10 -0.53</td>
<td>-0.77* -0.65 -0.40 -0.49</td>
<td>-0.33 -0.90 0.17 0.53</td>
<td>-0.32 0.64 -0.41 -0.83*</td>
</tr>
<tr>
<td>Canada</td>
<td>-0.25* -0.43* 0.05 -0.01</td>
<td>-0.01 1.24* -1.61* 0.24</td>
<td>-0.26* -0.24 -0.11 -0.30*</td>
<td>-0.23* -0.11 -1.32* 0.93*</td>
<td>-0.27* -0.39 -0.11 0.38</td>
<td>-0.24* 0.06 -0.26 -0.46*</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.00 0.11 0.14 -0.21</td>
<td>-1.09* -0.28 -1.86* -0.22</td>
<td>-0.24* -0.32 -0.55* -0.14</td>
<td>-0.60* 0.25 -1.51* -0.28</td>
<td>-0.39* -0.73* -0.45* -0.63*</td>
<td>-0.49* -0.12 -0.66* 0.08</td>
</tr>
<tr>
<td>Finland</td>
<td>-0.86* -0.35 -2.05* -0.74</td>
<td>0.54 -1.48 2.44* 1.20</td>
<td>0.05 -0.34 -1.43* 1.06*</td>
<td>-0.11 -0.91 1.05* -0.55</td>
<td>-0.54* -0.70 -0.76* 0.81</td>
<td>-0.49* -0.78* -0.73* 0.10</td>
</tr>
<tr>
<td>France</td>
<td>-0.53* -1.41* -0.14* -0.47</td>
<td>-0.61* 0.12 -1.92* -0.31</td>
<td>-0.03 -0.05 -0.19 -0.16</td>
<td>-0.43* -0.29 -1.20* -0.26</td>
<td>-1.61* -2.78 -5.10* -3.48</td>
<td>-0.11 -0.01 -0.50* 0.31</td>
</tr>
<tr>
<td>Germany</td>
<td>0.05 -0.13 0.58* 0.03</td>
<td>-0.43 -0.20 0.19 -1.63*</td>
<td>-0.02 0.02 -0.49* 0.26</td>
<td>-0.07 -0.24 0.05 0.60</td>
<td>-0.22 -0.70* -0.24* 0.00</td>
<td>-0.01 -0.17 0.07 0.26</td>
</tr>
<tr>
<td>Italy</td>
<td>-0.23* -0.26 -0.42* 0.12</td>
<td>-0.23 -0.61 0.48 0.71</td>
<td>-0.19* -0.06 0.29 -0.79*</td>
<td>-0.21 -0.11 0.76 -0.59*</td>
<td>-0.19 0.12 -0.67* 0.25</td>
<td>-0.08 -0.24 0.37 -1.10</td>
</tr>
<tr>
<td>Japan</td>
<td>-0.20 -0.05 -0.14 -0.26</td>
<td>-0.35* 0.30 -0.47* -0.82*</td>
<td>-0.04 0.01 -0.29 0.02</td>
<td>-0.15 -0.05 0.02 -0.83*</td>
<td>-0.01 -0.13 0.29 -0.09</td>
<td>-0.06 0.07 -0.10 -0.34</td>
</tr>
<tr>
<td>Netherlands</td>
<td>-0.18 0.15 -0.30* -0.24</td>
<td>-0.88 1.31 -2.23 -2.02</td>
<td>-0.36 -0.39 -0.47 0.00</td>
<td>-0.72 -0.65 -1.11 -1.73</td>
<td>-0.24 -0.44 0.26 0.31</td>
<td>-0.09 0.74 -0.34 -0.78</td>
</tr>
<tr>
<td>Norway</td>
<td>0.10 0.11 -0.29* 0.20</td>
<td>0.13 0.74 -1.62 0.07</td>
<td>-0.28* -0.34 -0.29 0.10</td>
<td>0.00 -0.09 0.41 0.34</td>
<td>-0.19 -0.50 -1.09* 2.23*</td>
<td>-0.25* -0.49* -0.08 -0.89*</td>
</tr>
<tr>
<td>Spain</td>
<td>-0.14 -0.02 -1.99* 0.43</td>
<td>-0.34 -0.67 -0.05 -0.48</td>
<td>-0.05 -0.15 -0.36* 0.77*</td>
<td>-0.18 -0.45 0.08 -0.22</td>
<td>0.06 -0.02 0.92* -0.22</td>
<td>-0.08 -0.05 -0.02 -0.01</td>
</tr>
<tr>
<td>Sweden</td>
<td>-0.06 0.04 -0.05 0.24</td>
<td>-0.36 -0.58 -1.01* -0.05</td>
<td>-0.13 1.09* -0.15 -0.34*</td>
<td>-0.40* -0.26 -0.86* -0.70*</td>
<td>-0.33* 0.88* -0.35* -0.66*</td>
<td>-0.19* 0.45 -0.30 -0.18</td>
</tr>
<tr>
<td>Switzerland</td>
<td>-0.03 0.22 -0.07 -0.23</td>
<td>-0.13 -0.45 0.01 -0.77</td>
<td>-0.19* 0.07 -0.23 -0.38*</td>
<td>-0.21 -0.07 -0.10 -0.97*</td>
<td>-0.25* -0.23 -0.74 0.17</td>
<td>-0.22* 0.06 -0.32 -0.51*</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0.03 0.07 -0.18 -0.05</td>
<td>0.21 0.52* -0.17 0.95*</td>
<td>0.05 0.04 0.06 0.09</td>
<td>0.15 0.20 0.16 0.37*</td>
<td>0.13 0.16 0.05 0.16</td>
<td>0.07 0.12 0.06 0.02</td>
</tr>
<tr>
<td>United States</td>
<td>0.01 0.11 -0.24* 0.43*</td>
<td>0.91* 1.46* 0.51 1.09*</td>
<td>-0.03 -0.01 0.01 -0.07</td>
<td>0.47* 0.88* 0.38 0.04</td>
<td>-0.03 0.20 -0.24 -0.11</td>
<td>0.05 0.12 -0.17 0.08</td>
</tr>
<tr>
<td>Average</td>
<td>-0.23 -0.23 -0.54 -0.15</td>
<td>-0.20 0.10 -0.57 -0.04</td>
<td>-0.13 -0.02 -0.28 -0.09</td>
<td>-0.22 -0.10 -0.27 -0.28</td>
<td>-0.28 -0.40 -0.51 -0.07</td>
<td>-0.15 0.01 -0.20 -0.21</td>
</tr>
</tbody>
</table>

Notes: (1) The column labeled “NT” corresponds to the estimated pass-through coefficients with no thresholds but with the error correction component. The columns labeled C-, C+, and C correspond to the estimated pass-through coefficients when only observations associated with errors below, above, and within, thresholds, respectively, are included, as illustrated in equation (3). (2) * refers to 10% level of significance.
Table 4.7: Critical values and the simulated p-values for testing the null of no thresholds

<table>
<thead>
<tr>
<th>Country</th>
<th>Food and Agricultural</th>
<th>Energy</th>
<th>Manufacturing</th>
<th>Non-manufacturing</th>
<th>Raw materials</th>
<th>All goods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hansen test</td>
<td>Hansen test</td>
<td>Hansen test</td>
<td>Hansen test</td>
<td>Hansen test</td>
<td>Hansen test</td>
</tr>
<tr>
<td>Australia</td>
<td>33.71</td>
<td>0.252</td>
<td>56.63</td>
<td>0.018</td>
<td>50.69</td>
<td>0.060</td>
</tr>
<tr>
<td>Austria</td>
<td>41.99</td>
<td>0.112</td>
<td>17.97</td>
<td>0.921</td>
<td>44.30</td>
<td>0.117</td>
</tr>
<tr>
<td>Canada</td>
<td>33.43</td>
<td>0.483</td>
<td>64.17</td>
<td>0.005</td>
<td>46.69</td>
<td>0.098</td>
</tr>
<tr>
<td>Denmark</td>
<td>30.44</td>
<td>0.634</td>
<td>35.80</td>
<td>0.301</td>
<td>43.21</td>
<td>0.097</td>
</tr>
<tr>
<td>Finland</td>
<td>45.30</td>
<td>0.100</td>
<td>26.50</td>
<td>0.789</td>
<td>50.10</td>
<td>0.039</td>
</tr>
<tr>
<td>France</td>
<td>50.14</td>
<td>0.049</td>
<td>36.95</td>
<td>0.381</td>
<td>30.38</td>
<td>0.696</td>
</tr>
<tr>
<td>Germany</td>
<td>34.84</td>
<td>0.386</td>
<td>30.57</td>
<td>0.618</td>
<td>57.25</td>
<td>0.013</td>
</tr>
<tr>
<td>Italy</td>
<td>41.54</td>
<td>0.184</td>
<td>93.18</td>
<td>0.050</td>
<td>93.44</td>
<td>0.030</td>
</tr>
<tr>
<td>Japan</td>
<td>29.48</td>
<td>0.694</td>
<td>59.19</td>
<td>0.004</td>
<td>17.41</td>
<td>0.992</td>
</tr>
<tr>
<td>Netherlands</td>
<td>38.15</td>
<td>0.294</td>
<td>28.82</td>
<td>0.726</td>
<td>29.24</td>
<td>0.702</td>
</tr>
<tr>
<td>Norway</td>
<td>28.55</td>
<td>0.722</td>
<td>31.03</td>
<td>0.552</td>
<td>39.84</td>
<td>0.272</td>
</tr>
<tr>
<td>Spain</td>
<td>40.13</td>
<td>0.196</td>
<td>26.48</td>
<td>0.846</td>
<td>41.71</td>
<td>0.146</td>
</tr>
<tr>
<td>Sweden</td>
<td>47.24</td>
<td>0.080</td>
<td>91.40</td>
<td>0.070</td>
<td>100.28</td>
<td>0.000</td>
</tr>
<tr>
<td>Switzerland</td>
<td>109.94</td>
<td>0.000</td>
<td>51.50</td>
<td>0.040</td>
<td>100.40</td>
<td>0.030</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>39.92</td>
<td>0.240</td>
<td>46.64</td>
<td>0.108</td>
<td>51.41</td>
<td>0.040</td>
</tr>
<tr>
<td>United States</td>
<td>94.61</td>
<td>0.030</td>
<td>65.94</td>
<td>0.002</td>
<td>94.26</td>
<td>0.080</td>
</tr>
</tbody>
</table>

The p-values are obtained by simulating the original data with no cointegration and calculating the empirical distribution of the probability that the Lo and Zivot’s test statistic exceeds the simulated critical values.
Table 4.8: The correlation between the NEER and the bilateral nominal exchange rate with the US Dollar for each country

<table>
<thead>
<tr>
<th>Country</th>
<th>National Currency / $</th>
<th>$ / National Currency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>-0.78</td>
<td>0.80</td>
</tr>
<tr>
<td>Austria</td>
<td>-0.69</td>
<td>0.76</td>
</tr>
<tr>
<td>Canada</td>
<td>-0.82</td>
<td>0.83</td>
</tr>
<tr>
<td>Denmark</td>
<td>-0.77</td>
<td>0.79</td>
</tr>
<tr>
<td>Finland</td>
<td>-0.48</td>
<td>0.53</td>
</tr>
<tr>
<td>France</td>
<td>-0.75</td>
<td>0.83</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.72</td>
<td>0.78</td>
</tr>
<tr>
<td>Italy</td>
<td>-0.80</td>
<td>0.88</td>
</tr>
<tr>
<td>Japan</td>
<td>-0.95</td>
<td>0.98</td>
</tr>
<tr>
<td>Netherlands</td>
<td>-0.70</td>
<td>0.78</td>
</tr>
<tr>
<td>Norway</td>
<td>-0.55</td>
<td>0.60</td>
</tr>
<tr>
<td>Spain</td>
<td>-0.73</td>
<td>0.81</td>
</tr>
<tr>
<td>Sweden</td>
<td>-0.75</td>
<td>0.80</td>
</tr>
<tr>
<td>Switzerland</td>
<td>-0.78</td>
<td>0.77</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>-0.18</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Source: IMF-IFS CD-ROM
Table 4.9: The mean and variance of nominal effective exchange rate expressed as an index with 1995=100 (1975q1 – 2002q2)

<table>
<thead>
<tr>
<th>Country</th>
<th>Mean</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>103.88</td>
<td>172.51</td>
</tr>
<tr>
<td>Austria</td>
<td>89.10</td>
<td>59.16</td>
</tr>
<tr>
<td>Canada</td>
<td>108.54</td>
<td>210.11</td>
</tr>
<tr>
<td>Denmark</td>
<td>93.04</td>
<td>37.41</td>
</tr>
<tr>
<td>Finland</td>
<td>103.24</td>
<td>98.49</td>
</tr>
<tr>
<td>France</td>
<td>97.53</td>
<td>78.30</td>
</tr>
<tr>
<td>Germany</td>
<td>81.78</td>
<td>148.45</td>
</tr>
<tr>
<td>Italy</td>
<td>143.79</td>
<td>2799.70</td>
</tr>
<tr>
<td>Japan</td>
<td>65.05</td>
<td>485.53</td>
</tr>
<tr>
<td>Netherlands</td>
<td>86.05</td>
<td>70.87</td>
</tr>
<tr>
<td>Norway</td>
<td>106.55</td>
<td>91.96</td>
</tr>
<tr>
<td>Spain</td>
<td>124.62</td>
<td>1184.19</td>
</tr>
<tr>
<td>Sweden</td>
<td>133.25</td>
<td>779.66</td>
</tr>
<tr>
<td>Switzerland</td>
<td>82.59</td>
<td>174.10</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>122.37</td>
<td>313.42</td>
</tr>
<tr>
<td>United States</td>
<td>112.97</td>
<td>225.57</td>
</tr>
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</table>

Source: IMF-IFS CD-ROM
Figure 4.1: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: Australia)
Figure 4.2: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: Austria)
Figure 4.3: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: Canada)
Figure 4.4: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: Denmark)
Figure 4.5: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: Finland)
Figure 4.6: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: France)
Simple VAR model

Threshold VEC model

Food and Agricultural

Energy

Manufacturing

Non-manufacturing

Raw materials

All goods

Figure 4.7: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: Germany)
Figure 4.8: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: Italy)
Figure 4.9: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: Japan)
Simple VAR model

Food and Agricultural

Threshold VEC model

Energy

Manufacturing

Non-manufacturing

Raw materials

All goods

Figure 4.10: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: Netherlands)
Figure 4.11: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: Norway)
Simple VAR model

Food and Agricultural

Threshold VEC model

Energy

Manufacturing

Non-manufacturing

Raw materials

All goods

Figure 4.12: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: Spain)
Figure 4.13: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: Sweden)
Figure 4.14: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: Switzerland)
Figure 4.15: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: United Kingdom)
Figure 4.16: The impulse responses of import prices to a one standard deviation shock in the nominal effective exchange rate (country: United States)
Figure 4.17: Optimal thresholds by industry
Figure 4.17 (Continued)
4.8 References


Hansen, B., 1996, “Inferences when a nuisance parameter in not identified under the null hypothesis,” Econometrica, 64, 413-430.


Tille, C., 2000, "'Beggar-Thy-Neighbor' or 'Beggar-Thyself'? The Income Effect of Exchange Rate Fluctuations", Federal Reserve Bank of New York, Staff Report 112.

Chapter 5

Conclusions

5.1 Summary of Results

We revisit the issue of exchange rate flexibility by undertaking three interrelated approaches. In chapter two, we analyze the optimal choice of exchange rate regime for developing countries that depend largely on the export of primary commodities, such as oil. We use a fully specified stochastic general equilibrium model with three sources of uncertainty: random monetary (demand), productivity (real), and oil-price (supply) shocks, which we assume follow a log-normal process. We found that the optimal exchange rate regime for an oil-exporting country depends on the response of its trading-partners to their productivity shocks and to the oil-price shocks. A flexible exchange regime can improve the welfare of home agents provided that the central bank in the home country (oil-exporting country) is able to predict both the shocks and the response of the foreign central banks to these shocks. This does not seem feasible given the current monetary and financial
developments in such countries. In other words, the impact of monetary, productivity, and oil price shocks on the utility of agents in an oil-exporting country is lower when a fixed exchange rate regime is adopted and at the same time the response of the central bank in this country is passive to these shocks compared to the response of the central bank in the country with which it fixes its currency.

In chapter three, we empirically tackle the issue of the role of exchange rate regimes in the response of some key economic variables to oil price shocks. We use a panel VAR technique to test for the impact of oil price shocks on nine major OECD oil-importing countries under alternative exchange rate regimes using the Reinhart and Rogoff *de facto* classification scheme, after controlling for other factors that might affect the responsiveness to oil price shocks. We found that flexible exchange rate regimes better absorb positive oil price shocks, consistent with Friedman’s hypothesis. The necessary adjustments are borne by the nominal exchange rate mostly in the same period of the oil price shocks. We found that under flexible exchange rate regimes, and in response to a one standard deviation positive oil price shock, both the real exchange rate and output growth show faster speeds of adjustment when returning to their long-run equilibrium relative to the fixed exchange rate regimes. In addition, the inflation rates show relatively higher contemporaneous increases due to positive oil shocks under fixed exchange regimes. Our results show that monetary policy reactions to the oil price shocks have no significant contribution to the response of the real exchange rate, output growth, and the inflation rate following oil price shocks. These findings have policy implications for emerging economies as they experience growing industrial sectors and more dependence on imported oil.

In chapter four, we document a significant threshold cointegrating relationship between the effective nominal exchange rate and import prices. By allowing for such nonlinearity in estimating the degree of pass-through from the
nominal exchange rates to import prices, we find that the average degree of pass-through improves dramatically from the 50% average documented in the literature. The results of our threshold cointegration model show that import prices respond faster and by a larger extent to nominal exchange rate shocks compared to models with no threshold cointegration. The findings of this chapter support the hypothesis of an equilibrium rate of pass-through (e.g. Bacchetta and Van Wincoop (2002) and Devereux, Engel, and Storgaard (2003)). They also indicate the significance of accounting for adjustment costs in estimating the relationship between nominal exchange rates and import prices. The chapter finds that the manufacturing industry exhibits a large difference in the degree of pass-through when incorporating threshold cointegration compared to models with no thresholds. The findings of this study have policy implications for both trade-protection strategies through competitive pricing and monetary policies directed toward inflation targeting especially for countries with relatively large imports.

5.2 Plans for Future Research

As noted in chapter two, relaxing the assumption of complete asset markets and endogenizing the international oil price should bring the model closer to the real world. This, of course, requires the use of numerical methods to obtain a solution to the model. Another possible extension to the second chapter is to analyze the impact of fiscal policy in a primary-commodity economy in the way real shocks (foreign and domestic) are transmitted. A general feature of most developing countries is the large governmental sector. This might have serious consequences for the conduct of optimal monetary/exchange rate policy. In summary, incorporating such frictions should increase our understanding of optimal monetary policy in open economies with varying economic structures.
For the fourth chapter, one can further investigate the presence of threshold cointegration by performing a similar analysis on specific goods within each industry. This might filter any aggregation problems and help enrich our understanding of the factors determining the critical thresholds. The findings of chapter four suggest that more work needs to be done to emphasize the short-run dynamics in the way import prices respond to nominal exchange rates, possibly through the use of less aggregated data. More evidence of this kind will certainly change the view of the limited stabilizing role for exchange rate flexibility that has appeared in recent new open economy literature.