Department of Economics

Three Essays on the "Oil-Macroeconomy" Relationship

Alessandro Maravalle

Thesis submitted for assessment with a view to obtaining the degree of Doctor of Economics of the European University Institute

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DEDICATION

This dissertation is dedicated to my family.

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CONTENTS

Part I

Introduction

Oil represents a key commodity in the world energy market and it is not a surprise that its price is largely viewed as one of the leading indicator of the global economic health. Therefore, the recent soaring up of the price of oil has generated a large concern about its potential effects on global economic activity. Indeed, even though most developped economies are generally better prepared to deal with oil shocks nowdays than in the 1970s (better conduct of monetary policies, technological progress), the effective role of oil price shocks in affecting macroeconomic performance is still debated. The aim of this thesis is then to investigate some aspects of the relationship between oil and the macroeconomy by means of both an empirical and a theoretical analysis.

In the first chapter I perform an empirical analysis of the impact of oil price shocks on the US economy, notably focusing on GDP and a price index. I first present some facts which justify the adoption of a non-standard approach in the investigation of the US oil-macroeconomy relationship, which appears to be non-linear and tends to become weaker over time. Indeed, I show that when the US economy is split into a traded and a non-traded goods sector then both the GDP share and the value added share of the non-traded sector appear to have increased over the last decades. It is then reasonable to investigate whether this change in the composition of the US economy might have affected the oil-macroeconoy relationship, all the more when it is added that the two sectors also show different business cycle properties, with the traded goods sector being much more volatile than the non-traded sector, but at the same time are very similar in terms of energy intensity. The purpose of this first chapter is then an attempt to detect whether a composition effect may contribute to explain both the non-linearity and the weakening of the oil-macroeconomy relationship. To this end I adopt VAR analysis as it allows me to treat the price of oil as an endogenous variable while and provides me with a flexible scheme for the identification of oil innovations. This disaggregated analysis of the effects of oil price innovations then produces interesting results. First of all, I find a strong evidence that the traded and the non-traded goods sectors are very differently affected by oil price innovations. Indeed, both the growth rate of GDP and the inflation rate of the traded good sector tend to react much more to oil price innovations than the corresponding variables of the non-traded good sector. Secondly, the analysis of the non-linearity of the oil-macroeconomy relationship at the sectorial level reveals a different behaviour across sectors too. Indeed, while traded goods sector variables appear to be much more sensitive to positive than to negative oil price innovations, this is not much evident for non-traded goods sector variables. Thirdly, I show that the 'oil-macroeconomy' relationship appears to be more stable at the sectorial level than at the aggregate level, and I conclude that data do not reject the possibility that the observed weakening of the oil-macroeconomy relationship at the aggregate level might be partially explained by the change in the sectoral composition of the US economy.

In the second paper I move to a theoretical investigation of the link between structural change in the sectoral composition of the economy and the decreasing impact of oil price shocks on economic activity. Indeed, this approach has never followed by previous investigation which has explained the weakening of the 'oil-macroeconomy' relationship, which has been usually explained either emphasizing the role of monetary policies, or that of more efficient technologies, or, finally, as a consequence of the "great moderation, as it is commonly labelled the global trend of large reduction in business cycle volatility. Two empirical pieces of evidence motivate a theoretical analysis of this composition effect. Firstly, the increase of the GDP share of the non-traded good sector at the expense of that of the traded good sector over the last decades. Secondly, the fact that the non-traded goods sector is less sensitive to the effects of oil shocks than the traded good sector. The analysis is then based on a two-country, two-sector model, with traded and non-traded intermediate goods which are produced with oil, labor and sector-specific capital. The model is able to reproduces the larger impact of oil price shocks on the traded good sector through consumption smoothing. In particular, for this result to hold I assume that the investment good is composed only of traded goods, while the consumption good is composed of both traded and non-traded goods. I then use the model to perform an experiment through which I can analyse if an increase of the GDP share of the non traded good sector can change the way oil shocks affect the economic activity. In order to reproduce this structural change I then refer to the two main mechanisms that the literature puts forward: the 'utility-based' and the 'unbalances productivity growth' (UPG) mechanism. The first mechanism is based on the idea that the increase of the GDP share of the non-traded good sector is induced by households preferences. The second mechanism, instead, relies on different growth rates of total factor productivities (TFP) across sectors, which in turn induce an increase of the GDP share of the slowest-growing sector. To perform the experiment that is based on the UPG mechanism I have nonetheless to perform a preliminary analysis. First, I have to determine what are the specific demand conditions that the model must satisfy for the UPG mechanism to work properly. Second, I have to get an understanding of how the oil-macroeconomy relationship in the model is directly affected by increasing the TFPs. In order to find an analytical answer to these two problems I set-up a basic model which allows for a closed form solution. I then show that the only demand condition which must be satisfied is that the elasticity of substitution between traded and non-traded goods be sufficiently small, namely below unity. Furthermore, I find that in an international framework it is a sufficient condition that a UPG mechanism be at work abroad for a country to experience a structural change in the sectoral composition of its economy. I then show that with a Cobb Douglas technology the oil price elasticity of GDP is not affected by changes in total factor productivities. Once I am provided with these pieces of information, I can then perform the experiment using both mechanisms. I then find that, whatever is the mechanism which causes the structural change in the economy, the increase of the GDP share of the non traded good sector weakens the effects of oil shocks on economic activity, even though only marginally, and I argue that this effect is mainly caused by the fact that the structural change reduces the size of international spillovers.

In the third paper I pass to examine a third debated aspect of the oil-macroeconomy relationship, that is the fact that oil shocks appear to have a 'large' effect on economic activity, where by 'large' I mean an oil price elasticity of GDP greater than the oil share. Indeed, as the GDP share of oil costs in the economy is usually small, being on average around 3-4% for OECD countries, the reported estimation of the impact of the oil price shocks in the 1970s is far larger than the mere GDP share of oil costs. Thus, this raises the question on what mechanism is at work in amplifying the effect of oil shocks on economic activity. This paper then analyses the impact of oil price shocks on GDP in an open economy framework and develops a mechanism which is able to amplify them beyond the oil share. For these purposes, I set up two theoretical models. I first set up a basic two-country model whose analytical tractability allows me to obtain the following results on the 'oil-macroeconomy' relationship in an open economy framework. First, I show that the introduction of nominal rigidities considerably modifies the way oil shocks affect the economy with respect to the flexible price regime. In the flexible price regime the effect of oil shocks on economic activity is symmetric across countries and the oil price elasticity of both GDP and price level is constant. Instead, with the introduction of nominal rigidities oil shocks turn to have asymmetric effects across countries, and the oil price elasticity of both GDP and price becomes an increasing function of the size of oil shocks. Second, I show analytically that a small open economy model, in comparison to a general equilibrium model, underestimates the effect of oil price shocks on GDP. Third, I show that the use of either the nominal or the real price of oil has different implications as to the impact of oil shocks on the economy, even though both measures lead to similar results as long as the oil share is small. The basic model has a limited explaining power for the 'large' effect of oil shocks on GDP. I then show that in an extended two-country, two-sector model with sector specific capital, oil price shocks can cause a 'large' effect on GDP even with flexible prices. Differently from former multi-sector models that have been developed to analyse the 'oil-macroeconomy' relationship, I do not assume different technologies across sector, namely I assume that the two sectors have the same oil intensity. Indeed, the model may produce 'large' effects of oil price shocks on GDP even with an identical technology across sectors as long as consumption and investment have a different composition in terms of sectorial intermediate goods. The introduction of nominal wage rigidities then further amplifies the effects of oil price shocks on GDP with respect to the flexible price regime. In particular, oil shocks do not only cause a larger impact on GDP but also their effect on economic activity become more persistent.

Part II

Chapters

CHAPTER 1

CAN A DISAGGREGATE ANALYSIS EXPLAIN THE EFFECTS OF OIL PRICE INNOVATIONS ON THE US ECONOMY?

1.1 Introduction

The empirical oil literature highlights that the effects of oil innovations on the aggregate economic activity, notably GDP and the price level, are non-linear and tend to become weaker over time. [1]

The decreasing impact of oil innovations on economic activity has then been explained in many ways: the consequence of mismeasurements and mispecifications in the empirical analysis, the effect of technological progress, a lower degree of real wage rigidities and the by-product of the so-called 'great moderation', that is the ongoing global trend of a lowering output and inflation volatility.[2] [3]

The non-linearity of the 'oil-macroeconomy' relationship has instead been explained either assuming reallocation costs in multi-sector models, or via the asymmetry of monetary policy or by highlighting the effect of oil innovations on the level of uncertainty in the economy.

To investigate these aspects of the 'oil-macroeconomy' relationship I move away from the standard approach, which takes GDP and the price level at the aggregate level. In fact, I argue that this approach is valid as long as at least one of the two following conditions is fulfilled. First, different sectors of the economy must react similarly to oil price innovations. Second, the GDP share of any sector in the economy must remain constant over time.

[1] The non-linearity or asymmetry of the 'oil-macroeconomy' relationship refers to the evidence that during periods of large oil price fall the economic activity did not boost by the same amount it has been disrupted in periods of large oil price increases.

[2] Evidence in favor of a structural change in most time series of the US economy is reported by Blanchard and Simon (2000), McConnell and Perez Quiroz (2001), Sargent and Cogley (2001) and Stock and Watson (2003).

[3] The intense research on the reasons of the Great Moderation has then produced a number of different explanations which include, among others, changes in monetary policy (Clarida et al 2000, Cogley and Sargent 2003, Boivin and Giannoni 2002 and Lubik and Schorfheide 2004). the change in the way technology shocks are transmitted to the economy (Galì 1999, Christiano Eichenbaum and Vigfusson 2003, Uhlig 2004, Dedola and Neri 2004, Francis and Ramey 2005), the change in the way fiscal policy is conducted and the deepening of global financial markets.

I show that in the US both conditions are not respected when the economy is split into a traded and a non-traded goods sectors. Indeed, it is evident that over the last decades the US GDP share of the non-traded goods sector has constantly increased at the expense of that of the traded goods sector. Second, I also show that the price and the output of the traded goods sector have cyclical components which are much more volatile than the corresponding ones of the non-traded goods sector. Finally, my analysis also differ from former disaggregate analysis of the effects of oil price shocks as it does not focus on differences across sectors in energy intensity. In particular, I also show that the traded and the non-traded goods sectors are not much different in terms of energy intensity.

I then use VAR analysis to address three questions on the effects of oil price innovations on a disaggregated economy. First, I ask whether oil innovations affect similarly the price and the output of the two sectors. Second, I check whether positive and negative oil price innovations have a symmetric effect on sectorial outputs and prices. Finally, I ask whether the 'oil-macroeconomy' relationship is more stable at the sectorial level than at the aggregate level.

My results are as follows. First, the size of the response to oil price innovations of the price and the output of the traded goods sector is much larger than those of the corresponding variables of the non traded good sector. Second, I show that data strongly reject a linear 'oil-macroeconomy' relationship at the sectorial only for the traded goods sector.[4] Third, I show that data do nt reject the possibility that the 'oil-macroeconomy' relationship is more stable at the sectorial rather than at the aggregate level.

I conclude that it is not possible to reject the possibility that the observed weakening in the US of the oil-macroeconomy relationship at the aggregate level might be partially explained by the change in the sectoral composition that has the US has experienced over the last decades. Moreover, I argue that the observed non-linear oil-macroeconomy relationship at the aggregate level is principally caused by the behavior of the traded goods sector.

The paper is organized as follows. Section 2 briefly reviews the relevant literature. Section 3 reports a preliminary analysis which supports the choice of the disaggregate analysis. Section 4 presents the VAR analysis and provides results. Section 5 concludes.

1.2 Literature Review

Empirical studies on the 'inverse relationship' between oil and economic activity at the aggregate and disaggregate level.

[4] At the aggregate level, non-linear effects of oil price shocks to the economy are a well-established result. Cfr. Mork (1989), Loungani (1986) and Davis(1987).

Hamilton (1983) was the first to observe that in the period 1945-1973 almost any US recession was preceded by a sharp increase in the price of oil, and that these recessions could not be explained through other variables. Since then, empirical analysis has confirmed the presence of an 'inverse-relationship' between oil and the economic activity at the aggregate level. [5]

At the disaggregate level, a negative relation between oil price and industrial performance is reported by Keane and Prasad (1996), Davis et al. (1996), Davis and Haltiwanger (2001), Lee and Ni (2002) and Bohi(1989, 1991). The main focus of these works is on the link between the energy intensity of an industry and its sensitivity to oil innovations, but their conclusions are not concordant. Bohi (1991) does not find a clear link between the energy intensity of an industry and its output decline after an oil shock. Hamilton argues that this result by Bohi is due to the fact that he does not take into account the costs of input reallocation which are induced by oil price innovations and are independent of the industry specific energy intensity. Lee and Ni (2002), instead, find evidence that positive oil price shocks reduce the output of energy-intensive industries but also that the demand in other industries gets reduced. Davis and Haltiwanger (2001) find some evidence on positive oil price shocks reducing employment the most in industries that are more capital intensive. Finally, Keane and Prasad (1996) analyze the effect of oil price shocks on wages across industries and find that this effect is very diversified.

The weakening of the 'oil-macroeconomy relationship'

The evidence of a weakening of the oil-macroeconomic relationship over the last 20 years has been highlighted by Hooker (1996,1999), Hamilton (1996), Loungani and Yücel (2000), and Blanchard and Galì (2007).[6]

Many theoretical explanations of the phenomenon have then been put forward. A first argument, referred to here as the oil-intensity argument, is based on gain in technology efficiency (Brown and Yücel 1995, Pomarantz and Robber 2005, Blanchard and Galì 2007): over time, a more efficient use of energy resources and the adoption of new technologies have both reduced the oil share required for a unit of output. Pomarantz and Robber (2005) provide evidence that the oil intensity, that is defined as the quantity of oil per unit of output, has declined in all G-7 countries, with the US, for example, requiring a quarter less

[5] Early empirical studies include Pierce and Enzler (1974), Rasche and Tatom (1977), Mork and Hall (1980), Gisser and Goodwin (1986), Darby (1982), Burbidge and Harrison (1984) and Bruno and Sachs (1981, 1985) Later studies comprend Woodford and Rotemberg (1996), Raymond and Rich(1997), Carruth et al. (1998).

[6] In particular, the debate on the robustness of the 'oil-macroeconomy' relationship between Hooker (1996) and Hamilton (1996) has been crucial to put in evidence how the oil price stopped to have a strong predictive power for GDP growth after 1985.

of oil per unit of output in 2003 than it did in the early1980s. However, the real effectiveness of the oil-intensity argument is still debated.

Loungani and Yücel (2000) and Brown (2000) argue that the oil shocks in the 1990s were not so disruptive, in comparison to those in the1970s, because their effect has been muted by the contemporaneous occurrence of other factors, namely a strong global productivity growth.

Some authors attribute the weakening of the oil-macroeconomy relationship to a more effective monetary policy. They argue that after the dramatic experience of the 70's and 80's, monetary policy began to react better to oil price innovations. Hooker (1999), for example, argues that when Volcker took over the chair of the Federal Reserve the monetary policy become less accommodating to oil price innovations than in the past and no longer triggered expectations of higher inflation.

Hooker (1996) and Lee et al. (1995) investigate the role of statistical mismeasurement as a possible cause of the breakdown in the oil-macroeconomic relationship. Hooker considers as possible sources of mismeasurement the uneven distribution of oil price innovations over the sample period, the change in the statistical properties of the price of oil after 1973, and the occurrence of structural innovations in many US macro series. However, even taking all these sources of mismeasurement into account, he is not able to reaffirm the statistical significance of the oil-macroeconomy relationship. Lee et al., instead, argue that the it was the increase in the oil price volatility of the mid 1980s to cause of the breakdown in the oil-macroeconomy relationship. They then build up an oil price measure that takes into account the oil price volatility and are able to re-establish a statistically significant relationship between oil and macroeconomic variables.

Rogoff (2006) considers that the weakening of the oil-macroeconomy relationship might also be a consequence of the "Great Moderation", that is the constant decline in global output volatility which since 1985 has characterized much of the world, and whose causes can be found in the increased flexibility of labor markets, in a better monetary policy and in deeper financial markets.

Finally, Blanchard and Galì (2007) show with a neokeynesian model that the reduction in the real wage rigidity, a better monetary policy and technological progress are all key factors to explain the smaller impact of oil shocks in the recent period.

The asymmetric effect of oil price innovations on economic activity

In the mid-1980s the price of oil fell dramatically, but the global economic activity did not appear to boost in the same it had been depressed by oil price increases in the 1970s. Thus, the empirical literature started to reject a linear relationship between oil prices and real activity, arguing that the loss of statistical significance of the 'oil-macroeconomy' relationship might be due to the fact that only positive oil price innovations affect the macroeconomic performance.

The idea of an 'asymmetric effect' of oil price innovations, that is that positive oil price innovations affect economic activity more largely than negative ones, has found support in Mork (1989) and Olsen and Mysen (1994). Some authors have then suggested the use of non-linear transformations of the price of oil to reestablish the statistical significance of the oil-macroeconomy relationship (Mork 1989, Lee *et al.* 1996, Hamilton 1996).

The main theoretical arguments that have been proposed to explain the asymmetric effect of the price of oil either highlight the role of monetary policy, or that of uncertainty, or, finally, that of sectoral shifts.

According to the monetary policy argument, the asymmetric effect of the price of oil is a consequence of an asymmetric monetary policy which tights when the price of oil increases, but does not expand when it decreases.

The uncertainty argument states that any oil price innovation, whether positive or negative, by increasing the degree of uncertainty within the economy reduces the demand for investment and durable goods. Thus, as oil price innovations increase uncertainty in the economy, they always have a recessive effects; the asymmetry arises because the recessive effect is either reinforced by positive oil price innovations or mitigated by negative ones.

Finally, the sectoral shift argument explains the asymmetric effect of oil price innovations by reallocation costs, as after an oil price innovations inputs have to be reallocated from high oil-intensive to low oil-intensive sectors. These reallocation costs reinforce the recessive effect of positive oil price innovations and reduce the expansionary effects of negative oil price innovations.

The identification of oil innovations.

Oil innovations are usually identified through oil-price measures. Hamilton (1983) firstly considered the nominal price of oil as exogenous with respect to other macroeconomic variables. However, Rotemberg and Woodford (1996) showed that the exogeneity of the nominal price of oil can be accepted only until 1973, as the emergence of the OPEC caused a structural change in the oil market regime which made the price of oil endogenous. The use of the price of oil to identify oil innovations has then started to be related to exogenous political events.

Barnsky and Kilian (2004) and Kilian (2006) raise doubts about the presence and strength of a link between political events and oil price. In this respect, Hamilton (2003) and Kilian (2006) have proposed the use of oil-production measures as alternative variables to identify oil innovations. They argue that not every oil supply innovation turns out to be associated with an oil price increase, and, at the same time, not any oil price increase occurs because of innovations in the industrial demand (Kilian 2006). However, the limit of this approach is that it focuses only on oil supply innovations.

Kilian (2007) has recently proposed a new identification procedure which distinguishes among different causes of oil price innovations; he argues that the effects of oil price innovations on economic activity are really dependent on the cause of the innovation itself.

Finally, I refer to that part of the VAR monetary policy literature which adopts a recursive approach and oil price measures to identify monetary policy innovations (Bernanke, Gertler and Watson 1997, Bernanke and Mihov 1995, Bernanke and Blinder 1992, Hamilton and Herrera 2004).

1.3 Preliminary analysis

In what follows I first define the criterion I use to choose the two sectors I decompose the economy into, I then show that the economic share of the two sectors has drastically changed over time, verify that the two sectors have different cyclical behavior and finally check for differences in the energy intensity between sectors.

1.3.1 Data

I disaggregate the US economy into a traded and a non-traded goods sector. For this preliminary analysis I use the annual BEA dataset "Gross-Domestic-Product-by-Industry Accounts, 1947-2006", which provides annual data on nominal value added and prices on an industry-by-industry base.[7] The use of nominal value added then allows me to disregard the possibility that differences across sectors be due to differences in the use of intermediate inputs.

In order to set up sectorial measures for value added and prices I have to define any industry as either tradeable or non-tradeable, a question which is debated in empirical works. What is standard is to identify goods producing industries as tradeables and services producing industries as non-tradeables. However, literature presents different approaches to define an industry as either tradeable or not. For example, De Gregorio et al. (1993) define an industry as tradeable if the ratio of the value of total exports to the value of total production is above 10%.[8]

[7] Data are netted out of the public sector component.

[8] According to this criterion, the sector of transportation, which is classified as a services producing industry, is considered a tradeble industry. However, this criteria set anyway an arbitrary threshold for the

I decide to adopt the standard criterion, which while may lead be considered a rough approximation, it is nonetheless easy to apply also to different datasets. Thus, to classify an industry as either tradeable or non-tradeable I turn to the distinction between goods producing and services producing industries. The non tradeable sector is then composed of the following industries (with their average relative weight in parenthesis): Utilities (3,5%); Construction (8,7%); Wholesale trade (9,5%); Retail sale(12%); Transportation and warehousing (7,6%); Finance insurance, real estate, rental and leasing (27,2%); Professional and business services (12,9%); Educational services, health care, and social assistance (8,6%); Arts, entertainment, recreation, accommodation and food services (5,3%); Other services except government (4,7%). The tradeable sector, instead, consists of the following sectors (with their average relative share in parenthesis): Manufacturing (71,5%); Agriculture, forestry, fishing and Hunting (10,4%); Mining (5,7%); information (12,4%).

1.3.2 The pattern of the economic share of the non traded good sector

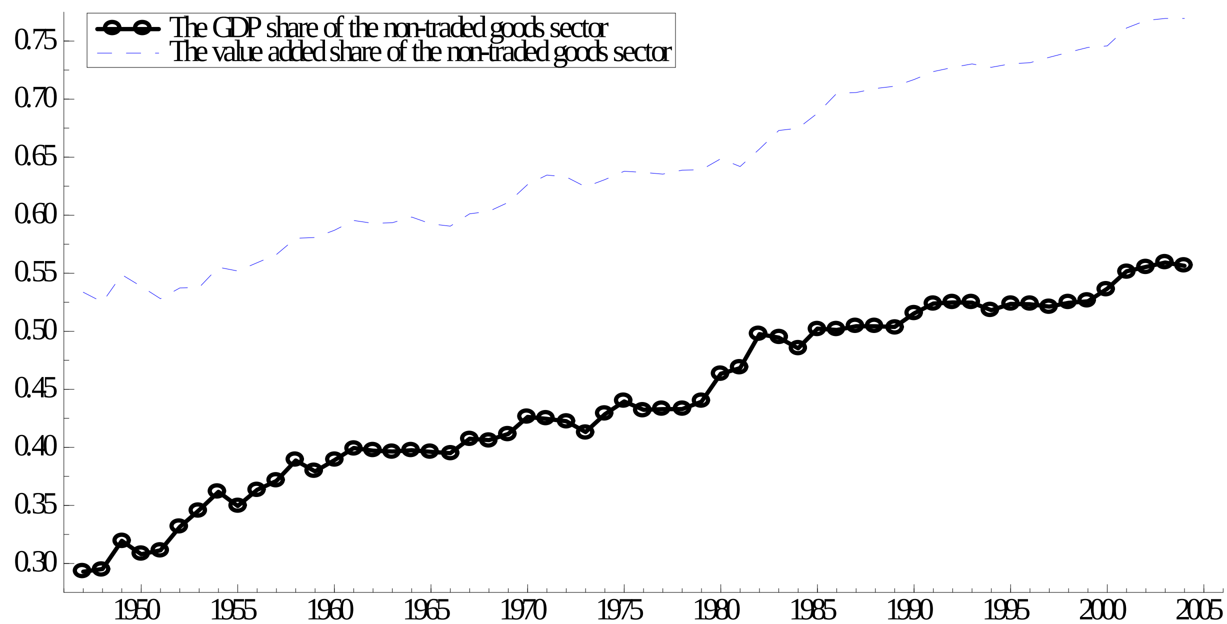

Figure 1.1 - The pattern of the US GDP and added value share of the non-traded goods sector, 1947-2005

Figure 1.1 reports the share of US value added represented by the non-traded goods

definition of an industry as either tradeable or not, and at the same might be misleading. For example, it is possible that a tradeable industry with a domestic production insufficient to the internal demand to register a value of the ratio of exports over production below 10% and so being classified as non-tradeable.

sector over the period 1947-2004. It is evident that it has steadily increased over the years: in 1947 it was less than 53% of the aggregate value added, but by 2004 it was around 76%. In the same figure I also report the pattern of the GDP share of the non-traded goods sector, which also shows a clear upward trend.[9]

The clear change in the composition of the US aggregate economy then raises the question whether the two sectors have different cyclical components as to sectorial price and output, as if it is the case then a disaggregated analysis of the 'oil-macroeconomy' relationship based on such a decomposition would be justified.

1.3.3 Cyclical Fluctuations in the traded and the non-traded goods sector

I now consider the business cycle components of the time series of the price and the nominal value added for the two sectors. I also consider the markup to get an insight on the role of marginal costs in driving prices. In fact, according to which between marginal cost or markup drives the price fluctutation, I can indirectly evaluate the strength of the energy intensity argument. Indeed, the latter explains the propagation of oil innovations to the economy principally through their effects on marginal costs. I then estimate the time series of the markups for the two sectors using the procedure by Woodford and Rotemberg (1995).

I obtain the cyclical and the trend component of the time series by applying the Hodrick-Prescott filter. I then divide the cyclical component of each time series by its corresponding trend component to be able to make a comparison across sectors.

[9] The GDP share of the non-traded goods sector is computed using disaggregate data on GDP and Price indexes by NIPA (table 1.5.4."Price Indexes for Gross Domestic" and Table 1.5.5"Gross Domestic Product, Expanded Detail"). The nominal GDP of the traded goods sector is obtained by aggregating the following entries: personal consumption expenditures on Durable goods (Motor vehicles and parts; Furniture and household equipment; Other) and Nondurable goods (Food, Clothing and shoes, Other durable goods); Gross private domestic investment in Nonresidential Fixed Investment (Information processing equipment and software; Industrial equipment; Transportation equipment; Other equipment), Change in private inventories. The nominal GDP of the non-traded sectors is computed by aggregating the following entries: Personal consumption expenditures on Services (Housing; Electricity and gas; Other household operations; Transportation; Medical care; Recreation ; Other), the Gross private domestic investment in Residential fixed Investment, the Gross private domestic investment in Nonresidential fixed Investment (infrastructure). The time series of GDP price deflator for the two sectors are constructed using a weighted average of the sectorial entries, each weighted by its relative GDP share within the sector.

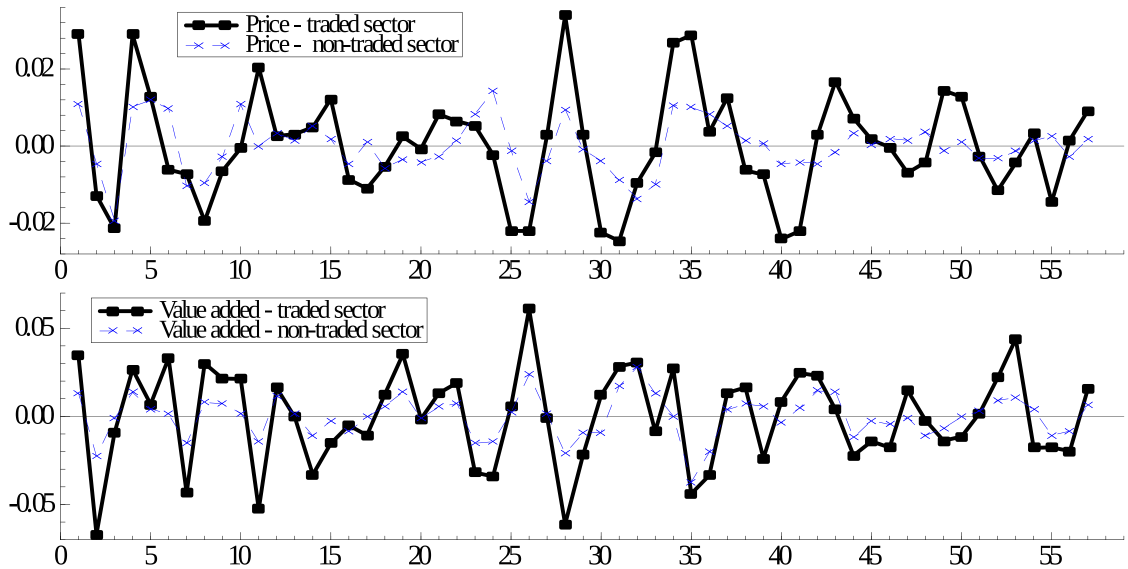

Figure 1.2 - The fluctuations of Price and Value Added in the traded and non-traded goods sectors

Figure 1.2 shows the cyclical component of the value added (bottom panel) and the price (top panel) of the two sectors. The cyclical components of both variables appear to comove positively across sectors and, most importantly, both the price and the value added of the traded good sector are more volatile than the the price and the value added of the non-traded sector.

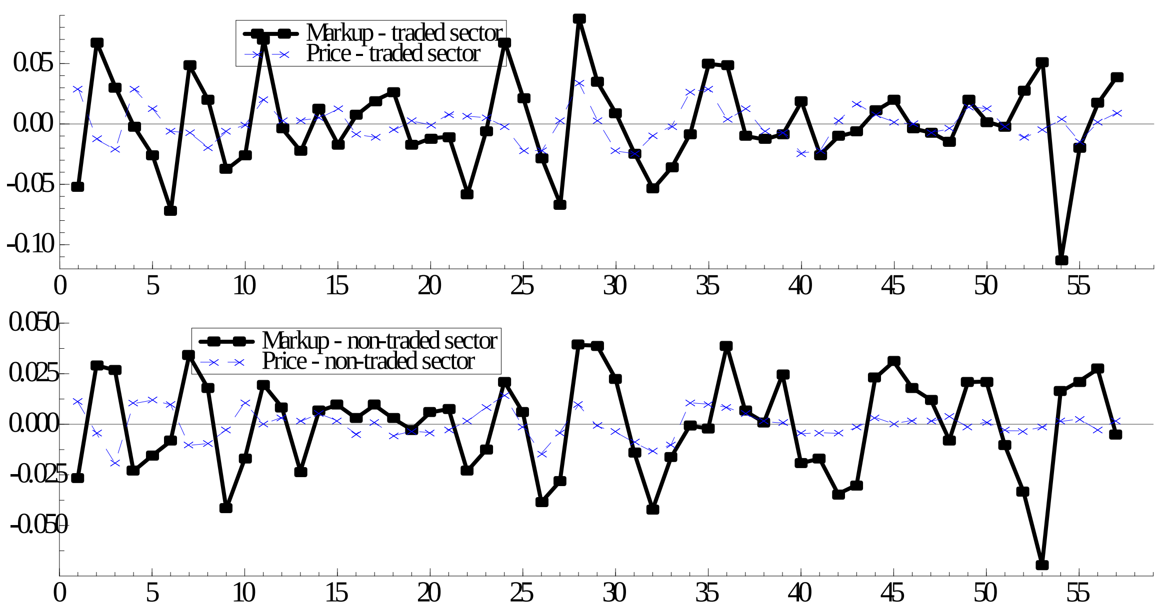

Figure 1.3 - Price and markup fluctuations in the traded and non-traded goods sectors

Figure 1.3 compares the fluctuations of the price and the markup of the non-traded (top panel) and traded goods sectors (bottom panel). In both sectors the markup fluctuates more than the price at almost any period. As the latter may be driven either by the marginal cost or by the markup, it is crucial to check for the sign of both the price and markup fluctuation at every period: if they have the same sign, then is the markup to drive the price, the opposite otherwise.

In both sectors it appears as if the price and the markup have opposite signs before the 70's , and the opposite thereafter. This impression is confirmed by the data: the price and the markup of the traded good sector have the same sign for 22 out of 34 years in the 1970-2003 period, while only for 6 out of 23 years in the preceding period. Similarly, in the non-traded good sector the price and the markup have the same sign for 25 out of 34 years in the 1970-2003 period, but only for 7 out of 26 years in the preceding period.

I then argue that the lower volatility of the non-traded sector, together with the fact that its share of the economy has constantly increased over time, justifies a disaggregated analysis of the oil-macroeconomy relationship.

1.3.4 Energy intensity

Share of Gross Output - (1997-2004)									
	1997	1998	1999	2000	2001	2002	2003	2004	average
All industries	2,00%	1,70%	1,70%	2,00%	2,00%	1,90%	1,90%	2,00%	1,90%
Traded good industries*	1,75%	1,60%	1,60%	1,70%	1,80%	1,60%	1,70%	1,80%	1,7%
non-traded good industries**	1,90%	1,60%	1,60%	1,90%	1,80%	1,80%	1,80%	1,90%	1,8%
Share of Value Added - (1997-2004)									
	1997	1998	1999	2000	2001	2002	2003	2004	average
All industries	3,6%	3,1%	3,1%	3,7%	3,6%	3,4%	3,4%	3,6%	3,46%
Traded good industries*	4,68%	4,20%	4,23%	4,47%	4,69%	4,09%	4,33%	4,72%	4,4%
non-traded good industries**	3,02%	2,57%	2,58%	3,15%	2,92%	2,90%	2,91%	3,08%	2,9%

*Consists of agriculture, forestry, fishing, and hunting; mining except oil and gas extraction; and manufacturing except petroleum and coal products;computer and electronic products; publishing industries (includes software); information and data processing services; and computer systems design and related services.
**Consists of utilities,construction; wholesale trade; retail trade; transportation and warehousing; information; finance, insurance, real estate, rental, and leasing, arts, entertainment, recreation, accommodation,professional and business services, educational services,health care, social assistance, food service, other services except government.
Source: BEA.

Table 1.1 - Energy intensity measures in the traded and non-traded goods sectors

Table 1 reports two measures of the energy intensity for the two sectors over the period 1997-2004.[10] The first energy intensity measure is the energy share per unit of sectorial

[10] Data are from the Bureau of Economic Analysis, and for each industry it is reported the share of GDP represented by value added, Compensation of employees, Taxes on production and imports less subsidies, Gross Operating Surplus and Intermediate inputs. The category of Intermediate inputs is further decomposed into Energy inputs, Material inputs and Purchased-services inputs.

gross output, while the second is the energy share per unit of value added. The first energy measure is small in size and almost equal across sectors: it is, on average, 1.7% for the traded good sector, and 1.78% for the non-traded sector sector. Instead, when I consider the second energy measure, I find that the tradeable sector, whose energy measure is 4.4%, is 1.5 times more energy intensive than the non-tradeable sector (2.9%).

It follows that different energy intensities between sectors cannot be used to explain a different response to oil innovations when GDP data are used. However, when value added data are used the energy intensity argument may explain a larger response to oil innovations of the tradeable sector up to 1.5 times than that of the non-tradeable sector

1.4 VAR Analysis

1.4.1 Data

I use quarterly data over the period 1960Q2-2005Q4. I use NIPA disaggregate data on GDP and Price indexes to construct GDP and price indexes for the traded and the non traded goods sectors. [11]

The advantages from using this dataset for the VAR analysis, with respect to that used in the preliminary analysis, are two, and notably the higher data frequency and the exploitation of the result that GDP data imply almost identical energy intensity across sectors.

The traded good sector GDP is obtained by aggregating the following entries: personal consumption expenditures on Durable goods (Motor vehicles and parts; Furniture and household equipment; Other) and Nondurable goods (Food, Clothing and shoes, Other durable goods); Gross private domestic investment in Nonresidential Fixed Investment (Information processing equipment and software; Industrial equipment; Transportation equipment; Other equipment), Change in private inventories.

The non-traded sector GDP is computed by aggregating the following entries: Personal consumption expenditures on Services (Housing; Electricity and gas; Other household operations; Transportation; Medical care; Recreation ; Other), the Gross private domestic investment in Residential fixed Investment, the Gross private domestic investment in Nonresidential fixed Investment (infrastructure). The time series of the price indexes for the two sectors are constructed using a weighted average of the sectorial entries, each weighted by its relative GDP share within the sector.[12]

Finally, Datastream provides the time series of the spot price of crude Brent oil or

[11] NIPA table 1.5.4."Price Indexes for Gross Domestic Product, Expanded Detail" and Table 1.5.5 "Gross Domestic Product, Expanded Detail", downloadable from http://www.bea.gov/beahome.html .

[12] GDP and prices for the two sectors are netted out of the government and energy component

nominal oil price (US$/barrel) and the IFS dataset the time series of the Federal Fund rate.

1.4.1.1 The choice of the oil price measure

The first and more natural measure of the price of oil is the difference of the logs of the nominal price of oil. However, this measure has been considered unsatisfactory given the instability and asymmetry of the oil-macroeconomy relation detected at the aggregate level. Alternative measures have therefore been proposed by Mork (1989), Hamilton (1996) and Lee et al. (1996)[13]

In my research I consider three oil price measures: the difference of the logs of the nominal price of oil (Brent measure), a version of the oil price measure by Mork (Mork measure) and a version of the net oil price measure by Hamilton (Hamilton measure). In my analysis the Mork measure is defined by the difference of the logs of the nominal price of oil with zero replacing negative values. The Hamilton measure is defined by the percentage change by which the nominal price of oil at quarter t exceeds the peak value in the previous year, with zero replacing negative values

I decide to focus on nominal measures of the price of oil as the use of nominal price measures has the advantage of not incorporating inflation innovations.

1.4.2 The identification of oil innovations: a recursive approach

The oil-macroeconomy relationship is not clear in its causes and effects. Thus, the identification of oil innovations is often related to exogenous political events. However, the same possibility of using exogenous events has been challenged by Barsky and Kilian:

> even major OPEC oil price increases in the 1970s would have been far less likely in the absence of conducive macroeconomic conditions resulting in excess demand in the oil market. (Barsky and Kilian 2004, p 2)

I then decide to perform a VAR analysis as this permits me both to consider the price of oil as an endogenous variable and to adopt a recursive approach to identify oil innovations. The use of a recursive approach, while has the advantage of being an extremely flexible identification scheme, brings also a cost, which is the degree of arbitrariness that is introduced through those economic beliefs which are required for the identification.

[13] Hamilton (2003) tests for most measures of the price of oil to determine which one best represents the non-linear oil-macroeconomy relationship, and concludes in favor of the net oil measure (Hamilton 1996) together with second-moment based measures (Lee et al. 1996).

To understand in details how the recursive approach may be used to identify oil innovations let us consider a general representation of a structural VAR:

$$B_0 X_t = B_1(L) X_{t-1} + \varepsilon_t,$$

where X_t denotes the vector of endogenous variables, ε_t the vector of orthogonal innovations and $B_0,\ B_1(L)$ are, respectively, a square matrix and a matrix in the lag operator of parameters.

In empirical analysis it is generally estimated the reduced form of the VAR:

$$\begin{aligned} X_t &= A_1(L) X_{t-1} + U_t \\ A_0 &= (B_0)^{-1}\ ;\ A_1(L) = A_0 B_1(L)\ ;\ U_t = A_0 \varepsilon_t. \end{aligned}$$

The problem of identification consists in identifying the vector of innovations (ε_t) using the reduced form residuals (U_t). As U_t can be represented as a linear combination of ε_t the problem of identification amounts to estimating the matrix A_0.

Let us denote by x_t an element of Y_t and by $x_{t\_}$ the set of elements of X_t other than x_t. It is possible to write a generic equation of the system $U_t = A_0 \varepsilon t$ in the following form:

$$u_t^x = \varepsilon_t^x + \Lambda \varepsilon_t^{x-}.$$

At any period t, the reduced form residual of the generic variable x_t, u_t^x, is determined by two components: its own innovation or structural error, ε_t^x, and a linear combination of innovations of the other variables, $\Lambda\ \varepsilon_t^{x-}$. The intuitive interpretation of this second term is the automatic or systematic response of the variable x_t to contemporaneous innovations in the other variables.

Economic beliefs on the transmission mechanism of innovations might allow us to write the matrix A_0 in a triangular form so that it would be possible to identify recursively innovations via an equation-by-equation OLS estimation.[14]

[14] To better clarify this last point let's consider a generic matrix A_0 :

$$A_0 = \begin{pmatrix} A0_{11} & A0_{12} & A0_{13} & A0_{14} \\ A0_{21} & A0_{22} & A0_{23} & A0_{24} \\ A0_{31} & A0_{32} & A0_{33} & A0_{34} \\ A0_{41} & A0_{42} & A0_{43} & A0_{44} \end{pmatrix}.$$

A recursive structure on A_0 requires it to be triangular. This feature implies that the ordering of the variables becomes crucial. In fact, the ordering has a direct effect on the structure of the contemporaneous innovations: the variable set first is assumed not to be contemporaneously affected by other variable innovations. In practice, this assumption implies that in the above matrix $A0,\ A0_{12},\ A0_{13},\ A0_{14} = 0$ and $A0_{11} = 1$. The variable set in second position is then affected by its own innovation and by the innovation in the variable set in the first position. Again, this means that $A0_{23},\ A0_{24} = 0,\ A0_{22} = 1$ and $A0_{21} \neq 0$. A similar reasoning applies to all other variables so that A_0 results triangular.

However, economic beliefs are not necessary when the information that are contained in the price of oil are orthogonal to those contained in the other variables. In this respect, Kilian (2007) finds that oil price reduced form innovations are nearly all due to oil specific demand shocks.[15] Thus, to verify whether oil innovations are indeed orthogonal to all the other innovations I follow a 'rough strategy' in which I consider any possible ordering of the variables (apart from the Fed Funds rate) and impose to each a recursive structure that is independent on any economic beliefs. If the IRFs that I obtain from every variable ordering do not differ substantially I can interpret it as a signal that the information contained in the oil price is nearly orthogonal to that contained in the other variables.

1.4.2.1 Economic beliefs on monetary policy innovations

I interpret innovations in the Federal Fund rate as monetary policy innovations.[16][17] I then refer to the VAR monetary policy literature to get insights into how monetary policy innovations affect the economy. As monetary policy is committed to macroeconomic stability, it is commonly argued that changes in the Federal Funds rate are at least partially endogenous.[18] This is often the reason why monetary policy variables are usually set after

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In general, being k the number of endogenous variables, in order to identify oil innovations I need some identifying assumptions whose number depend on the variable ordering. Without loss of generality, let's set the oil price as the $k_1 + 1$ variable, then A_0 will look like:

$$\underset{(kxk)}{A_0} = \begin{pmatrix} \underset{(k_1 x k_1)}{A_0^{1,1}} & \underset{(k_1 x 1)}{A_0^{1,2}} & \underset{(k_1 x (k-k_1-1))}{A_0^{1,3}} \\ \underset{(1 x k_1)}{A_0^{2,1}} & \underset{(1x1)}{A_0^{2,2}} & \underset{(1x(k-k_1-1))}{A_0^{2,3}} \\ \underset{((k-k_1-1)xk_1)}{A_0^{3,1}} & \underset{((k-k_1-1)x1)}{A_0^{3,2}} & \underset{((k-k_1-1)x(k-k_1-1))}{A_0^{3,3}} \end{pmatrix}.$$

As I am interested in identifying oil price innovations, I only need to estimate the $k_1 + 1$ column of A0. I first notice that it is possible to assume $A_0^{1,1}$ triangular without loss of generality, as long as we do not need to identify innovations of the first k_1 variables. Moreover, to identify oil price innovations I do not need any assumption on the parameters of A_0 relative to variables set after the oil price measure. Thus, I need $(k_1 x (k - k_1 - 1)) + k - 1$ identifying assumptions.

[15] Oil innovations, as classified by Kilian (2006), may be due to supply shocks driven by political events, other supply shocks, shocks to the aggregate demand for industrial commodities and demand shocks that are specific to the crude oil market (usually shifts driven by higher precautionary demand associated with fears about future oil supplies).

[16] A problem in using the Federal Funds rate is that, in general, it is not possible to test whether innovations in the federal funds rate are dominated by demand-side or supply-side forces. However, many authors offer evidence in support of the view that innovations in the Federal Fund Rate are mostly attributable to the Federal Reserves policy decisions (Bernanke and Blinder 1992).

[17] As stressed by Eichenbaum (1992), there is no a well-established methodology to compare across alternatives measures of the monetary policy stance. Therefore, the literature presents different proposals: Federal Funds Rate (Bernanke and Blinder 1992, Laurent 1988, Bernanke 1990, Christiano and Eichenbaum 1996); short-term rates (Sims 1992); non-borrowed reserves (Christiano and Eichenbaum 1992, 1996); proportion of non-borrowed reserves growth rate orthogonal to total reserves growth (Strongin 1995); borrowed reserves (Cosimano and Sheehan 1995).

[18] A further problem related to policy innovations, pointed out by Cochrane (1996), is that in the evaluation of the effects of policy innovations on the economy it is not possible to distinguish between the part of the change in the economy due to the innovation per se and the part of the change due to the change in policy

non-policy variables in the variable ordering of VARs. I then follow the literature in assuming that monetary policy innovations do not have any systematic effect on non-policy variables. Moreover, I also assume that monetary policy innovations have no contemporaneous effect on the price of oil. Indeed, monetary innovations would affect the oil market only indirectly, through their effects on US aggregate demand, which in turn affects the global demand of oil. As it is usually estimated that monetary policy innovations are not quantitatively important and take more than a quarter to produce a peak reaction to GDP and inflation (i.e. Christiano and Eichenbaum 1996) I consider this evidence as supportive of my assumption.

I then set the Fed Fund rate always as last in the variable ordering of the VAR.[19]

1.4.2.2 Reasons for oil innovations being orthogonal to other innovations

As a result of the rough strategy it turns out that results are independent of the specific variable ordering that is assumed, and so of the implied economic beliefs and structural restrictions. Thus, even though I adopt a recursive model it is not strictly necessary to justify the analysis on the basis of a specific structural restriction, as anyone else would lead to the the same results. It is then possible to investigate a possible explanation of why oil innovations are orthogonal to innovations of the other variables. I argue that this result relies on the characteristics of the pricing system of the oil market. Indeed, crude oil is a commodity that cannot be immediately incorporated into final consumption goods: it has first to be transformed by refineries into oil products, which are in turn used in final good productions. Accordingly, a change in the price of oil requires some time to propagate into the economy.

Historically, until 1979 the oil pricing system was dominated by long-term contracts and the spot price of oil had a marginal role in the oil market. After 1979, with the end of the OPEC era, the importance of the spot price of oil has increased up to the point it become the reference price in the so-called spot price continuum (table 1.2), that is the set of possible prices used in the oil market.[20] Any price in the spot price continuum refers to a specific contract with its own characteristic in terms of price determination and of the temporal lag, that is the span of time which passes between the date of agreement and that of delivery. For example, today's spot price of oil is used to trade oil to be delivered in at least 1 month.

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expectation (Lucas Critique). However, this problem does not appear for non-policy innovations, like oil price innovations.

[19] In terms of the general representation of A_0 which I report in note 12, these assumptions amount to set $A_0^{1,3}$ and $A_0^{2,3}$ equal to zero.

[20] The proportion of crude traded at spot prices increased from the average 5% of the preceding period to 35 % in 1979.

Moreover, the sharp increase in the oil price volatility, which followed the end of the OPEC era, led to the creation of the oil future and forward market, which allowed refineries and oil producers to hedge against sudden large changes in the price of oil.[21]

Spot Price Continuum

Spot	single cargo, fixed price, delivery in a month
Forward spot	single cargo, fixed price, future delivery (2-3 month)
Spot linked	Spot sale at some relation to published spot prices
Term (1)	All supply arrangements are determined but the price is set cargo-by-cargo in relation to some open market price
Term (2)	Supply obligation at a fixed price but with frequent (often quarterly) price reopeners and with phase-out provisions
Term (3)	The more traditional sort of term transaction, over a period but with the price fixed at the time of agreement
Evergreen	As for term(2) but automatically renewable, with prices agreed at the time of the renewal
Life of field	A commitemnt to lift crude from the field during its life on a price basis fixed at regular intervals in relation to the market

Source: Hartshorn (1993)

Table 1.2 - The Spot Price Continuum

Both the dominant use of term prices in the oil market and the development of the oil futures and forward market make it plausible to suppose that at the time an oil price innovation occurs, oil quantities and prices, for the present and the near future time, have to a large extent already been settled.

It is also true that oil price changes, by acting on agents' expectations, might contemporaneously affect GDP. However, what is not clear is the time lag necessary for this to happen. In fact, the oil market is characterized by a low price elasticity of both demand and supply which makes it highly volatile. It follows that even a sharp change in the price of oil might be regarded as temporary, as the mere consequence of the normal functioning of the oil market, so that more than a quarter might be required for it to be effectively incorporated in agent expectations.[22]

[21] The first attempt to develop an oil futures market dates back to 1935 in New York, but it did not succeed. It started again in New York in 1974, then followed the Forward Contract Exchange Company in Amsterdam (1974) and the International Petroleum Exchange in London (1981). The birth of a future and forward market for oil reduced even further the power to control the price of oil. In fact, the oil future market allows outsiders and speculators to intervene in the pricing process. It does not come as a surprise, then, that the 1980s are often considered as the end of the era of the exogeneity of the price oil.

[22] This is the reason for Hamilton's proposal of the net measure of oil price and for Lee et al. proposal of a second-moment based measure of the oil price. The former aimed at disregarding changes in the price of oil that would be due to temporary movements of the supply and the demand; the latter aimed at creating a measure of the price of oil which could take into account the change in the oil price volatility.

1.4.2.3 The Standard Aggregate VAR (SA-VAR)

The Standard Aggregate VAR (SA-VAR) includes four variables: the log difference of aggregate real GDP (ΔGDP_t), the log difference of the aggregate GDP deflator (Π_t), the Fed fund rate (i_t) and the log difference of a measure of the price of oil $\left(\Delta P_t^{oil}\right)$.[23][24] Denoting the vector of endogenous variable by X_t^{SA} and the vector of reduced form residuals by U_t^{SA} the reduced form VAR can be written as:

$$X_t^{SA} = B^{SA}(L) X_{t-1} + U_t^{SA},$$

where $B^{SA}(L)$ is a polynomial in the lag operator L, $X_t^{SA} \equiv \left[\Delta GDP_t, \Pi_t, \Delta P_t^{oil}, i_t\right]$ and $U_t^{SA} \equiv \left[u_t^y, u_t^\pi, u_t^{oil}, u_t^i\right]$.

The vector of reduced form residuals is then a linear combination of the vector of structural errors or innovations $\varepsilon_t^{SA} \equiv \left[\varepsilon_t^y, \varepsilon_t^P, \varepsilon_t^{oil}, \varepsilon_t^i\right]$,

$$U_t^{SA} = A_0^{SA} \varepsilon_t^{SA},$$

Let's consider a possible variable ordering such that A_0^{SA} appears in the following recursive form:

$$A_0^{SA} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ \lambda_{GDP}^{\pi} & 1 & 0 & 0 \\ \lambda_{GDP}^{oil} & \lambda_{\pi}^{oil} & 1 & 0 \\ \lambda_{GDP}^{i} & \lambda_{\pi}^{i} & \lambda_{oil}^{i} & 1 \end{pmatrix}.$$

For the purpose of my analysis, the identification of all the parameters in A_0^{SA} is not necessary. In fact, as I am interested in Impulse Response Function (IRFs) to oil price innovations, what I need is the matrix of parameters of the reduced form, $B^{SA}(L)$, and the column of A_0^{SA} relative to the oil price innovation. It is thus possible to assume, without loss of generality, a recursive structure for the first two rows of A_0^{SA}, corresponding to the equations of ΔGDP and Π_t, as long as we are not interested in identifying their innovations. I then perform the rough strategy and identify oil innovations and compute IRFs for any possible variable ordering to check if results are not sensitive to any specific variable ordering.

[23] In VARs a commodity price index is sometimes used to eliminate the price puzzle (Sims 1992). I do not consider it because the price puzzle influences monetary policy innovations, while Bernanke, Gertler and Watson (1997) report that its introduction does not change the effects of oil price innovations. Further, I consider the GDP deflator and not the CPI index. This distinction matters as Barsky and Kilian (2001) show that, theoretically, while the CPI index must increase after an oil price innovation the GDP deflator may take any direction, so that any price puzzle could be claimed.

[24] I use the software Jmulti to perform the Saikkonen & Luetkepohl cointegration test between the time series of GDP, GDP deflator and nominal oil price. The null hypothesis of zero cointegration rank is not rejected when considering non zero mean and a deterministic trend and under different lag specifications.

1.4.2.4 The Disaggregated VAR (D-VAR)

The Disaggregated VAR (D-VAR) consists of six variables: the log difference of the traded good sector GDP deflator (Π_t^M) , the log difference of the non-traded good sector GDP deflator (Π_t^S), the log difference of traded good sector GDP (ΔGDP_{tt}^M), the log difference of non-traded good sector GDP (ΔGDP_t^S), the Fed Fund rate (i_t) and the log difference of a measure of the price of oil ($\Delta P_{oil,t}$).

By denoting the vector of endogenous variable by Z_t^D and the vector of reduced form residuals by U_t^D the reduced form VAR can be written as:

$$Z_t^D = B^D(L) Z_{t-1} + U_t^D,$$

where $B^D(L)$ is a polynomial in the lag operator L,

$$Z_t^D = \begin{pmatrix} \Delta GDP_t^M \\ \Delta GDP_t^S \\ \Pi_t^M \\ \Pi_t^S \\ \Delta P_t^{oil} \\ i_t \end{pmatrix} .\ and\ U_t^D = \begin{pmatrix} u_t^{Y^M} \\ u_t^{Y^S} \\ u_t^{\pi^M} \\ u_t^{\pi^S} \\ u_t^{oil} \\ u_t^i \end{pmatrix} .$$

The vector of reduced form residuals is then a linear combination of the vector of structural errors or innovations $\varepsilon_t^D \equiv \left[\varepsilon_t^{y^M}, \varepsilon_t^{y^S}, \varepsilon_t^{\pi^M}, \varepsilon_t^{\pi^S}, \varepsilon_t^{oil}, \varepsilon_t^{i}\right]$,

$$U_t^D = A_0^D \varepsilon_t^D,$$

It is then possible to apply to the D-VAR the same identification procedure I have outlined for the SA-VAR and similarly perform the rough strategy to check if the IRFs to oil innovations do not change significantly as the order of the variables changes.

1.4.3 Do oil price innovations have similar effects on the traded and the non-traded goods sector?

To check whether oil price innovations have different effects across sectors I estimate the D-VAR and compute the IRF to a positive oil price innovation for four sectorial variables ($\Delta GDP_t^M, \Delta GDP_t^S, \Pi_t^M, \Pi_t^S$). Moreover, I also estimate the SA-VAR to compare the results between the aggregate and the disaggregate approach.

In the specification of the D-VAR I consider a non-zero constant and 4 lags. In the choice of the number of lags I take into account the information criteria, previous empirical studies and the number of lags necessary to reject serial correlation and conditional heteroscedasticity in the residuals.[25] The number of lags suggested by the information criteria is at most three (AIC and HQ) and with three lags I can exclude both serial correlation and heteroscedasticity in the residuals. However, as the oil empirical literature shows that the most important lags coefficient are the fourth and the third, I decide to consider no fewer than 4 lags (see table 1.3)

Summary of Most important Lag Coefficients in Previous Empirical Studies
of the Effects of Oil Price Shocks

Study	Sample Period	Lag With Greatest Coefficient	Lag With second Greatest Coefficient
Hamilton (1983)	1949:II-1972:IV	Fourth Quarter	Third Quarter
Hamilton (1983)	1973:I-1980:IV	Fourth Quarter	Third Quarter
Gisser and Goodwin (1986)	1961:I-1982:IV	Fourth Quarter	Third Quarter
Mork (1989)	1949:I-1988:II	Fourth Quarter	Third Quarter
Raymond and Rich (1997)	1952:II-1995:III	Fourth Quarter	Third Quarter
Hamilton (2003)	1949:II-1999:IV	Fourth Quarter	Third Quarter

Source Hamilton and Herrera (2004)

Table 1.3 - Summary of the most important lag coefficients in past empirical studiies.

In the specification of the SA-VAR I consider a non-zero constant and 6 lags. The information criteria deliver very different results: the Akaike criteria (AIC) reports 11 lags, the Hannan and Quinn criteria (HQ) 3 and the Scwarz criteria (SC) 1. The choice of six lags follows from the fact that it is the minimum number of lags necessary to reject serial autocorrelation in the residuals.

In presenting the results I report the IRFs together with 95 % bootstrap confidence intervals.[26]

[25] I use the software Jmulti to compute the information criteria and to perform the residual analysis (the Portmentau and the LM test for residual autocorrelation, performed at different lag lenghts, and the univariate ARCH-LM test for conditional Heteroscedasticity)

[26] Bootstrap confidence intervals are the 5% and 95% quantiles of the empirical distribution of the impulse response of interest and are constructed following Efron and Tibshirani (1993). First, the residuals estimated in the reduced form VAR are centered and a new dataset is computed using both the estimated parameters and a drawn from centered errors. The new dataset is then used to obtain a new impulse response that is stored. These steps are repeated 5000 times, and the confidence interval is computed taking the values which delimit the 5-95% interval of the empirical distribution of the impulse responses.

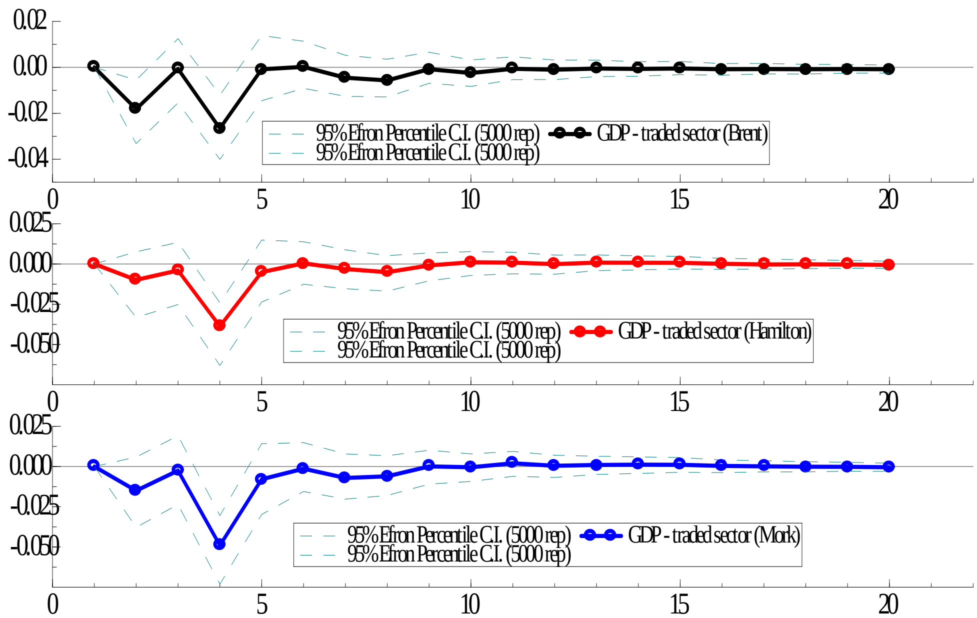

Figure 1.4 - IRFs of ΔGDP^T

Figure 1.4 reports the response of ΔGDP^T to a 1% positive oil price innovation for any of the three different measures of the price of oil (Brent, Mork and Hamilton). The pattern of the IRF of ΔGDP^T is similar across different measures of the price of oil, but the size of the trough is the largest with Mork measure and the smallest with the Brent measure. For any measure of the price of oil the trough is reached at the 4th period and it is always statistically significant at the 10 percent level, but only when the Brent measure is adopted there is also a statistically significant effect in the 2nd period.

In figure 1.5 I report the response of ΔGDP^N to a 1% positive oil price innovation for any of the three different measures of the price of oil. For each measure of the price of oil the IRF is never statistically significant at the 10 percent level.

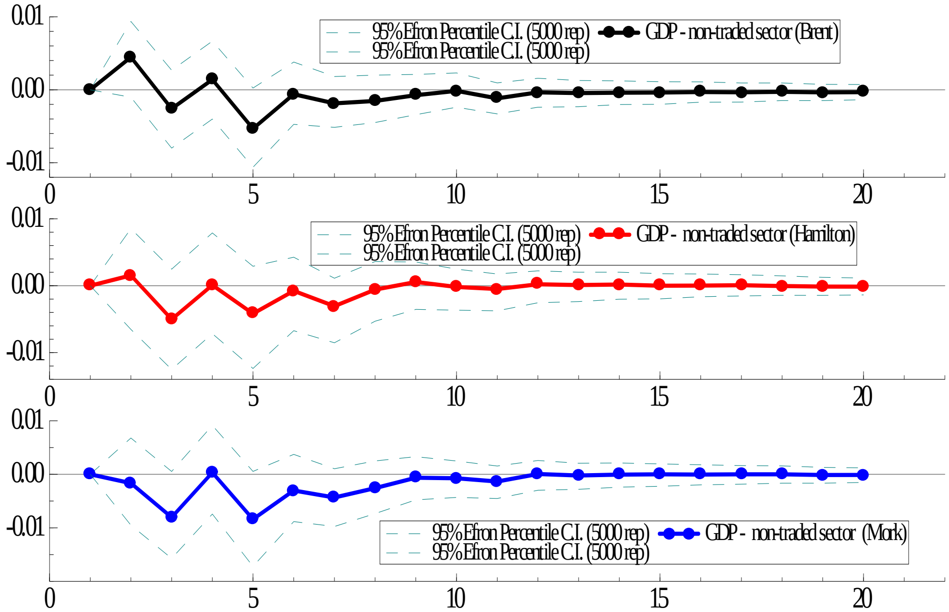

Figure 1.5 - IRFs of ΔGDP^N

In figure 1.6 I report the response of Π^T to a 1% positive oil price innovation for any of the three different measures of the price of oil.

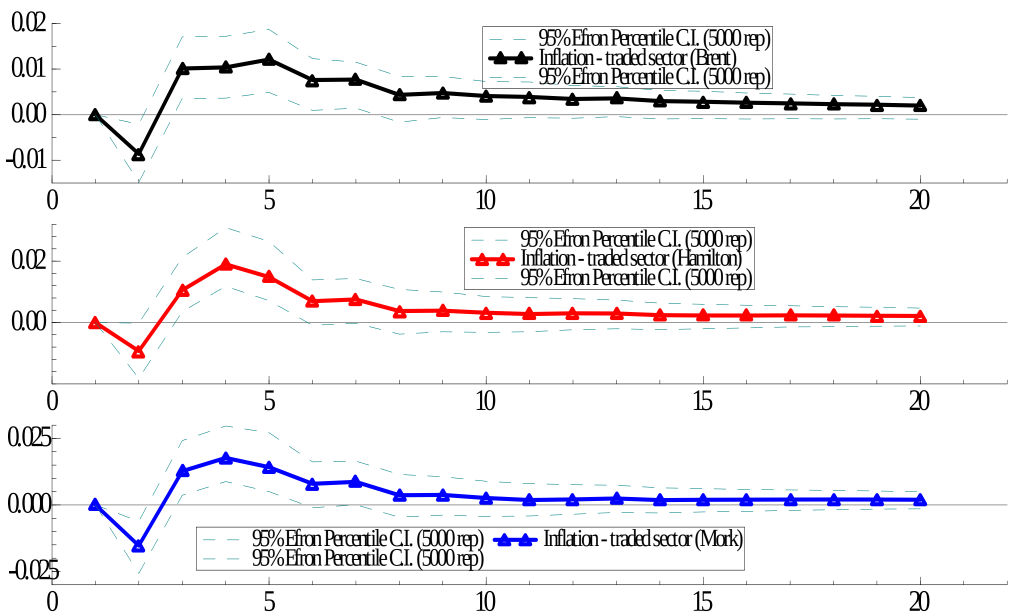

Figure 1.6 - IRFs of Π^T

The pattern of Π_t^T is similar across different measures of ΔP_t^{oil}, but the size of the peak is the largest for Mork measure and the smallest for the Brent measure. The impulse response is statistically significant at the 10 percent level either up to the 5th period (Hamilton, Mork) or up to the 7th period (Brent), and the peak occurs either at the 4th (Mork, Hamilton) or at the 5th period (Brent).

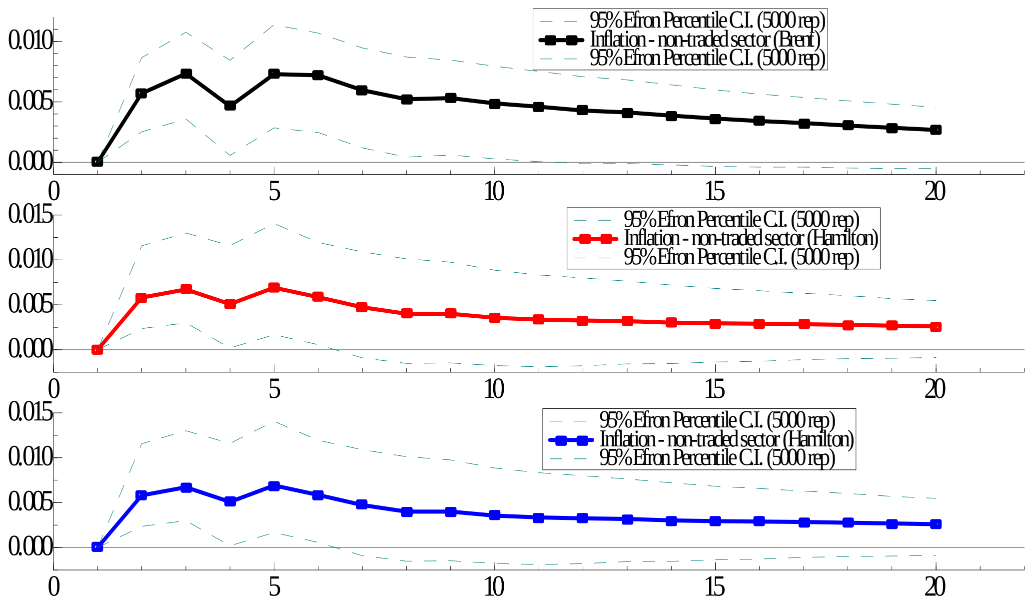

Figure 1.7 - IRFs of Π^N

In figure 1.7 I report the IRFs of Π^N to a 1% positive oil price innovation for the three different measures of the price of oil. The pattern of the IRF is pretty similar across different measures of oil price, with a peak reached either at the 3rd (Mork, Brent) or at the 5th period (Hamilton). The IRF is statistically significant at the 10 percent level either for the first 6 periods (Mork,Hamilton) or for the first 10th period (Brent).

In general, I find that in both sectors the size of the responses of both Π and ΔGDP is the largest when I use Mork oil price measure, while when I use the Brent measure the size of the responses is the smallest but it is statistically significant for more periods. It is also evident that the non-traded sector is less sensitive to oil innovations than the traded sectors. Indeed, not only the size of the responses of both Π (at the peak) and ΔGDP (at the trough) are much larger in the traded good sector than in the non-traded good sector, but also the response of ΔGDP^N is never statistically significant for any measure of the price of oil.

F tests in the non-standard VAR

	Test value	No restr	p-value*	
H0: no GDP asymmetry across sectors	3,83	4	0,0043	Reject H0
H0: no inflation asymmetry across sectors	7,61	4	4,94E-07	Reject H0
H0: no GDP & inflation asymmetry across sectors	5,63	8	5,50E-03	Reject H0

* F ~(#,T-k):# is the no. of linear restriction, T=no. observations k= no.of parameters

Table 1.4 - testing the null hypothesis of identical direct effects of oil price on the traded and the non-traded goods sector.

Finally, I test the null hypothesis that the parameters which describe the effect of lags of ΔP^{oil} on time ΔGDP_t^T are statistically identical to those which describe the effect of lags of ΔP^{oil} on ΔGDP_t^N. I also perform an analogous test for the parameters which describe the effect of lags of ΔP^{oil} on Π_t^T and Π_t^N.

These linear restrictions are tested through F tests, whose results are reported in table 1.4 with the null hypothesis that is always rejected. If I interpret the parameters which describe the effect of lags of ΔP^{oil} on a a time t variable as the direct effect of the price of oil on that variable I then conclude that data reject the hypothesis that the price of oil might have a similar direct effect across sectors.

1.4.3.1 A comparison between the aggregate and the disaggregate analysis of the 'oil-macroeconomy' relationship

I use the results from the two VARs to make a comparison between the aggregate and the disaggregate analysis of the oil-macroeconomy relationship. Thus, I have to create a synthetic measure of the IRF of the aggregate Π from Π^T and Π^N, and one of aggregate ΔGDP from ΔGDP^T and ΔGDP^N. While I am aware that a simple weighted average of the disaggregated impulse responses may be a poor measure for a comparison with the aggregate impulse response, I consider this simply as an exercise which aims to grasp an intuition on the possible effects of the change in the composition of the economy on the strength of oil price innovations.

I build up three synthetic IRFs of aggregate inflation and ΔGDP, where each IRF is a GDP-weighted average of the IRFs of ΔGDP^T and ΔGDP^N but with different weights. In the synthetic IRF labelled *'1961-1970'* the weight of any sector is its average GDP share over the first 10 years of the sample period; in the synthetic IRF labelled *'average'* the weight of any sector is its average GDP share over the entire sample period (1961-2005); in the synthetic IRF labelled *'1996-2005'* the weight of a sector is its average GDP share over the last ten years of the sample period.

In computing the synthetic IRFs I use Hamilton oil price measure because I observe that its use often delivers results that are quantitatively half way between those obtained with the other two oil price measures.

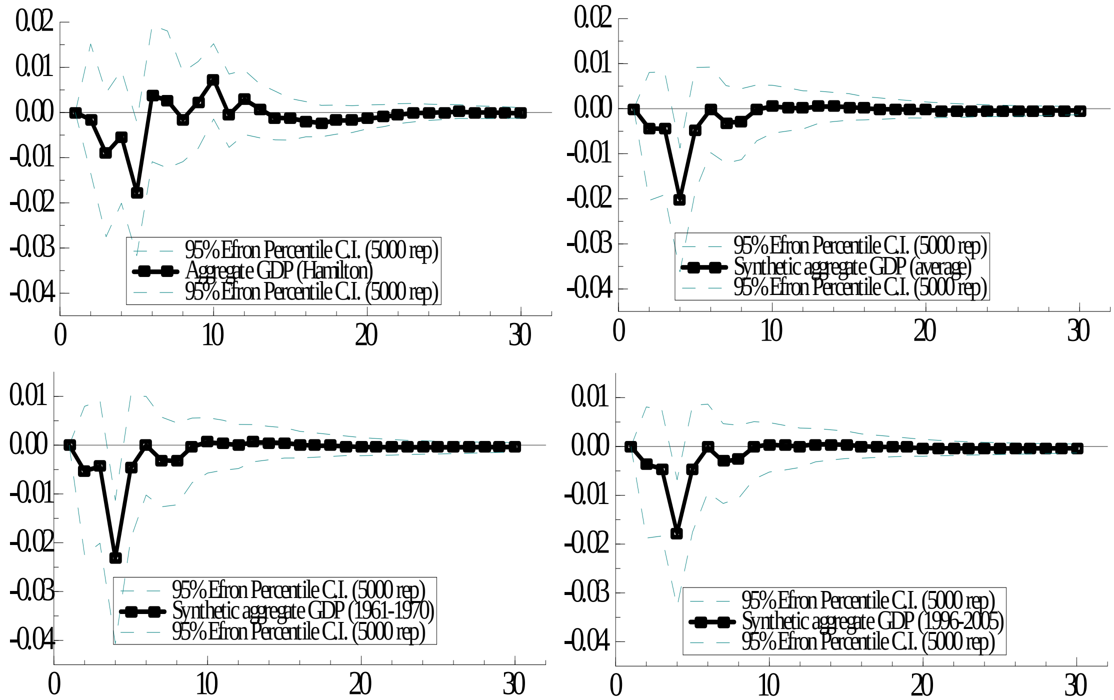

Figure 1.8 - IRFs of aggregate ΔGDP^{SA} and synthetic aggregate ΔGDP^{D}

Figure 1.8 reports the three synthetic IRFs of aggregate ΔGDP^{D} and the IRF of ΔGDP^{SA}. The IRF of the synthetic *average* aggregate ΔGDP^{D} is the natural measure to be used for a comparison with the corresponding IRF of ΔGDP^{SA}, as in *average* ΔGDP^{D} the weight of each sector is computed taking into account the entire sample period. The IRFs of the other two synthetic aggregate ΔGDP^{D}, instead, help to get an intuition on whether the change in the sectorial composition of the economy might change the response of the aggregate economic activity.

I first note that the pattern of the IRF of *average* aggregate ΔGDP^{D} has a pattern similar to that of ΔGDP^{SA}. By comparing the size of the trough of the IRFs of the other two synthetic aggregate ΔGDP^{D} I notice that the size of the trough of *'1961-1970'* aggregate ΔGDP^{D} is larger than that of the *'1996-2005'* aggregate ΔGDP^{D}.

These results suggest that the change in the sectorial composition of the GDP might partially explain the weakening of the effects of oil innovations on US GDP.

In figure 1.9 I report the IRFs of the three synthetic aggregate Π^{D} and the IRF of the aggregate Π^{SA}.

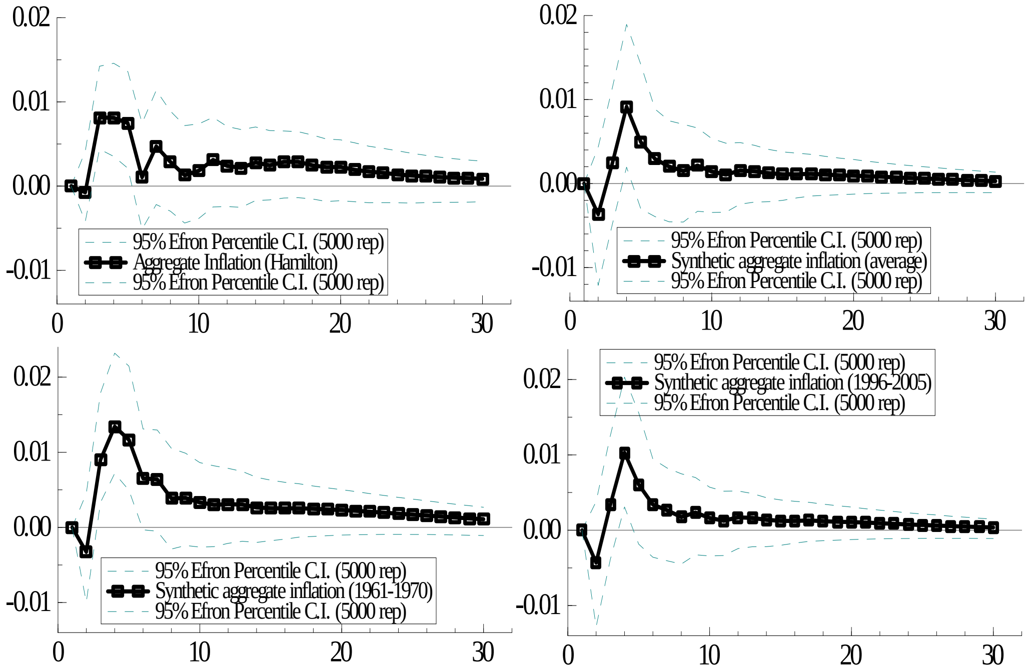

Figure 1.9 - IRFs of aggregate Π^{SA} and of synthetic aggregate Π^{D}

The IRF of the 'average' synthetic aggregate Π^{D} and the corresponding IRF of aggregate Π^{SA} are pretty similar: both are statistically significant at the 10 percent level at the 3rd, 4th and 5th period, and also show the same size at the peak. Moreover, by comparing the IRFs of the other two aggregate synthetic Π^{D} I observe no relevant differences.

I interpret these results as a signal that the change in the sectorial composition of the GDP does not seem to modify the effects of oil innovations on aggregate Π.

1.4.4 Are the relationships between oil and the traded and the non-traded goods sectors linear?

In this section I verify whether there is some evidence for non-linear effects of oil innovations on both the traded and the non-traded goods sectors. For this, I follow Mork (1989) and split the time series of the nominal price of oil into two time series: the first one comprises positive changes in the nominal price of oil and zero otherwise; the second one comprises negative changes in the nominal price of oil and zeros otherwise.

I then perform a seven variable VAR composed of: positive nominal oil price changes $\left(\Delta P^{+}_{oil,t}\right)$, negative nominal oil price changes $\left(\Delta P^{-}_{oil,t}\right)$, log differenced traded goods sector inflation $(\Pi_{T,t})$, log differenced non-traded goods sector inflation $(\Pi_{N,t})$, log differenced traded goods sector GDP($\Delta GDP_{T,t}$), log differenced non-traded goods sector GDP ($\Delta GDP_{N,t}$), and the Fed Fund Rate (i_t).

This modified Disaggregate VAR (MD-VAR) is fully specified with a non-zero constant and four lags.[27]

I perform two tests to check for a linear relationship between the price of oil and any of the two sectors. First, for each sector I compute the response of ΔGDP and Π to both a positive and a negative oil price innovation. A linear relationship between oil and a specific sector implies that sectorial variables should respond symmetrically to positive and negative oil price innovations, that is with similar size but opposite sign.

Figure 1.10 shows the IRFs of ΔGDP to positive and negative oil price innovations in the two sectors. The IRF of ΔGDP appears to have an asymmetric pattern in both sectors, as both positive and negative oil price innovations cause recessive effects. The IRF of ΔGDP^T is never statistically significant after a negative oil price innovation, while it is significant for the first nine periods after a positive oil price innovation. Instead, the IRF to both positive and negative oil price innovations of ΔGDP^N shows some symmetry as it is almost never statistically different from zero at the 10 percent level.

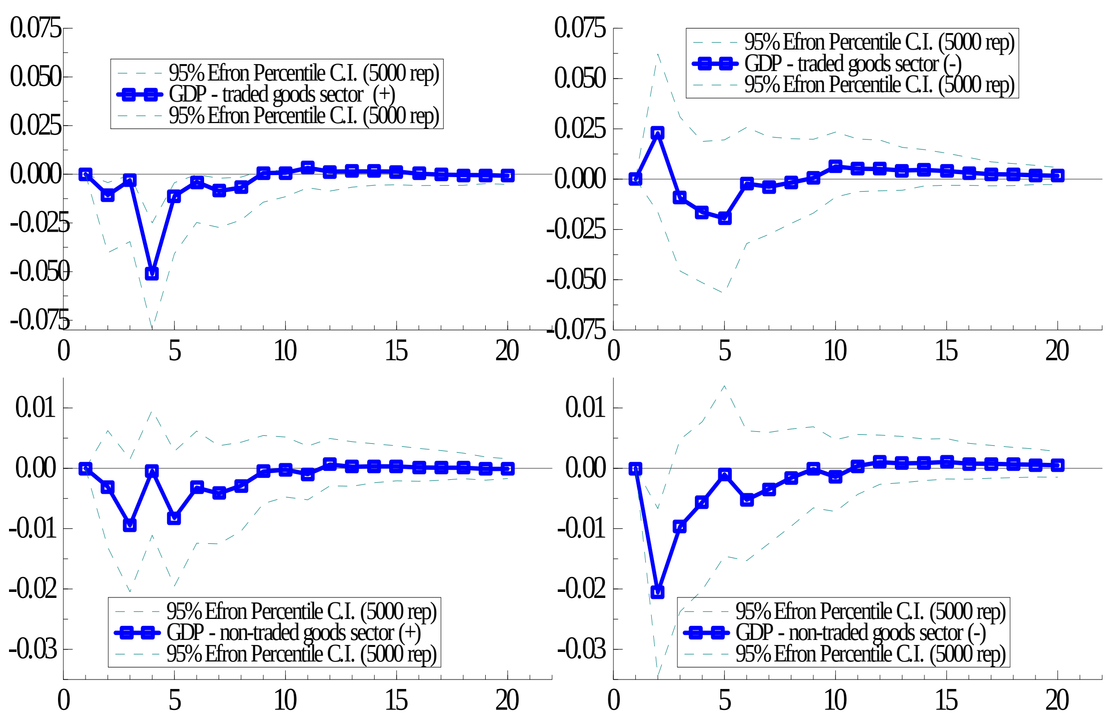

Figure 1.10- IRFs of ΔGDP^T and ΔGDP^N to positive and negative oil price innovations

[27] The identification procedure is identical to that already illustrated apart from the further assumption of no contemporaneous relationships between positive and negative oil price innovations.

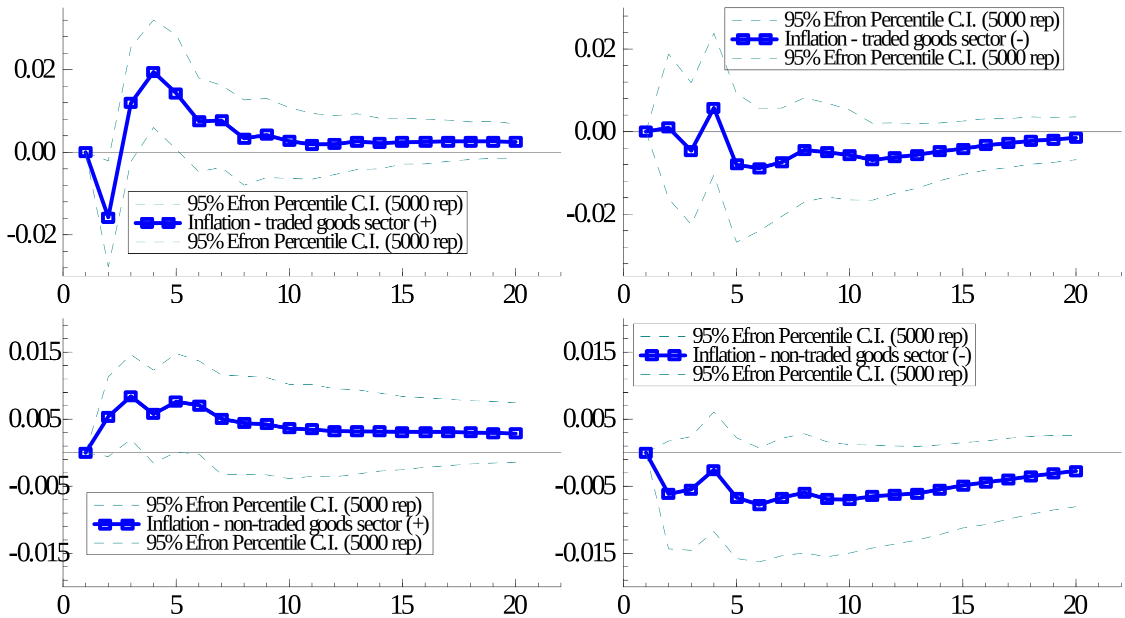

Figure 1.11 - IRFs of Π^T and Π^N to positive and negative oil price innovations

Figure 1.11 shows the IRF of both Π^T and Π^N to a positive and a negative oil price innovation. The IRFs of Π^N to the two innovations appear symmetric in the pattern, even if both are almost never statistically significant. The IRFs of Π^T, instead, are slightly symmetric in the pattern, but while the IRF to negative oil price innovation is never statistically different from zero, the IRF to positive oil price innovation is significant for 4 periods (from the 2nd to the 5th period).

To sum up, both Π^N and ΔGDP^N might appear to be symmetric as the response of the two variables to positive and negative oil price innovations is almost never significantly affected by oil price innovations. The traded good sector, instead, appears to be asymmetric as the IRFs of both the Π^T and ΔGDP^T to a negative and positive oil price innovation are asymmetric and almost never statistically significant only in case of negative oil price innovations.

The second test that I perform to check for non-linear effects of oil innovations on the two sectors is based on the Forecast Error Variance Decomposition (FEVD) of sectorial Π and ΔGDP. The FEVD measures the contributions by any innovation in the VAR to the h-step forecast error variance of the variable of interest. Thus, by comparing the contribution of positive and negative oil price innovations to the FEVD of the variable of interest I may assess whether positive and negative oil price innovations have similar effects.

For each variable of interests Table 6 presents the proportion of forecast error accounted for by positive and negative oil price changes. The forecast error of both ΔGDP^T and Π^T, except for early forecast horizons, is more largely accounted for by positive oil price innovations than by negative ones. I interpret these results as in favor of a non-linear relationship between the price of oil and the traded goods sector.

The case of the non-traded good sector, instead, is different. Indeed, the contribution of positive oil innovations to the forecast error of Π^N is barely larger than that of negative ones at almost any forecast horizon. As to the forecast error of the ΔGDP^N, table 1.5 shows that the contribution of negative oil price innovations is slightly higher than that of positive ones. I interpret this result as not in favor of a non-linear relationship between the price of oil and non-traded good sector.

Table - Proportion of Forecast Error accounted for by positive and negative oil price changes in:

	%GDP Manufacturing		%GDP Services		Inflation Manufacturing		Inflation Services	
Forecast horizon	positive oil %	negative oil %	positive oil %	negative oil %	positive oil %	negative oil %	positive oil %	negative oil %
1	**0**	0	**0**	0	**0,00**	0,00	**0,00**	0,00
2	**0,01**	0,02	**0,00**	0,06	**0,05**	0,00	**0,03**	0,02
3	**0,01**	0,02	**0,03**	0,07	**0,07**	0,00	**0,07**	0,03
4	**0,1**	0,02	**0,03**	0,07	**0,12**	0,00	**0,08**	0,03
5	**0,1**	0,02	**0,04**	0,06	**0,14**	0,01	**0,09**	0,04
6	**0,1**	0,02	**0,04**	0,07	**0,14**	0,02	**0,10**	0,05
7	**0,1**	0,02	**0,05**	0,07	**0,14**	0,02	**0,09**	0,05
8	**0,1**	0,02	**0,05**	0,07	**0,13**	0,02	**0,09**	0,05
9	**0,1**	0,02	**0,05**	0,07	**0,13**	0,02	**0,09**	0,06
10	**0,1**	0,02	**0,05**	0,07	**0,12**	0,03	**0,09**	0,06
11	**0,1**	0,02	**0,05**	0,07	**0,12**	0,03	**0,09**	0,07
12	**0,1**	0,02	**0,05**	0,07	**0,12**	0,03	**0,08**	0,07
13	**0,1**	0,03	**0,05**	0,07	**0,12**	0,03	**0,08**	0,07
14	**0,1**	0,03	**0,05**	0,07	**0,12**	0,03	**0,08**	0,07
15	**0,1**	0,03	**0,05**	0,07	**0,12**	0,03	**0,08**	0,07
16	**0,1**	0,03	**0,05**	0,07	**0,12**	0,03	**0,08**	0,07
17	**0,1**	0,03	**0,05**	0,07	**0,12**	0,03	**0,08**	0,07
18	**0,1**	0,03	**0,05**	0,07	**0,12**	0,03	**0,08**	0,07
19	**0,1**	0,03	**0,05**	0,07	**0,12**	0,03	**0,08**	0,07
20	**0,1**	0,03	**0,05**	0,07	**0,12**	0,03	**0,08**	0,07

Table 1.5 - Proportion of Forecast Error accounted for by positive and negative oil price changes

To sum up, none of the tests appears to strongly reject a linear relationship between the non-traded good sector and oil price, while a linear relationship between oil and the traded good sector is always rejected.

1.4.5 Why do oil price innovations matter less today than in the past?

In this section I test empirically whether it is plausible that the increasing economic weight of the non-traded good sector might contribute to explain why oil price innovations affect the aggregate economic activity less today than in the past. Indeed, in the previous sections I have observed both that over time the GDP share of the non-traded good sector has increased at the expenses of that of the traded good sector and that the non-traded good sector is less sensitive to oil price innovations than the traded good sector.

To find whether data support the hypothesis of a 'composition effect' as further explanation of the weakening of the oil-macroeconomy relationship I split the sample period of the dataset into two subperiods and estimate the SA-VAR and the D-VAR for each of them. By comparing the IRFs to a 1% positive oil price innovation across subperiods I can check how stable is the 'oil-macroeconomy' relationship at both the aggregate and the sectorial level. If the oil-macroeconomy relationship is more stable at the disaggregate level than at the aggregate level, then data would not reject the possibility that the 'composition effect' has a role in explaining the weakening of the oil-macroeconomy relationship.

To measure the weakening of the effects of oil innovations on the economy I check how both the size and the statistical significance of the IRFs of Π and ΔGDP change across subperiods. If I find evidence that the IRFs estimated with the SA-VARs show a larger weakening than the IRFs estimated with the D-VARs, I will interpret this result as in favor of the hypothesis of a composition effect at work in weakening the oil-macroeconomy relationship.

I first need to choose the breakpoint date of the oil-macroeconomy relationship. In the oil literature the breakpoint is usually set in the first half of the1980's (Ferderer 1996, Mork 1989, Lee et al. 1996 and Hooker 1996). However, as the composition effect is also based on the increase over time of the GDP share of the non-traded good sector, I also check for the presence of a structural break in this time series through two kinds of Chow tests.[28]

[28] The time series shows a clear trend that might be either deterministic or stochastic. I use the software Jmulti to perform a unit root test with structural break which excludes the presence of unit root or stochastic trend. The Data Generating Process of the time series is then well represented by a AR(1) with a deterministic time trend.
I use the software Jmulti to perform the break-point Chow Test and the sample-split Chow test. The two tests provide bootstrapped p-values that are based on 5000 repetitions.

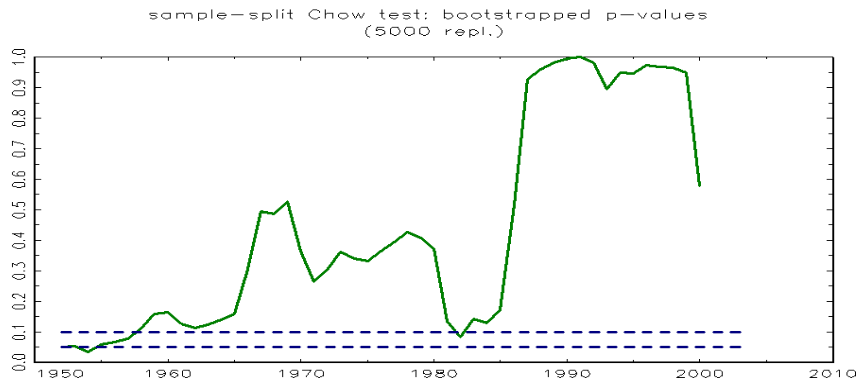

Figure 1.12

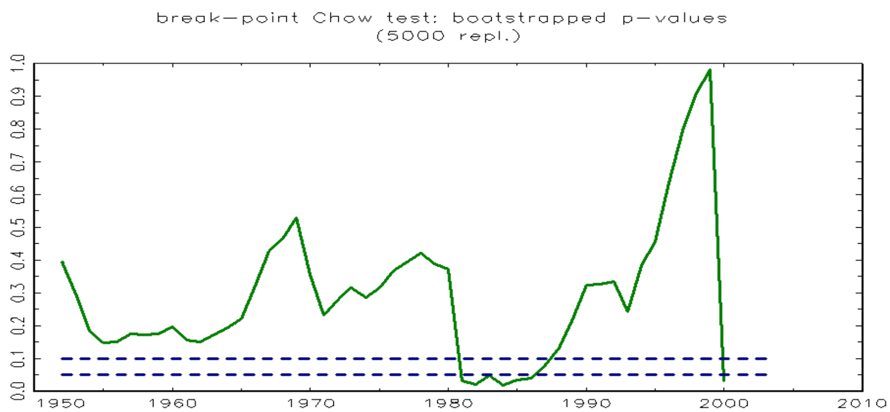

Figure 1.13

Both Chow tests reveal the presence of a structural break exactly in the early 1980's (figures 1.12 and 1.13). In the choice of the breakpoint date I further take into account the fact that in 1979 the oil market experienced a structural change with the end of the OPEC era. One of the consequences of this change has been the huge increase in the volatility of the price of oil in the post-80 period with respect to the pre-80 period.[29] Therefore, by considering the results from oil literature, the specific history of the oil market and the presence of a structural break in the time series of the GDP share of the non-traded good sector, I decide to set the breakpoint date at 1979:Q4.[30] It follows that I label 'before 1980s' any VAR which is estimated with the 1960:Q2-1979:Q4 subperiod dataset, and 'after 1980s ' any VAR estimated with the 1980:Q1-2005:Q4 subperiod dataset.

[29] In particular, Lee et al. (1994) and Ferderer (1996) report that the standard deviation of the crude oil PPI growth rate in the post-80 period was about three times greater than in the pre-80 period.

[30] I also perform the analysis for another breakpoint date, the one that both Chow tests reported as a breakpoint date: 1982:4, and results do not change much.

In the empirical estimation I use all the three measures of the price of oil, and in the specification of the VARs I always consider a non-zero constant and four lags.

Table - synthesis of the changes across subperiods in the response to positive oil price innovations of sectorial and aggregate %GDP and inflation

		From Pre-1980 to post-1980	Significancy (trough or peak)	
		Size (trough or peak)	Pre-1980	Post-1980
S-VAR	%GDP	Decrease(B,H,M)	Yes (B,H,M)	No (B,H,M)
D-VAR	%GDP Man	Decrease(B,H,M)	Yes (B,H,M)	Yes (B,M) / No(H)
	%GDP Serv	Stable(H,M) / Decrease(B)	No (B,H,M)	No (H,M)/ Yes(B)
S-VAR	Inflation	Decrease(B,H,M)	Yes (B,H,M)	Yes (B,H,M)
D-VAR	Inflation Man	Decrease (B,H,M)	Yes (B,H,M)	Yes (B,H,M)
	Inflation Serv	Decrease (B,M) / Increase (H)	No (B,H,M)	Yes (B,H,M)

H=Hamilton; M=Mork;B=Brent

Table 1.6

Table 1.6 synthesizes how changes across subperiods the IRF to oil price innovations of ΔGDP and Π at both aggregate and the sectorial level. At the aggregate level, there is a clear evidence of a large weakening of the effect of oil price innovations on the economy. Indeed, the size and the statistical significance of the IRFs to oil price innovations of both ΔGDP^{SA} and Π^{SA} (fig. 1.14) get reduced in the post-1980s' subperiod. In particular, the response of ΔGDP^{SA} in the 'post-1980s' subperiod becomes statistically not significant at any horizon for any of the three oil price measures.

At the sectorial level, instead, the weakening of the effects of oil innovations is less evident (figure 1.15-1.19). Indeed, while on one side the IRFs to oil price innovations of both Π^T and ΔGDP^T get reduced in the size when estimated in the 'post-1980s' subperiod, on the other there is not loss of statistical significance at the trough response of ΔGDP^T (apart for Hamilton measure) or at the peak response of Π^T.

The case of the non-traded sector is even more interesting. The response of ΔGDP^N gets reduced in size in the 'after 1980s' subperiod only for one oil price measure out of three. Moreover, the IRF of ΔGDP^N becomes statistically significative at the trough in the 'after 1980s' subperiod when the Brent measure is used. Similarly, the response of Π^N also becomes statistically significant at the peak when estimated in the 'post 1980s' subperiod, and for any oil price measure, even though the size of the response gets reduced for two oil-price measure out of three.

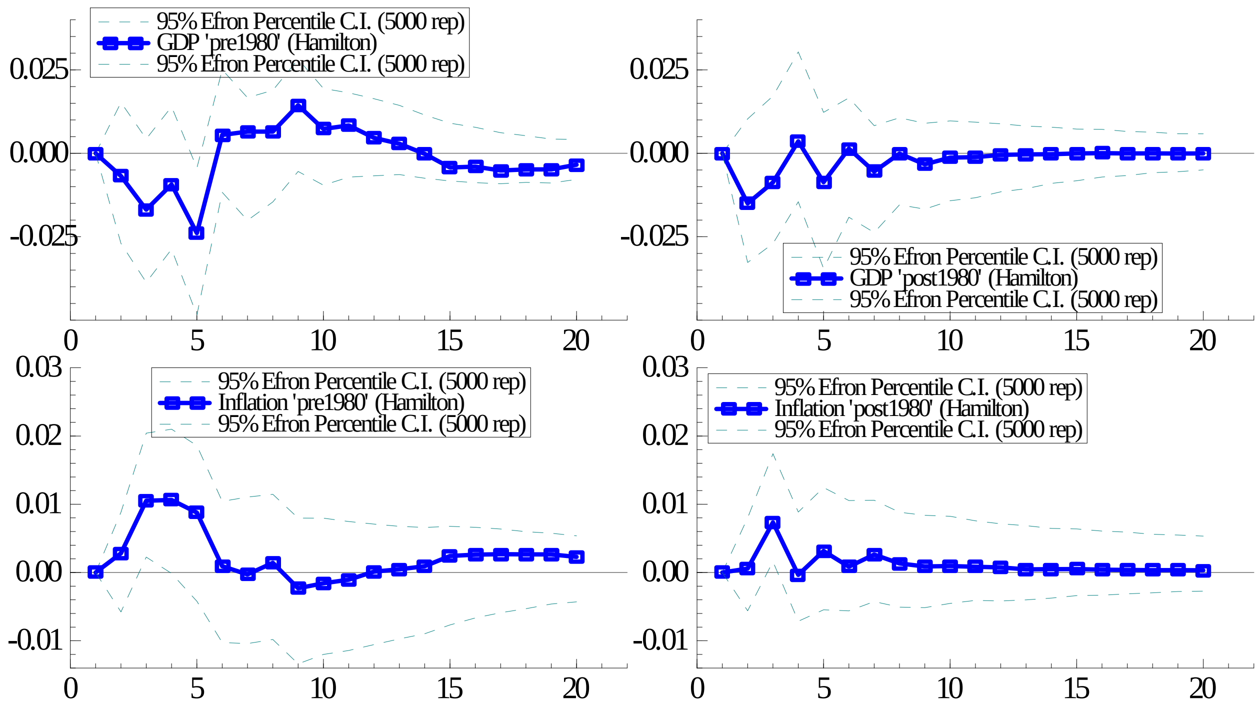

Figure 1.14 - IRFs of ΔGDP and ΔGDP in the 'pre-1980' and 'post-1980s' subperiod (Hamilton)

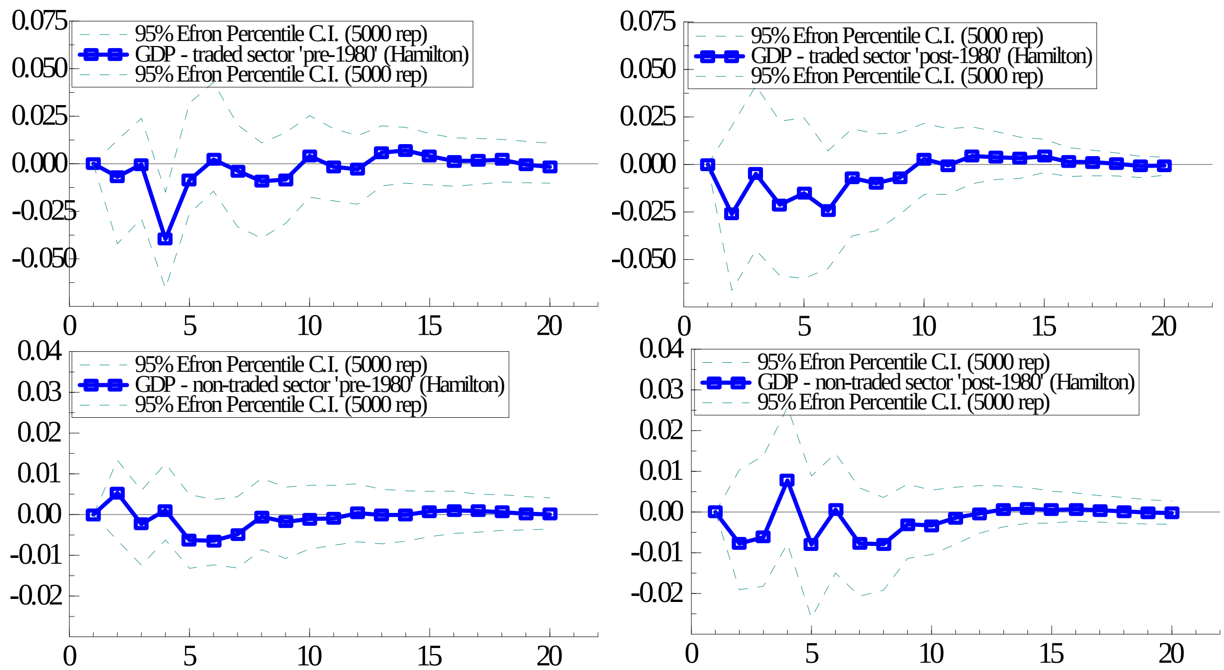

Figure 1.15 - IRFs of ΔGDP^T and ΔGDP^N in the 'pre-1980' and 'post-1980s' subperiod

(Hamilton)

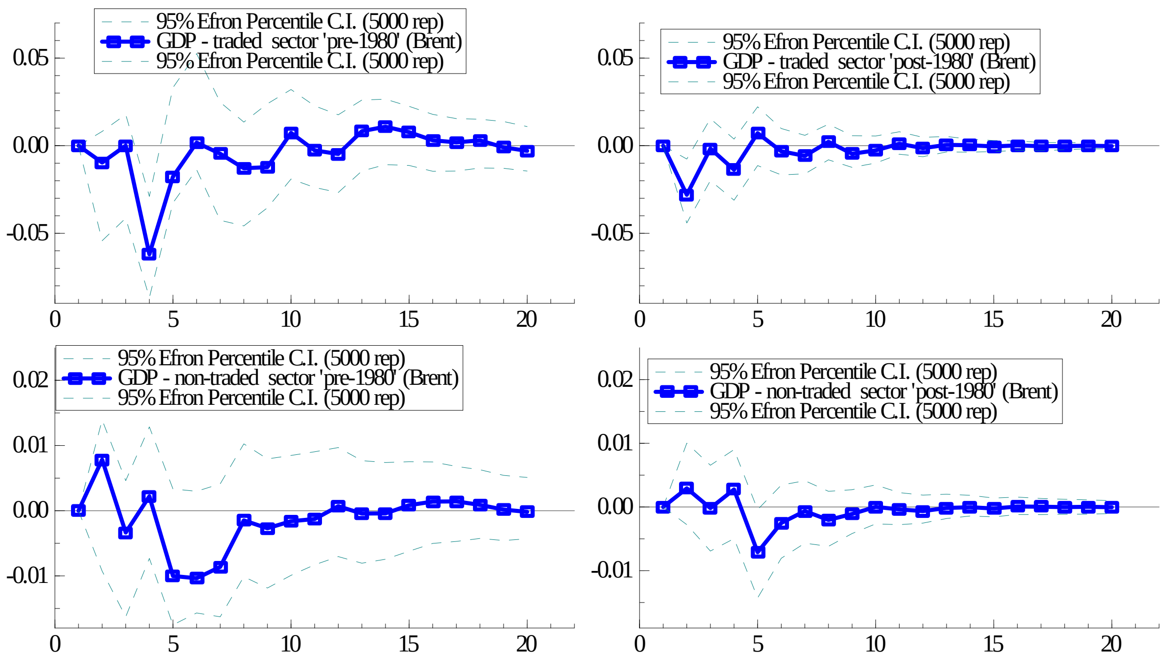

Figure 1.16 - IRFs of ΔGDP^T and ΔGDP^N in the 'pre-1980' and 'post-1980s' subperiod (Brent)

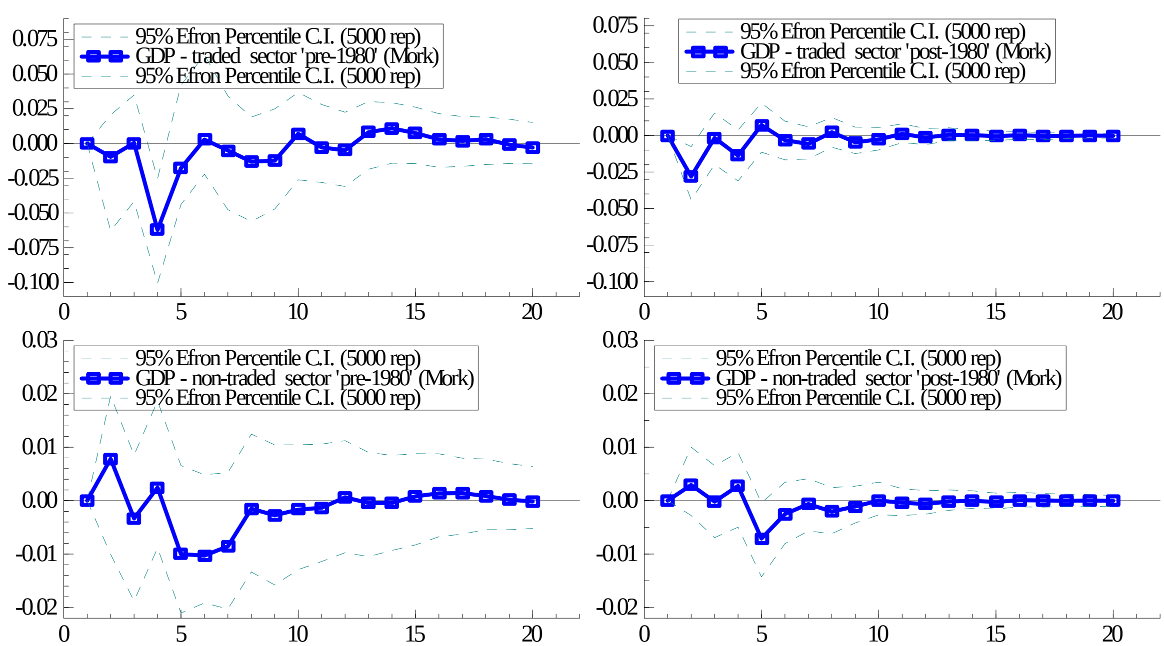

Figure 1.17 - IRFs of ΔGDP^T and ΔGDP^N in the 'pre-1980' and 'post-1980s' subperiod (Mork)

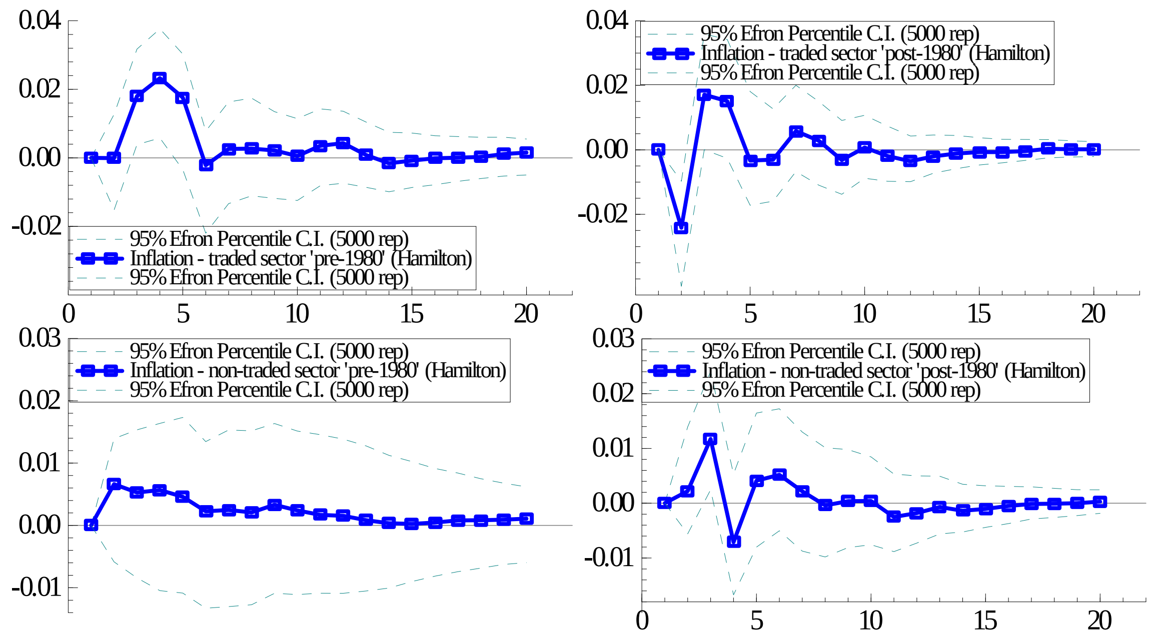

Figure 1.18 - IRFs of Π^T and Π^N in the 'pre-1980' and 'post-1980s' subperiod (Hamilton)

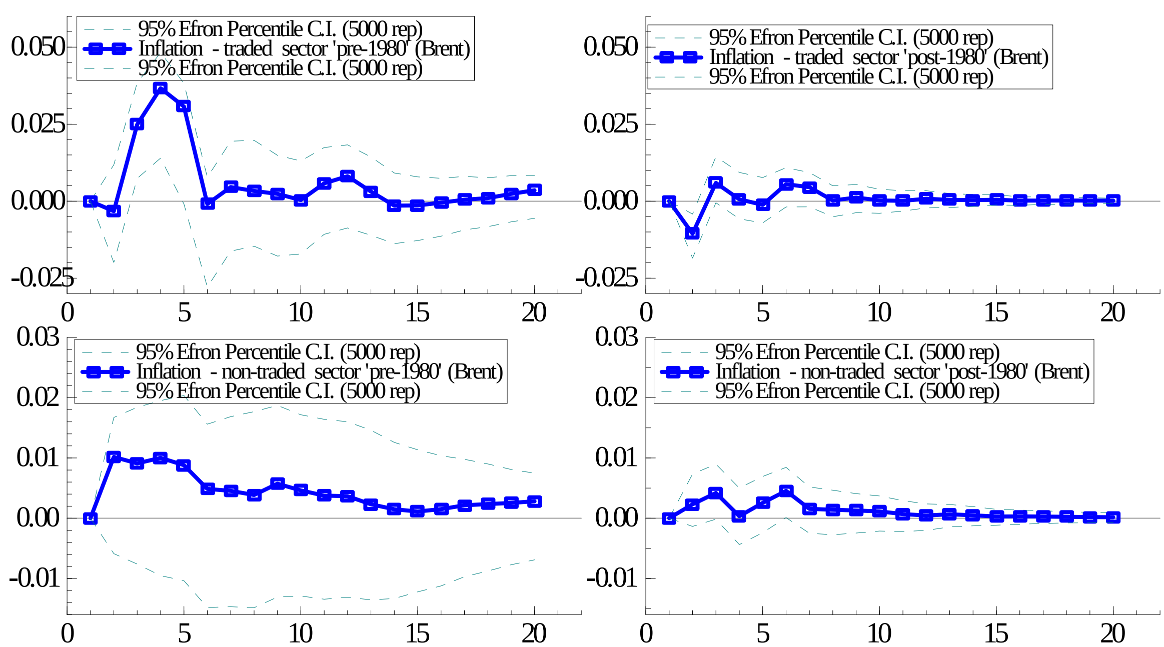

Figure 1.19 - IRFs of Π^T and Π^N in the 'pre-1980' and 'post-1980s' subperiod (Brent)

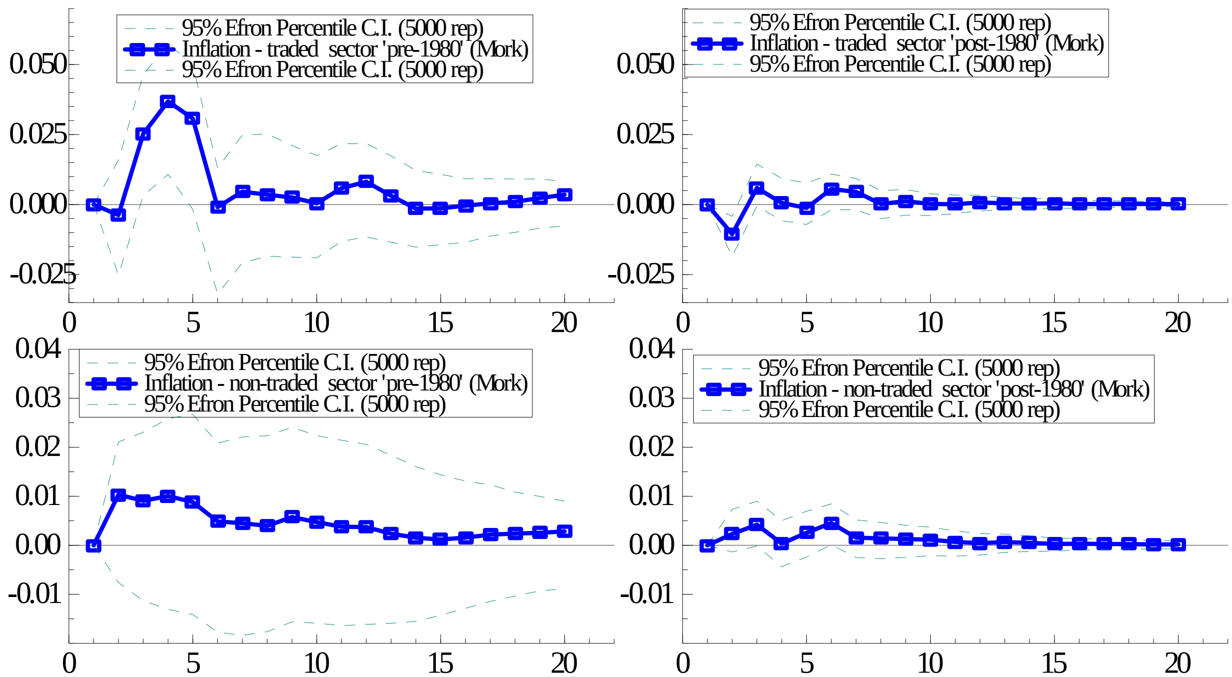

Figure 1.20 - IRFs of Π^T and Π^N in the 'pre-1980' and 'post-1980s' subperiod (Mork)

1.5 Conclusions

The main results emerging from my analysis are three. First, I provide evidence that the effects of oil price innovations on both the sectorial ΔGDP and Π are larger in the traded good sector than in the non-traded good sector.

Second, I show that while data reject a linear relationship between oil and the traded good sector they cannot reject a linear relationship between oil and the non-traded good sector.

Third, I show that the weaker effects of oil price innovations on the responses of both ΔGDP and Π are more evident at the aggregate than at the disaggregate level. I then argue that data do not reject the possibility of a composition effect at work, that is that the increase of the GDP share of the non-traded goods sector contributes to partially explain the weakening of the oil-macroeconomy relationship in the US.

Appendices

1.A: Computing the time series of the markup

$$\hat{\mu}_t^i = \frac{e - \mu s_k}{e - e\mu s_k}\hat{y}_t^i + \frac{(1-e)\mu s_k}{e - e\mu s_k}\hat{k}_t^i - \frac{\mu s_H}{1-\mu s_k}\hat{h}_t^i - \hat{w}_t^i \ ; \ i = T, N \ ,$$

where μ is the markup, e is the input elasticity of substitution between capital and labor, s_k and s_H are, respectively, the labor and the capital share of value added, h stands for the number of hours worked, w is the real wage, and$i = M$ stands for traded good sector while $i = S$ stands for Services and $t : 1947 \longrightarrow 2003$. A Hodrick-Prescott filter is then applied to extract the business cycle component from the time series.

I need to assume some values for the steady state markup (μ) and the elasticity of input substitution (e). As pointed out by Woodford and Rotemberg (1996), it is extremely difficult to calibrate the elasticity of input substitution (e). The difficulty arises from the fact that the elasticity may vary according to the temporal horizon considered and the assumed production function. For example, a putty-clay production function requires an elasticity of substitution lower in the short run than in the long run, while the assumption of cyclical capital utilization implies exactly the opposite. As there is no agreement on the right value I opt for estimating the time series for the markup under different values of e, notably $e \in$ [0.75, 1, 1.25].

As to the steady state value for the markup I estimate it for both sectors following Hall (1988). The two sectorial estimates of the markup are fairly close. Thus, I consider a common value for both sectors equal to μ =1.55. I perform the analysis for three possible values of the input elasticities but I report the results only for the case of e=1.25, as by changing the value of the input elasticity the results do not change much. Notably, since markup fluctuations are reduced with larger values of e, the results that I report are the most conservative, that is they are those for which the fluctuations in the markup are the smallest.

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CHAPTER 2

A THEORETICAL EXPLANATION OF THE DECREASING IMPACT OF OIL SHOCKS ON US GDP

2.1 Introduction

Over the last decades the effects of oil shocks on US economic activity have been decreasing. This phenomenom, which is commonly defined as the weakening of the 'oil-macroeconomy' relationship, has then been variously explained either emphasizing the role of monetary policies, or that of more efficient technologies, or as a consequence of the "great moderation, as it is commonly labelled the global trend of large reduction in business cycle volatility.

In this paper I ask whether and to what extent a change in the sectorial composition of GDP may explain the decreasing impact of oil shocks on economic activity. Two empirical pieces of evidence motivate this analysis. Firstly, the increase of the GDP share of the non-traded good sector at the expense of that of the traded good sector over the last decades. Secondly, the fact that the non-traded goods sector is less sensitive to the effects of oil shocks than the traded good sector:

The analysis is based on a two-country, two-sector model, with traded and non-traded intermediate goods which are produced with oil, labor and sector-specific capital. The model is then able to reproduces the larger impact of oil price shocks on the traded good sector through consumption smoothing. In particular, for this result to hold I assume that the investment good is composed only of traded goods, while the consumption good is composed of both traded and non-traded goods.

I then use the model to perform an experiment in which I analyse if an increase of the GDP share of the non traded good sector changes the way oil shocks affect the economic activity. In order to reproduce this structural change I refer to the two mechanisms which the literature puts forward: the 'utility-based' and the 'unbalanced productivity growth' (UPG) mechanism. The first mechanism is based on the idea that the increase of GDP share of the non-traded good sector is induced by households preferences. The second mechanism, instead, relies on different growth rates of total factor productivities (TFP) across sectors, which in turn induce an increase of the share of the slowest-growing sector

To perform the experiment based on the UPG mechanism it is necessary to determine some constraints on the demand side of the economy which must be fulfilled in the model, other than understanding how in the model the oil-macroeconomy relationship is directly affected by increasing TFPs. In order to find an analytical answer to these two problems I set-up a basic model which allows for a closed form solution. I then show that the only demand condition which must be satisfied is that the elasticity of substitution between traded and non-traded goods be sufficiently small, namely below unity. Furthermore, I find that in an international framework it is a sufficient condition that a UPG mechanism be at work abroad to experience a structural change domestically a change in the sectoral composition of the economy. Finally, I contribute to the debate on the effects of technological progress on the oil-macroeconomy relationship by showing that with Cobb Douglas technology the oil price elasticity of GDP is not affected by changes in total factor productivities.

The experiment, for both mechanisms, shows that the increase of the GDP share of the non traded good sector has a marginal explanatory power for the weakening of the oil-macroeconomy relationship, which in turn is mainly caused by the induced reduced size of international spillovers.

The paper is organised as follows. Section 2 presents the relevant literature. Section 3 presents the model. Section 4 describes the experiment and presents results. Section 5 concludes.

2.2 Literature

Hooker (1996) and Hamilton(1996) first highlighted that the effects of oil shocks on US economic activity have weakened after the 1980s, an evidence that has been confirmed by Hooker (1999), Loungani and Yücel (2000), Brown and Yücel (1999) and Blanchard and Galì (2007).

The literature has then offered different theoretical explanations. A first argument, referred to here as the oil-intensity argument, is based on the idea that the technological progress, by reducing the oil intensity, that is the quantity of oil which is required to produce a unit of output, has in turn weakened the effect of oil shocks on economic activity (Brown and Yücel 1995, Pomarantz and Robber 2005, Blanchard and Galì 2007). In this respect, Pomarantz and Robber (2005) provide evidence that oil intensity has declined in all G-7 countries, with the US, for example, requiring a quarter less of oil per unit of output in 2003 than it did in the early1980s. However, the effective relevance of the oil-intensity argument is debated in the literature: Bohi (1991), for example, does not find any statistically significant evidence that the most oil-intensive industries are those most affected by oil price shocks in the 1970's.

Loungani and Yücel (2000) and Brown (2000), argue that the disruptive effects of the large oil price increase in the 1990s has been reduced by the contemporaneous verifying of both a strong productivity growth in the US and a strong global GDP growth expansions.

A third argument explains the weakening of the oil-macroeconomy relationship focusing on the interaction between monetary policy and oil price shocks. Some authors (Bohi 1991, Bernanke et al. 1997, Blanchard and Galì 2007) argue that the recessive effects of positive oil price shocks are principally due to the restrictive response of monetary policy. Thus, they attribute the weakening of the oil-macroeconomy relationship to a better conduct of the monetary policy, which learnt how to react to oil price shocks after the dramatic experience of the 70's and 80's. [1] In the opposite direction move Hamilton and Herrera (2000) and Leduc and Sylvain (2005), who instead challenge the view that monetary policy is key element in the mechanism of propagation of oil price shocks.

Hooker (1996) and Lee et al. (1996) explore the possibility that the weakening of the effects of oil shocks on US economy be the result of a statistical breakdown in the oil-macroeconomy relationship and try to reestablish it focusing on mismeasurement problems. Hooker considers three sources of mismeasurement: the uneven distribution of oil price shocks over the sample period, the endogeneity of the price of oil after 1973 and the occurrence of structural shocks in many US macro series. He concludes that even taking into account these sources of mismeasurement it is not possible to reestablish a stable oil-macroeconomy relationship over all the sample period. Lee et al. instead show that once the sharp increase of the oil price volatility in the 1980s is taken into account, it is possible to reestablish a stable oil-macroeconomy relationship over all the sample period.

Finally, the weakening of the oil-macroeconomy relationship is also interpreted in connection to the 'great moderation', with the increasing flexibility of labor markets and the deepening of international financial markets regarded as principally causes of both phenomena.

Empirical evidence on the increasing GDP share of the non traded good sector is reported, among others, by De Gregorio et al (1993). In general, this is a consequence of the increase of the GDP share of services (i.e. Kravis 1983, Kuznets 1966, Maddison 1980), which, to a rough approximation, represent the main component of the non-traded goods sector (i.e. Canzoneri et al 1996, Kravis et al. 1982). Empirical evidence of oil price shocks producing different effects on the non-traded and the non-traded goods sector is provided by

[1] Hooker (1999), for example, argues that when Volcker took over the chair of the Federal Reserve the monetary policy become less accommodating to oil price shocks than in the past and no longer triggered expectations of higher inflation.

Maravalle (2007). Finally, theoretical explanations of the mechanisms behind the increase of the GDP share of non-traded good sector are in Baumol (1967), Baumol et al. (1985), Ngai and Pissarides(2004), and De Gregorio et al (1993).

2.3 The baseline model

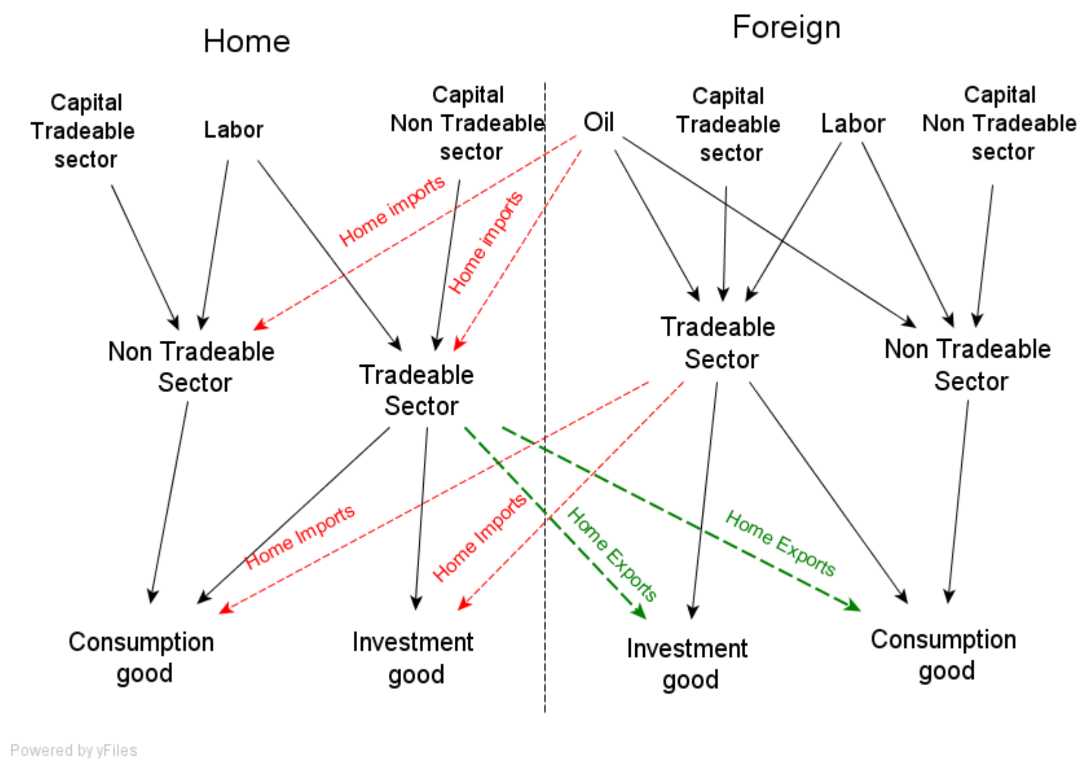

Figure 2.1 - Structure of the model

Figure 2.1 presents the structure of the two country, two-sector model which is a modified version of Pesenti (2003). The two countries, Home and Foreign, are inhabited by infinitely-lived households and are symmetric in every respect except for oil that is a Foreign-specific resource but whose price (P_e) is denominated in Home currency. Each country is composed of a competitive final good sector and a monopolistic competitive intermediate sector. The intermediate sector produces differentiated varieties of traded and non-traded goods through a CES production function which uses labor, capital and oil as inputs. The final good sector produces the consumption good by aggregating domestic and foreign traded goods and domestic non-traded goods. Labor is mobile within the country and immobile across countries. Capital is a sector-specific input that is complementary to oil.

Households can trade in country specific contingent bonds, so that perfect risk sharing is assumed within each country. In addition, households share the same preferences and have the same initial level of wealth (or identical budget constraint), therefore it is possible to assume a representative agent within each country. The characterization of the financial market is then completed with the introduction of a domestic and an international one-period riskless bond, with the latter denominated in Foreign currency. However, in such a framework any shock affecting the real interest rates would also change the steady state of the economy, implying a virtual loss of significance of the approximation to the steady state. The problem is overcome by the introduction of financial transaction cost (Pesenti 2003, Benigno 2004, Erceg et al 2006) that Home households suffer when they hold the international bond.[2]

In what follow I present the detailed set-up of the model for the case of Home: the case of Foreign is almost perfectly symmetric I also follow the convention of marking with an asterisk Foreign prices and quantities.

2.3.1 Households

Population is normalised to 1, and a generic household j must decide the flow of Consumption (C_{t+i}), Investment (I_{t+i}), sector-specific capitals ($K_{H,t+1+i},\ K_{N,t+1+i}$), nominal wage ($W_{t+i}$), domestic Bond ($B_{t+1+i}$) and international Bond (B^*_{t+1+i}) to maximise the present value of the flow of instant utilities subject to the flow of intertemporal budget constraints and the laws of motion of sector-specific capital:

$$\underset{\left\{C_t,I_t,K_{t+1},W_t,B_{t+1},B^*_{t+1}\right\}}{Max} E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{\left(C_{t+i}(j)\right)^{1-\sigma}}{1-\sigma} + \tau \frac{\left(1-L_{t+i}(j)\right)^{1+\gamma}}{1+\gamma} \right],\ s.t.$$

$$\begin{aligned} & B_{t+i+1}(j) + \varepsilon_{t+i} B^*_{t+i+1}(j) - \varepsilon_{t+i} B^*_{t+i}(j)(1+i^*_{t+i})\left(1-\Sigma_{t+i}\right) - B_{t+i}(j)(1+i_{t+i}) \\ = \ & W_{t+i}(j)L_{t+i}(j) - P_{t+i}C_{t+i}(j) - P^I_{t+i}I_{t+i}(j) + R_{N,t+i}K_{N,t+i}(j) + R_{H,t+i}K_{H,t+i}(j) \\ & +\Pi^f_{t+i}(j) + \Pi^b_{t+i}(j) \end{aligned}$$

$$\begin{aligned} K_{H,t+i+1}(j) &= K_{H,t+i}(j)(1-\delta) + I_{H,t+i}(j) \\ K_{N,t+i+1}(j) &= K_{N,t+i}(j)(1-\delta) + I_{N,t+i}(j). \end{aligned}$$

$\beta \in (0,1)$ is the intertemporal discount factor, $\sigma > 0$ is the inverse of the intertemporal elasticity of substitution, $\gamma > 0$ and $\tau > 0$ characterize labor disutility, $\delta \in (0,1)$ is the

[2] In the literature there are other possibilities to correct for the stabilization of the steady state: Mendoza introduces an endogenous rate of preference ; Cardia (1991) assumes a finite probability of death so that the subjective discount rate becomes a function of financial wealth; Cole and Obstfeld (1991) adopt a specific kind of utility so that price flexibility automatically ensures perfect insurance of consumption.

depreciation rate, $P_{t+i}$is the price of a unit of consumption good C_{t+i}, P^I_{t+i} is the price of a unit of investment good I_{t+i}, i_{t+i} and i^*_{t+i} are the one period riskless nominal interest rates set by Home and Foreign monetary policy authorities, $R_{H,t+i}$ and $R_{F,t+i}$ are the nominal rates of return on capital in the traded and the non-traded goods sector, $B_{t+i+1}(j)$ is the value of the stock of Home bond held by household j, $B^*_{t+i+1}(j)$ is the value of the stock of international bond held by household j, ε_{t+i} is the nominal exchange rate, $\Pi^f_{t+i}(j)$ is household j share of profits of the intermediate sector and $\Pi^b_{t+i}(j)$ is household's j share of profits of the financial transaction sector.

Financial transaction costs, Σ_{t+i}, are defined as follows:

$$\Sigma_{t+i} = \phi^1_\Sigma \frac{\exp \phi^2_\Sigma(\varepsilon_{t+i} B^*_{t+i}/P_{t+i-1}) - 1}{\exp \phi^2_\Sigma(\varepsilon_{t+i} B^*_{t+i}/P_{t+i-1}) + 1},$$

and depend on $\frac{B_{t+1}}{P_{t+1}}$, the real value of the aggregate stock of international bond held by Home households at the beginning of the period $t+i$, and on the parameters $\phi^1_\Sigma > 0$ and $\phi^2_\Sigma \in [0,1]$.

Wage Setting Mechanism

The wage is set through a monopolistic competitive mechanism as each household supplies a differentiated labor input to wage-taker firms in the intermediate sector. It follows that in setting the wage each household takes into account the aggregate demand for its labor specific input $L_t(j)$:

$$L_t(j) = \int L^T_j(i^T) di^T + \int L^N_j(i^N) di^N L_t(j) = L_t \left(\frac{W_t(i)}{W_t}\right)^{-\theta_L}$$ [3]

By assuming that all firms share identical preferences over differentiated labor inputs, it is possible to assume that each firm uses a labor aggregator á la Dixit-Stiglitz:

$$L_t = \left[\int_0^1 L_t(j)^{1-\frac{1}{\theta_L}} dj\right]^{\frac{\theta_L}{\theta_L - 1}},$$

where $\theta_L > 1$ is the elasticity of substitution among differentiated labor inputs. The aggregate nominale wage W_t is defined as:

$$W_t = \left[\int W_t(j)^{\frac{1}{1-\theta_L}} dj\right]^{1-\theta_L},$$

[3]The labor demand for a differentiated labor inputs is obtained by solving the firms' problem of profit maximization in the intermediate sector.
$L_t(j) = \left[\int_T L_t(t,j)dt + \int_N L_t(t,n)dn\right]$

and is interpreted as the wage that minimizes the cost of a unit of aggregate labor L.

2.3.2 Firms

2.3.2.1 The Final Good Sector

The final good sector produces a consumption good and an investment good in a perfect competitive framework.

The consumption good

The consumption good C_t is a CES aggregator of an index of domestic non-traded goods (N_t) and of an index of traded goods (T_t):

$$C_t = \left(\omega_C^{\frac{1}{\rho_C}} T_t^{1-\frac{1}{\rho_C}} + (1-\omega_C)^{\frac{1}{\rho_C}} N_t^{1-\frac{1}{\rho_C}} \right)^{\frac{\rho_C}{\rho_C - 1}},$$

where $\rho_C > 0$ is the elasticity of substitution between T_t and N_t and $\omega_C \in (0,1)$ defines the proportion between T_t and N_t in C_t.

T_t is a CES aggregator of $H_{C,t}$ and $F_{C,t}$, which are aggregators of, respectively, differentiated Home and Foreign traded good varieties, and each variety is defined over a continuum index of unit measure:

$$\begin{aligned}
T_t &= \left(\omega_H^{\frac{1}{\rho_T}} H_t^{C\ 1-\frac{1}{\rho_T}} + (1-\omega_H)^{\frac{1}{\rho_T}} F_t^{C\ 1-\frac{1}{\rho_T}} \right)^{\frac{\rho_T}{\rho_T - 1}} \\
H_{C,t} &= \left[\int_0^1 H_{C,t}(h)^{1-\frac{1}{\theta_H}} dj \right]^{\frac{\theta_H}{\theta_H - 1}}, \quad F_{C,t} = \left[\int_0^1 F_{C,t}(f)^{1-\frac{1}{\theta_F}} dj^* \right]^{\frac{\theta_F}{\theta_F - 1}} \\
N_t &= \left[\int_0^1 N_t(n)^{1-\frac{1}{\theta_N}} dj \right]^{\frac{\theta_N}{\theta_N - 1}}.
\end{aligned}$$

$\rho_T > 0$ is the elasticity of substitution between H_t and F_t, and $\omega_H \in (0,1)$ defines the proportion between H_t and F_t in T_t. $\theta_H, \theta_F, \theta_N > 1$ are the elasticities of input substitution which determine the degree of substitutability across varieties in, respectively, T_t, $H_{C,t}$ and N_t.

P_t, is defined as the price index which minimizes the expenditure of one unit of the consumption; a similar definition applies to $P_{T,t}$, the price index of T_t :

$$P_t = \left[\omega_C P_{T,t}^{1-\rho_C} + (1-\omega_C) P_{N,t}^{1-\rho_C} \right]^{\frac{1}{1-\rho_C}}, \quad P_{T,t} = \left[\omega_H P_{H,t}^{1-\rho_T} + (1-\omega_H) P_{F,t}^{1-\rho_T} \right]^{\frac{1}{1-\rho_T}}.$$

The investment good

The investment good I_t is a CES aggregator of Home $(H_{I,t})$ and Foreign traded goods $(F_{I,t})$:

$$I_t = \left(\omega_I^{\frac{1}{\rho_I}} H_{I,t}^{1-\frac{1}{\rho_I}} + (1-\omega_I)^{\frac{1}{\rho_I}} F_{I,t}^{1-\frac{1}{\rho_I}} \right)^{\frac{\rho_I}{\rho_I - 1}},$$

where $\rho_I > 0$ is the elasticity of substitution between $H_{I,t}$ and $F_{I,t}$, and $\omega_I \in (0,1)$ defines the proportion between $H_{I,t}$ and $F_{I,t}$ in I_t.

$$H_{I,t} = \left[\int_0^1 H_{I,t}(h)^{1-\frac{1}{\theta_H}} dj \right]^{\frac{\theta_H}{\theta_H - 1}}, \quad F_{I,t} = \left[\int_0^1 F_{I,t}(f)^{1-\frac{1}{\theta_F}} dj^* \right]^{\frac{\theta_F}{\theta_F - 1}}.$$

$H_{I,t}$ and $F_{I,t}$ are aggregators of, respectively, Home and Foreign differentiated varieties of traded goods, where each variety is defined over a continuum index of unit measure. $\theta_H, \theta_F > 1$ are the elasticities of input substitution, and determine the degree of substitutability across differentiated varieties in, respectively, $H_{I,t}$ and $F_{I,t}$.

The price of a unit of investment good is defined as the price index which minimizes the expenditure of one unit of the investment good:

$$P_{I,t} = \left[\omega_I P_{H,t}^{1-\rho_I} + (1-\omega_I) P_{F,t}^{1-\rho_I} \right]^{\frac{1}{1-\rho_I}}.$$

2.3.2.2 The Intermediate Sector

The intermediate sector produces differentiated varieties of traded and non-traded goods in a monopolistic competition setting.

The traded goods sector

The traded good sector consists of an infinite number of firms of unit mass, indexed by $h \in (0,1)$. Each firm uses a Cobb Douglas technology to produce a differentiated variety of the traded good $(H(h))$ using capital ($K_T(h)$) Labor $(L_T(h))$ and oil $(e_T(h))$:

$$H_t(h) = Z_{T,t} \left(L_t(h) \right)^{(1-\alpha)} \left(\nu^{\frac{1}{\nu}} e_{T,t}^{\frac{1}{\nu}}(h) K_t^T(h)^{1-\frac{1}{\nu}} \right)^{\alpha}.$$

$Z_{T,t} > 0$ is the total factor productivity that is common to all firms in the traded good sector, $(1-\alpha)$ determines how total income is distributed between labor and the bunch of capital and oil, and $\nu > 1$ is a parameter which determines the degree of substitutability between capital and energy.. The Production of every variety h must satisfy the domestic demand $(H_{T,t}(h),\ H_{I,t}(h))$, and the foreign demand, $\left(H_{T,t}^*(h), H_{I,t}^*(h) \right)$:

$$H_t(h) = H_{T,t}(h) + H_{I,t}(h) + H^*_{T,t}(h) + H^*_{I,t}(h)$$

The non-traded goods sector

The non-traded goods sector consists of an infinite number of firms of unit mass, indexed by $n \in (0,1)$. Each firm uses a Cobb Douglas technology to produce a differentiated variety of the non-traded good $N(n)$, using Capital $(K_N(n))$, Labor $(L_N(n))$ and oil $(e_N(n))$:

$$N_t(n) = (Z_{N,t}L_{N,t}(n))^{(1-\alpha)} \left(\nu^{\frac{1}{\nu}} e_N^{\frac{1}{\nu}}(n) K_{N,t}(n)^{1-\frac{1}{\nu}}\right)^{\alpha}.$$

$Z_{N,t} > 0$ is the total factor productivity that is common to all firms in the non-traded good sector, $(1-\alpha)$ determines how total income is distributed between labor and the bunch of capital and oil, and $\nu > 1$ is a parameter which determines the degree of substitutability between capital and energy.

The aggregate labor demand for the j-th labor input

Cost minimization determines the i-th firm demand for the j-th differentiated labor service $L_t(i,j)$:

$$\min_{\{l_t(i,j)\}} \int_0^1 W_t(j) L_t(i,j) dj \text{ ; } s.t. \ L_t(i) = \left[\int_0^1 L_t(i,j)^{1-\frac{1}{\theta_L}} dj\right]^{\frac{\theta_L}{\theta_L - 1}}.$$

that leads to

$$L_t(i,j) = L_t(i) \left(\frac{W_t(j)}{W_t}\right)^{-\theta_L}$$

By aggregating over traded and non-traded good intermediate sector firms, it is possible to obtain the aggregate labor demand for the j-th differentiated labor input:

$$\int_T L_t(t,j)dt + \int_N L_t(j,n)dn = \left(\frac{W_t(j)}{W_t}\right)^{-\theta_L} \left[\int_T L_t(j)dt + \int_N L_t(n)dn\right] = L_t(i) \left(\frac{W_t(j)}{W_t}\right)^{-\theta_L}$$

2.3.3 Monetary Policy

Monetary policy is assumed to follow a Taylor rule

$$i_t = \rho_M \ i_{t-1} + (1-\rho_M)\,\Theta_\pi\,(\pi_t - \pi^*) + (1-\rho)\,\Theta_Y\,(Y_t - Y^*) + \varepsilon_{M,t}$$

$\rho_M \in (0,1)$ is the parameter which determines the degree of persistence of the interest rate. $\Theta_\pi, \Theta_Y > 0$ determine, respectively, how the monetary authority react to deviation of the inflation rate to the inflation target and to the output gap.

2.3.4 Aggregate resource constraint

By aggregating the budget constraint over households it is possible to define the current account of Home country as the sum of the Net factor payment and of the trade balance:

$$\begin{aligned} CA_t &= \varepsilon_t \left(B^*_{t+1} - B^*_t \right) = \underbrace{i^*_t \varepsilon_t B^*_t}_{NET\ FACTOR\ PAYMENT} + \underbrace{P_{H,t} H^*_t}_{EXPORTS} - \underbrace{P_{F,t} F_t - P_{e,t} e_t}_{IMPORTS} \\ H^*_t &= H^*_{C,t} + H^*_{I,t} \ , \ F_t = F_{C,t} + F_{I,t} \ , \ e_t = e_{N,t} + e_{H,t}. \end{aligned}$$

2.3.5 Exogenous processes

In the model there are five exogenous variables, the four total factor productivities $(Z_{H,t}, Z_{F,t}, Z_{N,t}, Z^*_{N,t})$ and the real price of oil $(P_{e,t})$. I assume that in logs they all follow a stationary AR(1) process with zero covariance across error terms:

$$E(\varepsilon_{k,t}, \varepsilon_{j,t}) = \left\{ \begin{array}{ll} 0, & k \neq j \\ \sigma_j, & k = j \end{array} \right\} , \quad for\ k, j \in (H, F, N, N^*, e) \, ,$$

$$\begin{pmatrix} \ln Z_{H,t} \\ \ln Z_{F,t} \\ \ln Z_{N,t} \\ \ln Z^*_{N,t} \\ \ln P_{e,t} \end{pmatrix} = \begin{pmatrix} \rho_H & 0 & 0 & 0 & 0 \\ 0 & \rho_F & 0 & 0 & 0 \\ 0 & 0 & \rho_N & 0 & 0 \\ 0 & 0 & 0 & \rho^*_N & 0 \\ 0 & 0 & 0 & 0 & \rho_e \end{pmatrix} \begin{pmatrix} \ln Z_{H,t-1} \\ \ln Z_{F,t-1} \\ \ln Z_{N,t-1} \\ \ln Z^*_{N,t-1} \\ \ln P_{e,t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{H,t} \\ \varepsilon_{F,t} \\ \varepsilon_{N,t} \\ \varepsilon^*_{N,t} \\ \varepsilon_{e,t} \end{pmatrix}$$

The price of oil

In the model the oil market is not explicitly modelled. In particular, the real price of oil is assumed to be exogenous, and at that price any quantity of oil that is demanded may be satisfied without inducing variations in the price. A possible interpretation of this horizontal oil supply is that oil is an unlimited resource that is produced in a perfect competitive market through a constant return to scale technology. It follows that the constant marginal cost is exogenously determined, so that it is possible to interpret an exogenous oil price shock as a supply shock. A consequence of this simplifying assumption is that the price of oil is not does not react to the interaction between demand and supply but only to (exogenous) supply shocks.

2.3.6 Parametrization of the baseline model

Table 1a - Assumptions about Parameters - Baseline Model		
Parameters	**US (Home)**	**Rest of the World (F)**
Intertemporal Discount Rate - β	0,9975	0,9975
Depreciation Rate on Capital - δ	0,025	0,025
Inverse of The Intertemporal Elasticity of Subst.- σ	2,00	2,00
Labor disutility parameter 1 - γ	2,00	2,00
Labor disutility parameter 2 - τ	1,00	1,00
Elasticity of Input subst. for Consumption - ρ_C	0,50	0,50
Elasticity of Input subst. for Intermediate Goods - ρ_T	2,00	2,00
Elasticity of Input subst. for Investment Goods - ρ_I	2,00	2,00
Elasticity of Subst. across Tradeable varieties - θ_H,θ_F	6,00	6,00
Elasticity of Subst. across Non-Tradeable varieties - $\theta_N,\theta_N^?$	6,00	6,00
Elasticity of Subst. across varieties of labor - $\theta_N,\theta_N^?$	6,00	6,00
Relative weight of Trad. in Cons.Good - w_c (w_{c*})	0,47	0,47
Relative weight of Trad. in Inv.Good - w_I	0,50	0,50
Proportion between H and F Trad. in Cons.Good - w_H (w_F)	0,50	0,50
Proportion between H and F Trad. in Inv.Good - w_I	0,50	0,50
Labor Share Income - (1-α)	0,66	0,66
Elast.of Subst. between Capital and Energy - υ	5,00	5,00
Financial Transaction cost parameter 1 - φ_Σ^1	0,80	NA
Financial Transaction cost parameter 2 - φ_Σ^2	1,50	NA
Degree of Persistence in Monetary Policy - ρ_M	0,00	0,00
Weight of Inflation Gap in Mon.Policy - Θ_π	0,00	0,00
Weight of Output Gap in Mon.Policy - Θ_Y	1,50	1,50
Steady-State Ratios	**US (Home)**	**Rest of the World (F)**
Number of hours worked in the day[1]	0,3	0,28
Ratio of traded to non-traded goods	43%	44%
Ratio oil costs-to-GDP	5,00%	4,50%
Consumption to GDP ratio	82%	82%

[1] The day is normalised to unity

Table 2.1 Parametrisation - Baseline Model

Table 2.1 lists the parameters and the values they assume in the baseline model. I adopt the following strategy in the parametrization. First, preference and technolgy parameters are set equal for Home and Foreign, so that oil price shocks may have asymmetric effects only because of asymmetries in the oil market, namely for oil being a foreign-specific resource whose price is denominated in home currency. Second, most parameters are set in the range of similar macro simulation analysis (i.e.Bayoumi, Laxton and Pesenti 2004, Smets and Wouters 2002, Erceg Guerrieri and Gust 2003), and only for a few specific parametriation is adopted. Finally, the parametrization also aims at matching some steady state ratios. In particular, as the main interest of the analysis is to observe how structural changes might have affected the propagation mechanism of oil price shocks after the 1970s, in the baseline model Home steady state values matche beginning of the 1970's US ratios. The steady state ratios that are taken into account in the parametrization are: the GDP weight of the traded good sector, the consumption -to-investment ratio, the share of GDP represented by the cost of energy and the number of hours worked as a fraction of the day. It follows below a parameter-by-parameter explanation of the values chosen.

The discount factor β is set equal to 0.9975, and the capital depreciation rate δ is set equal to 0.025, so that the steady state rate of return on capital is around 3.5%. The inverse of the intertemporal elasticities of substitution, (σ) is set equal to 2. In standard real business cycle theory this parameter is usually set close to 1, but it is usual to find greater values in similar analysis (1.5 in both Smets and Wouters 2002 and Bayoumi et al 2004), and empirical analyses suggest for the US large values for σ (Yogo 2000,Hall 1988 both conclude for value close to 5, Favero 2005).I then opt for a value of 2 that is in the middle of the ranges of possible values.

The parameters that define the degree of monopolistic power in the intermediate sector $(\theta_H, \theta_N, \theta_F, \theta_N^*)$, and those that determine the monopolistic power held by wage-setters (θ_L, θ_L^*), are assumed identical across countries and sectors, and suh that imply a markup of 20% over the marginal cost (for firms) adn the intratemporal labor-leisure substitution (for wage-setter). The parameters that define labor disutlity $(\gamma, \gamma^*, \tau, \tau^*)$ are set so that in steady state the number of hours worked is in the range 0.25 - 0.33.

The parameters that determine the relative composition of the consumption good between tradeable and non-tradeables (ω_C) are set equal to 0.47, so that the proportion between traded and non-traded goods of Home matches that of the US in the early 70's (around 41%, the average share over the period 1965-1976). I also set $(\omega_H, \omega_H^*, \omega_I, \omega_I^*)$ equal to 0.5 so that I assume no home bias in the use of domestic tradeables for the composition of both the consumption and the investment good.

The parameters which determine the elasticity of substitution between Home and Foreign traded goods in the investment and traded good aggregator $(\rho_I, \rho_I^*, \rho_H, \rho_H^*)$ are set equal to 2, a value in the middle of the range of previous macro simulation analysis .

The parameters that determine the elasticity of substitution between traded and non-traded goods in the consumption good $(\rho_C, \rho_C^*,)$ are set equal equal to 0.5. This choice is motivated by a demand-side requirement value of $(\rho_C, \rho_C^*,)$ lower than unity that has to be fullfilled for an unbalanced productivity growth mechanism to be able to increase the economc share of the slowest growing sector.[4]

The financial transaction cost parameters $\left(\phi_{\Sigma,1}, \phi_{\Sigma,2}\right)$ are set $\phi_{\Sigma,1} = 0.8$ and $\phi_{\Sigma,2} = 1.5$[5],and the values for monetary policy parameters are set as follows: $\rho_M, \rho_M^*, \Theta_Y, \Theta_Y^* = 0$, and $\Theta_\pi, \Theta_\pi^* = 1.5$.[6]

The GDP weight of the oil share is determined by (ν, ν^*), the technology parameters, and by α, that determines the share of output represented by the non labor income. α is set to the standard value of one third, and ν is set in order to have a value of the GDP oil share around 5%, which is the average value for the US over the period 1970-2004[7]. The persistence of oil price shocks ρ_{oil}, is set by estimating the an AR(1) process for the time series of the real oil price. I then set ρ_{oil} =0.9, which is the value corresponding to the lower end of the 95 percent confidence.[8]

The real price of oil is denominated in Home consumption units and is normalised to 1. Analogously, the parameters that define the total factor productivity at the sectorial level (Z_H, Z_F, Z_N, Z_N^*) are normalised to unity.

As the model cannot be solved in a closed form solution I approximate it around a steady state and solve the corresponding linear expectation model by mean of the Uhlig algorithm.

2.4 The Experiment

In order to verify whether and to what extent the increase of the economic share of the non-traded goods sector can weaken the oil-macroeconomy relationship I perform an experiment in which I induce a structural change in the model. I refer to the two mechanisms that the literature put forward to explain a structural change: the 'utility-based' and the 'unbalanced productivity growth'(UPG) mechanism. The first mechanism is based on the idea that the increase of the economic weight of the non-traded good sector is induced by households preferences. The second mechanism, instead, relies on different growth rates of

[4] This result is similar to that found by Ngai and Pissarides (2004), and respect the intuition of Baumol's claim about the need for a sufficient inelastic demand for the UPG to increase the share of the slowest-growing sector.

[5] I also tried other values, but the results of the experiment I perform are not sensitive to change in the values of these parameters.

[6] As the experiment is performed under price flexibility, the results are not affected by the specific parametrization of the monetary policy rule.

[7] The GDP oil share is computed by dividing the nominal consumer expenditure for Petroleum over nominal GDP (Table 3.5 from the Annual Energy Review 2006).

[8] The persistence of the oil price shock is relevant for the pattern of the response of the economy after an oil price shock. However, it is worth noting that the effects of the oil price shocks are really persistent even for lower values of the ρ_{oil} . This follows because of the assumption of sector-specific capital.

total factor productivities (TFP) across sectors, which in turn induce an increase of the economic weight of the slowest-growing sector

2.4.1 The case of the structural change induced by the 'utility-based' mechanism

The 'utility-based' mechanism grounds on the idea that the utility function has an higher income elasticity for non-traded goods rather than for traded goods. Therefore, the structural change derives ultimately from the shift of households' preferences towards non-traded goods as the income increases.

The utility function that I use in the model does not allow for different income elasticities across traded and non-traded goods, so I reproduce the shift of households preference towards non-traded goods by changing the composition of the consumption good (w_C, w_C^*). This modification causes increases the relative quantity of non-traded goods produced in the economy, but it does not affect the relative price of traded goods in terms of non-traded goods. However, the change in households' preferences also changes the steady state values of other variables.[9] Thus, to fully evaluate the relevance of the structural change itself I have to consider how the changes in the steady state values of the other variables affect the response of the economy to oil price shocks.

I first define the 'structural change' channel as the channel through which the increase of the GDP share of the non-traded goods sector directly affects the response of GDP to oil price shocks. The structural change weakens the effects of oil shocks on the economy through the reduction of the size of international spillovers, which instead tend to amplify the effects of global shocks across countries.[10]

The 'intratemporal condition' channel points out how the change in the steady state values of labor and consumption affects the oil-macroeconomy relationship. Indeed, as the

[9] The quantity of labor increases for Home and decreases for Foreign; the steady state value of the real exchange rate increases; the Home production of traded goods and the Foreign production of non-traded goods all increase; GDP and consumption in both countries decrease.To understand why the change in the composition of the consumption good produces these effects, we have to consider that the amount of oil which is required to produce a given quantity of home consumption good is independent on the composition of consumption itself between traded and non-traded goods (technology is identical across sectors). It follows that, ceteris paribus, the Home demand of oil imports is unaffected by the change in households' preferences, and so is its value in home currency. However, the more the consumption good is intensive in the non-traded good the lower is the demand, and the production, of both Home and Foreign traded goods. It follows that Home has to make up for the induced trade deficit by making its exports cheaper. Therefore, in the new steady state the real exchange rate has to depreciate (it is implicitly assumed that it holds an elasticity condition for which the value of Home exports increases relatively to the value of Home imports as the rela exchange rate depreciates).

[10] This effect is highlighted by the lower steady state value of the ratio of imports over GDP, this last being a measure of openness.

steady state values of labor and consumption vary, also the incentive for households to lower the wage to buffer the recessive effects of oil shocks changes. In particular, for the specific utility function that is adopted in the model, this incentive is modified solely by changes in the steady state values of labor. Because to higher steady state levels of laborl correspond a stronger incentive to reduce nominal wage after an oil shock, it follows that through the 'intratemporal condition' channel the structural change will make the effects of oil price shocks stronger for Home and weaker for Foreign.

Finally, the change in the steady state value of the real exchange rate affects the GDP response to oil shocks through two channels: the 'real exchange rate' channel and the 'consumption-investment ratio' channel. The first channel weakens the effect of oil price shocks on Foreign economic activity as the steady state value of the real exchange rate depreciates. This happens because the real the real price of oil, which is denominated in Home real terms, becomes cheaper for Foreign as the exchange rate depreciates.

The 'consumption-investment ratio' channel, instead, highlights how an the depreciation of the real exchange rate strengthens the effect of oil shocks on Home economy and weakens that on Foreign economy. This happens because the real exchange rate depreciation induces a change in the relative sectorial productions across countries. In particular, the ratio of investment to consumption increases for Home and decreases for Foreign.[11] As the investment is more volatile than consumption, the 'consumption-investment ratio' channel increases the sensitivity of Home economy to oil price shocks and decreases that of Foreign.

To sum up, when I change the composition of the consumption good there are more channels at work which contribute to modify the response of GDP to oil price shocks. Table 2.2 reports how the change in Households' preference affect these channels (either strengthens or weakens them) and the effect of every channel on the GDP response to a positive oil price shock (increases or reduce it).

[11] The fact that Home traded goods become relatively cheaper increases their relative production with respect to Foreign traded goods. On the other hand, Foreign exploits its terms of trade gain by increasing its relative production of the non-traded goods. Thus, also the distribution of capital across sectors in both countries changes. A higher value of the real exchange rate goes with a relatively increase of the Home capital stock in the traded good sector, and with a relatively increase of the Foreign capital stock in the non-traded good sector.

Table

	How the GDP response to oil price shocks is affected by the channels	
	Home	Foreign
The intratemporal condition channel	Reduces the GDP response	Reduces the GDP response
The real exchange rate channel	-	Reduces the GDP response
The structural change channel	Reduces the GDP response	Reduces the GDP response
The consumption-investment ratio channel	Increases the GDP response	Reduces the GDP response
	The effect of the change in Households' preferences on the strenght of the channels	
	Home	Foreign
The intratemporal condition channel	Stronger	Weaker
The real exchange rate channel	-	Stronger
The structural change channel	Stronger	Stronger
The consumption-investment ratio channel	Stronger	Stronger

Table 2.2 - How the GDP response to oil price shocks is affected by the different channels and how the strength of the channels is affected by the structural change

Table

	Home		Foreign	
Share of the non-traded	41% -> 55%		44% -> 56%	
Openness Ratio	32% -> 26%		29% -> 23%	
Period	GDP response (1)	GDP response (2)	GDP response (1)	GDP response (2)
1	97,6%	97,48%	94,40%	93,4%
2	98,8%	98,33%	95,76%	93,6%
3	98,8%	98,33%	95,70%	93,7%
4	98,8%	98,34%	95,70%	94,0%
5	98,8%	98,34%	95,71%	94,3%
6	98,7%	98,35%	95,72%	94,6%
7	98,7%	98,35%	95,74%	94,9%
8	98,7%	98,35%	95,75%	95,3%

(1) Amount of hours worked unconstrained

(2) Amount of hours worked fixed

Table 2.3 - The effect of the change in households' preferences on the GDP response to oil price shocks

Table 2.3 presents results from the experiment. In particular, the composition of the consumption good is changed so that the Home share of the non-traded good sector passes from the steady state value of 41% (average US value in the early 1970s) to that of 55% (average US value in the early 2000s).

The table shows the first 8 periods of the GDP response to oil price shocks after the structural change in percent points of the GDP response obtained before it. Thus, a value of 98% means that after the change in households' preferences the effect of a positive oil shock on GDP is 2% weaker than before the change. In particular, the GDP response that is reported in the first column is the one resulting from the interactions of all the channels (unconstrained case), while the one reported in the second column is the one obtained by fixing the amount of hours worked (constrained case). I decide to fix the amount of hours worked in the two economies to follow the empirical evidence that the amount of labor employed in the economy is stable over time. Moreover, the unconstrained experiment also cancels the 'intratemporal condition' channel and reduces the influence of the others, therefore allows me to focuse more strictly on the effects of the 'structural change' channel.

In general the change in households' preferences weakens the effect of oil price shocks in both countries, but the size of the reduction is small in size. In particular, the reduction is the largest on impact, which corresponds to the through of the response of GDP, and it is slightly higher for Foreign. However, the change in households' preferences is able to explain only a small reduction of the effects of oil price shocks on GDP.

2.4.1.1 The role of the numeraire

In the previous experiment I do not take into account the fact that by varying the composition of the consumption good I also change the numeraire of the economy. To check whether this might distort the previous result, I repeat the experiment with the investment good as the numeraire, as its composition does not change in the experiment.

Table 2.4 shows the results. By changing the numeraire the weakening of the 'oil-macroeconomy' relationship appears to be more evident, especially on impact when the recessive effects of oil shocks are the largest. Moreover, the reduction of the effects of oil shocks on GDP is stronger for Foreign than for Home. [12] In particular, on impact the effect of the oil shock on Home GDP gets reduced by 12-15% and that on Foreign GDP by 20-23%, with the following periods showing a reduction in the range of 5-7% for Foreign and almost

[12] These two results are closely related to the 'consumption investment ratio' channel which becomes stronger with the investment good as a numeraire. In fact, with the investment good as the numeraire it follows that the change in the relative price between consumption and investment applies to the consumption, which represent 80% of total GDP in the steady state.

no change (constrained case) or even an increase for Home (unconstrained case).

Table

	Home		Foreign	
Share of the non-traded	41% -> 55%		44% -> 56%	
Openness Ratio	32% -> 26%		29% -> 23%	
Period	GDP response (1)	GDP response (2)	GDP response (1)	GDP response (2)
1	88,12%	85,35%	76,2%	79,8%
2	103,05%	99,92%	93,4%	95,4%
3	102,77%	99,75%	93,4%	95,4%
4	102,65%	99,71%	93,4%	95,5%
5	102,53%	99,66%	93,4%	95,5%
6	102,40%	99,61%	93,5%	95,6%
7	102,25%	99,55%	93,5%	95,7%
8	102,08%	99,49%	93,5%	95,8%

(1) Amount of hours worked unconstrained

(2) Amount of hours worked fixed

Table 2.4 - The effect of the change in households' preferences on the GDP response to oil price shocks

2.4.2 The case of a structural change induced by the 'unbalanced productivity growth' mechanism

Baumol (1967) first conjectured that different growth rates of total factor productivity (TFP) across sectors, or 'unbalanced productivity growth' (UPG), would cause the slowest-growing sector to increase its relative economic weight. Table 2.4 presents the rate of growth of both labor and total factor productivity of Manufacturing, non-Manufacturing and Non-Farm business in the US. It is evident that the growth rate of productivity of Manufacturing has been far larger than that of the other two sectors over the period 1973-1996. Thus, as Manufacturing represents the main component of the traded good sector, it is then plausible to argue that US might have experienced a structural change through a UPG mechanism, with the non-traded good sector as the slowest-growing sector.

I then check whether in the model a structural change induced by the UPG mechanism might explain the weakening of the oil-macroeconomy relationship. However, for the UPG mechanism to produce a structural change in this model I need to consider two factors: I have to find what demand conditions the model has to satisfy and I have to check if the increase in TFPs directly reduces the effect of oil shocks on economic activity through the reduction in oil intensity.

Table

Output per Hour	Non-Farm Business	Manufacturing	Estimated non Manufacturing
1949-73	2,8	2,6	3
1973-96	1,5	2,7	1
Multifactor productivity	Non-Farm Business	Manufacturing	Estimated non Manufacturing
1949-73	1,9	1,5	2,1
1973-96	0,2	0,8	0

Source: Triplett and Bosworth (2001)

Description: U.S. Labor and Multifactor productivity, Average Annual Rates of Change, 1949-96

Table 2.4 - U.S. Labor and Multifactor productivity, Average Annual Rates of Change, 1949-96

To do this, I extend the two-country model by Corsetti and Pesenti (2005) in two ways: I comnsider two sectors, the traded and the non-traded good sector, and introduce oil as an additional input factor other than labor. The model remains simple enough to allow me to obtain a closed form solution, so that I can derive analytically both the demand conditions for the UPG to increase the share of non-traded goods, and the direct effect of increasing TFPs on the oil price elasticity of GDP. The model is reported in details in the appendix, in what follows I only briefly present the main results.

I find that a sufficient condition for the UPG mechanism to increase the share of the non-traded good sector (which is assumed to be the slowest-growing sector) is that the elasticity of substitution between traded and non-traded goods in consumption is lower than unity.[13]

To get an intuition on the interpretation of this condition we have to consider that the UPG produces two effects. The first effect is to increase the price of the non-traded good in terms of both the traded and the consumption good, which obviously increases the share of GDP represented by the non-traded good sector. I define this effect as the price effect. The second effect, which I define as the quantity effect, is the expenditure switching from the non-traded to the traded good sector which is induced by the change in the relative price.

The elasticity of substitution between traded and non-traded goods then determines which one of the two effects will prevail. In particular, only if teh elasticity is below unity the quantity effect will be smaller than the price effect.

Finally, I also find that a sufficient condition for the domestic share of the non-traded good to increase is that the UPG occurs abroad, that is that the growth rate of productivity of the foreign traded good sector is higher than that of the foreign non-traded good sector.

[13] This result is similar to that found by Ngai and Pissarides (2004), and respect the intuition of Baumol's claim about the need for a sufficient inelastic demand for the UPG to increase the share of the slowest-growing sector.

2.4.2.1 The effect of Total Factor Productivity increases on the oil-macroeconomy relationship

The quantity of oil per-unit of output has been reducing over the last decades because of the adoption of more efficient technologies. However, I argue that not any technological progress automatically implies a reduction in the oil price elasticity of GDP, that is a weaker effect of oil shocks on GDP. In particular, I consider the case of an increase of the TFP. On the one hand, an higher TFP implies an higher marginal productivity, which reduces the quantity of oil per unit of output; on the other hand, the higher marginal productivity means that the reduction of one unit of oil in the production will cause a larger drop in the quantity of output produced. It is then not clear whether and how an increase in TFP would change the way oil shocks affect output.

I use the former model to show analytically that with a Cobb Douglas production function the oil price elasticity of GDP depends on technological parameters which are not affected by a change in the TFP. As in the baseline model I also adopt Cobb Douglas technology, it follows that even if the UPG mechanism requires an increase in TFPs to produce the structural shocks, I will expect the higher values of TFPs to have no direct effects on the way oil shocks affect GDP.

I then check for the validity of this conjecture by performing the following experiment: I compute the response of GDP to a positive oil price shock before and after increasing the TFPs of any sector and country in the same proportion, and then verify whether and how the increase in TFPs affect the oil price elasticity of GDP elasticity.

I notice that as I increase the TFPs the most relevant changes are in the steady state values of labor employed and in the relative prices of input factors.[14] In the attempt to isolate as much as possible the direct effect of the increase of TFPs on the oil price elasticity of GDP I also perform the experiment by constraining the steady state value of hours worked not to change (constrained case). Indeed, the lower level of steady state hours worked makes the wage-setters less willing to lower the wage after a positive oil price shock, so that I expect the effect of oil shocks on GDP to increase in the unconstrained case.

[14] An increase of the TFPs induce an increase in the relative use of capital and energy with respect to labor, because the real price of energy and the rate of return on capital do not change in the new steady state, while the real wage increases. The real price of oil does not change because it is exogenous. The rate of return on capital does not change because it depends on the real price of investments, which is not affected by changes in the TFPs that are proportional across countries and sectors. Instead, the real wage tends to rise because of both the increase in the marginal productivity of labor and the fact that leisure and consumption are normal goods, so that households find optimal in the new steady state to work less and consume more with a higher real wage.

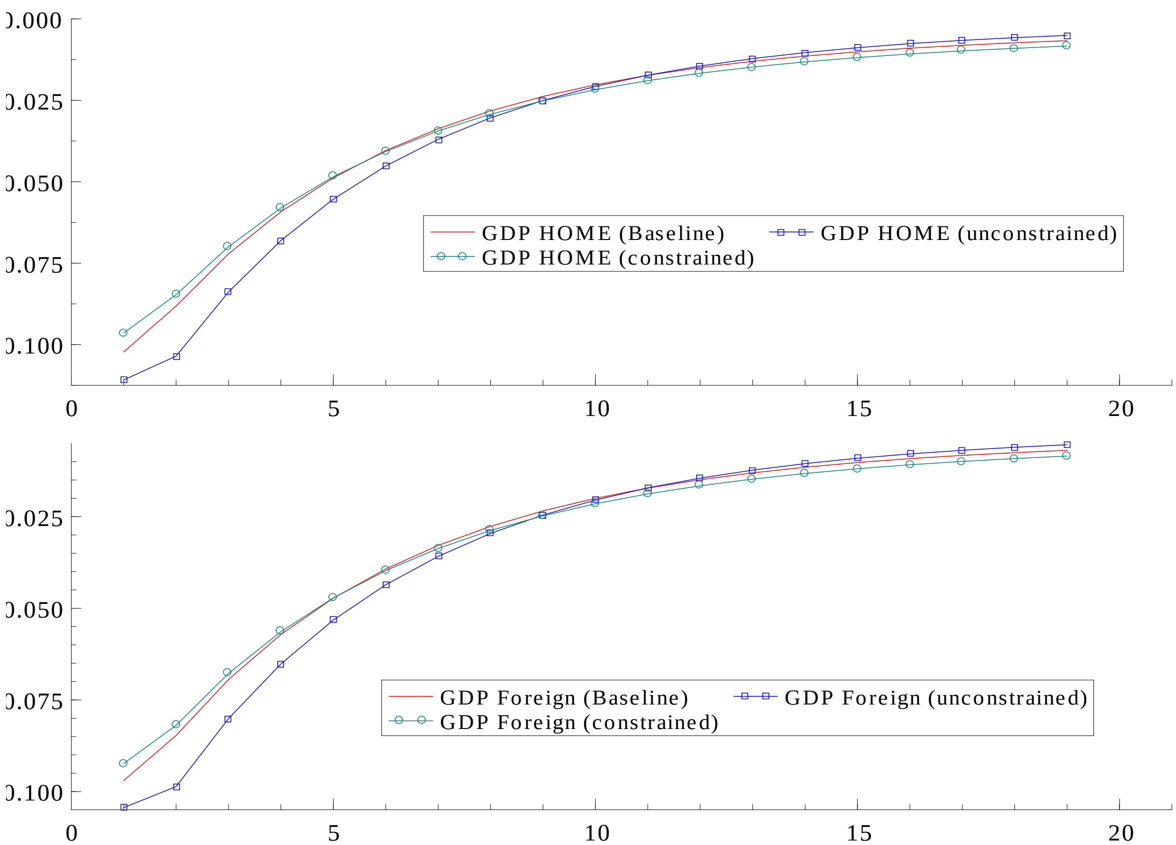

Figure 2.2 - The Home and Foreign GDP response to positive oil price shock when the Total Factor Productivity increases.

Figure 2.2 shows the response of both Home (top panel) and Foreign GDP (bottom panel) to a positive oil price shock in the unconstrained and constrained case. In both countries, the increase of TFPs in the unconstrained case augments the effect of oil price shocks on GDPs at any period, as it was expected. Instead, in the constrained case there is almost no change in the response of Home GDP to positive oil price shocks as TFPs increase. The Foreign GDP response, instead, varies even in the constrained case because the real exchange rate channel is at work.

I conclude that this experiment is in favor of the result of neutrality of oil price elasticity of GDP with respect to changes in TFPs even for the baseline model.

2.4.2.2 The effect of unbalanced productivity growth (UPG) on the oil-macroeconomy relationship

In the following experiment I verify whether a structural shock induced by the UPG mechanism may cause a weaker response of the economic activity to oil price shocks. I reproduce the structural shock induced by the UPG mechanism by increasing the TFPs of the traded good sectors in both countries (Z_H, Z_F) until theGome GDP share of the non-traded good sector passes from 41%, the average US value over the period 1970-1975, to 55%, the average US value over the period 2000-2005. It follows that I define as the 1970s-GDP the GDP response to an oil shock obtained before changing the TFPs; similarly, I define the GDP response obtained after changing the TFPs as the 2000s-GDP response.

Table

	Home		Foreign	
Share of the non-traded	41% -> 55%		44% -> 56%	
Openness Ratio	32% -> 26%		29% -> 23%	
Period	GDP response (1)	GDP response (2)	GDP response (1)	GDP response (2)
1	99,81%	91,84%	97,9%	91,7%
2	109,19%	94,68%	106,9%	94,3%
3	108,72%	95,57%	106,5%	95,1%
4	108,16%	96,58%	105,9%	96,1%
5	107,51%	97,72%	105,3%	97,2%
6	106,76%	99,00%	104,6%	98,4%
7	105,90%	100,41%	103,7%	99,7%
8	104,93%	101,96%	102,8%	101,1%

(1) Amount of hours worked unconstrained

(2) Amount of hours worked fixed

Table 2.5 - The effect of unbalance productivity growth on the GDP response to oil price shocks

Table 2.5 reports, for each country, the 2000s-GDP response in percent points of the 1970s-GDP response: that is, a value of 96% means that in the early 2000s the GDP response is 4 percent point weaker than in the early 1970s.

For each country, the first column of the table shows that, apart from the first period, the effect of oil shocks on GDP grows larger. This is mainly a consequence of the changes in the steady state values of the number of hours worked that is induced by increasing TFPs, and which tend to amplify the effects of oil shocks. [15]

[15] Other changes are in the real exchange rate and in the consumption-investment ratio.

I then compute the 2000s-GDP response by constraining the steady state values of number of hours worked to remain unchanged over the experiment. The second column reports the results for the constrained experiment, which confirms that once that the intratemporal condition channel is controlled for, the 2000s-GDP response becomes weaker than the 1970s GDP not only on impact but also in the following periods.

I then conclude that as the GDP share of the non traded good sector increases the effects of the oil price shocks on Home and Foreign GDP get weaker. I argue that what determines the weakening of the effects of the oil price shocks on economic activity is the reduced sensitivity of national economies to global shocks which is induced by the structural change. In other words, the greater the share of the non traded good sector, the smaller the size of international spillovers, which tend to amplify global shocks. This effect is highlighted by the observed decrease in the openness ratio after the increase in the TFPs.

2.5 Conclusions

I argue that the change in the composition of GDP that has been experienced by the US over the last decades provides an additional explanation for the weakening of the oil-macroeconomy relationship.

To analyse the relative importance of this channel I set up a two country two sector model with oil as additional input factor. I then use the model to analyse whether and to what extent the increase in the GDP share of the non traded goods sector weakens the effects of oil shocks on GDP. This experiment is performed by taking into account the two principal mechanisms that the literature on structural change puts forwards: the change in households preferences and the unbalanced productivity growth.

In performing the experiment I have to control for different channels, other than the change in GDP composition, which may affect the oil macroeconomy relationship. Once I control for these other channels, the experiment shows that the increase of the GDP share of the non-traded goods sector has a marginal role in explaining the weakening of the oil-macroeconomy relationship. I argue that this effect is mainly cause by the lowering size of international spillovers induced by the structural shocks.

I contribute to the debate on the role of technological progress in affecting the oil-macroeconomy relationship by showing that with Cobb Douglas technology the oil price elasticity of GDP is neutral to change in TFPs. Finally, I show that in an open economy framework for a country to experience a structural change induced by an unbalanced productivity growth mechanism it is sufficient that a Foreign country experiences the differences in the sectorial growth rates of TFPs.

Appendices

2.A: Notation of the model

Endogenous Variables

$C_t(j)$ = Home Consumption at time t by household j

$C_t^*(j)$ = Foreign Consumption at time t by household j

$L_t(j)$ =Home labor supplied at time t by household j

$L_t^*(j)$ = Foreign labor supplied at time t by household j

$L_{H,t}(j)$ =Home labor in the traded goods sector at time t by household j

$L_{N,t}(j)$ =Home labor in the non-traded goods sector at time t by household j

$L_{F,t}(j)$ =Foreign labor in the traded goods sector at time t by household j

$L_{N,t}^*(j)$ =Foreign labor in the non-traded goods sector at time t by household j

ε_t =Nominal exchange rate at time t (Home currency per unit of FOreign currency)

$B_t(j)$ = Value of the Home currency Bond held at time t by household j

$B_t^*(j)$ =Value of the Foreign currency International Bond held at time t by household j

i_{t+i} =Home nominal interest rate (set at the end of period t an dpaid at the beginning of period t+1)

i_{t+i}^* =Foreign nominal interest rate (set at the end of period t an dpaid at the beginning of period t+1)

$W_t(j)$ =Nominal wage rate at time t set by Household j

Σ_t =Financial transaction cost at time t

P_t = Home price of one unit of consumption good at time t

P_t^I =Home price of one unit of investment good at time t

P_t^* =Foreign price of one unit of consumption good at time t

P_t^{I*} =Foreign price of one unit of investment good at time t

$I_t(j)$ = Home investment at time t by Household j

$I_t^*(j)$ =Foreign investment at time t by Household j

$R_{N,t}$ = Home nominal rate of Return on capital in the non-traded goods sector at time t

$R_{H,t}$ = Home nominal rate of Return on capital in the traded goods sector at time t

$R^*_{N,t}$ = Foreign nominal rate of Return on capital in the non-traded goods sector at time t

$R_{F,t}$ = Foreign nominal rate of Return on capital in the traded goods sector at time t

$K_{N,t}(j)$ = Home capital in the non-traded goods sector at time by Household j

$K_{H,t}(j)$ =Home apital in the traded goods sector at time by Household j

$K^*_{N,t}(j)$ =Foreign capital in the non-traded goods sector at time by Household j

$K_{F,t}(j)$ =Foreign capital in the traded goods sector at time by Household j

$\Pi^f_t(j)$ =Share of profit from the intermediate sector at time t by Household j

$\Pi^b_t(j)$ =Share of profit from the financial sector at time t by Household j

T_t = Home Intermediate traded good used to produce C at time t

N_t = Home intermediate non-traded good used to produce C at time t

T^*_t = Foreign Intermediate traded good used to produce C^* at time t

N^*_t = Foreign intermediate non-traded good used to produce C^* at time t

$H_{C,t}$ = Home traded intermediate goods used in Home consumption production

$H_{I,t}$ = Home traded intermediate goods used in Home investment production

$F_{C,t}$ = Foreign traded intermediate goods used in Home consumption production

$F_{I,t}$ = Foreign traded intermediate goods used in Home investment production

$H^*_{C,t}$ = Home traded intermediate goods used in Foreign consumption production

$H^*_{I,t}$ = Home traded intermediate goods used in Foreign investment production

$F^*_{C,t}$ = Foreign traded intermediate goods used in Foreign consumption production

$F^*_{I,t}$ = Foreign traded intermediate goods used in Foreign investment production

π_t = Home inflation rate at period t

π_t = Foreign inflation rate at period t

Exogenous variable

Z_H = Total factor productivity in the Home traded goods sector

Z_F = Total factor productivity in the Foreign traded goods sector

Z_N = Total factor productivity in the Home non-traded goods sector

Z^*_N = Total factor productivity in the Foreign non-traded goods sector

P_e = Home real consumption denominated price of oil

Parameters

β = Subjective discount factor

σ = Inverse of the intertemporal elasticity of substitution

γ = Parameter of the Home disutility of labor effort

τ = Parameter of the Home disutility of labor effort

δ = Capital depreciation rate

$(1-\alpha)$ = Share of labor in any intermediate good production (technology are identical across countries and sectors)

υ = elasticity of substiitution between capital and oil

$\phi_{\Sigma}^{1}, \phi_{\Sigma}^{2}$ = Transaction cost parameters for Home households purchasing Foreign-denominated bonds

ω_C = Share of T_t in C_t

ω_C^* = Share of T_t^* in C_t^*

ω_H = Share of H_t in T_t

ω_H^* = Share of F_t^* in T_t^*

ω_I = Share of H_t in I_t

ω_I^* = Share of F_t^* in I_t^*

ρ_C = Home elasticity of input substitution in C

ρ_C^* = Foreign elasticity of input substitution in C^*

ρ_T = Home elasticity of input substitution in T

ρ_T^* = Foreign elasticity of input substitution in T^*

ρ_N = Home elasticity of input substitution in N

ρ_N^* = Foreign elasticity of input substitution in N^*

ρ_I = Home elasticity of input substitution in I

ρ_I^* = Foreign elasticity of input substitution in I^*

θ_H = Elasticity of substitution among Home traded differentiated intermediate goods

θ_N = Elasticity of substitution among Home non-traded differentiated intermediate goods

θ_F = Elasticity of substitution among Foreign traded differentiated intermediate goods

θ_N^* = Elasticity of substitution among Foreign non-traded differentiated intermediate goods

ρ = Persistence of the Home nominal interest rate

ρ^* = Persistence of the Foreign nominal interest rate

Θ_π = Weight of the inflation gap in Home Monetary policy

Θ_Y = Weight of the output gap in Home Monetary policy

Θ_π = Weight of the inflation gap in Foreign Monetary policy

Θ_Y = Weight of the output gap in Foreign Monetary policy

π = Home inflation rate target

π = Foreign inflation rate target

B.2: The closed form Model

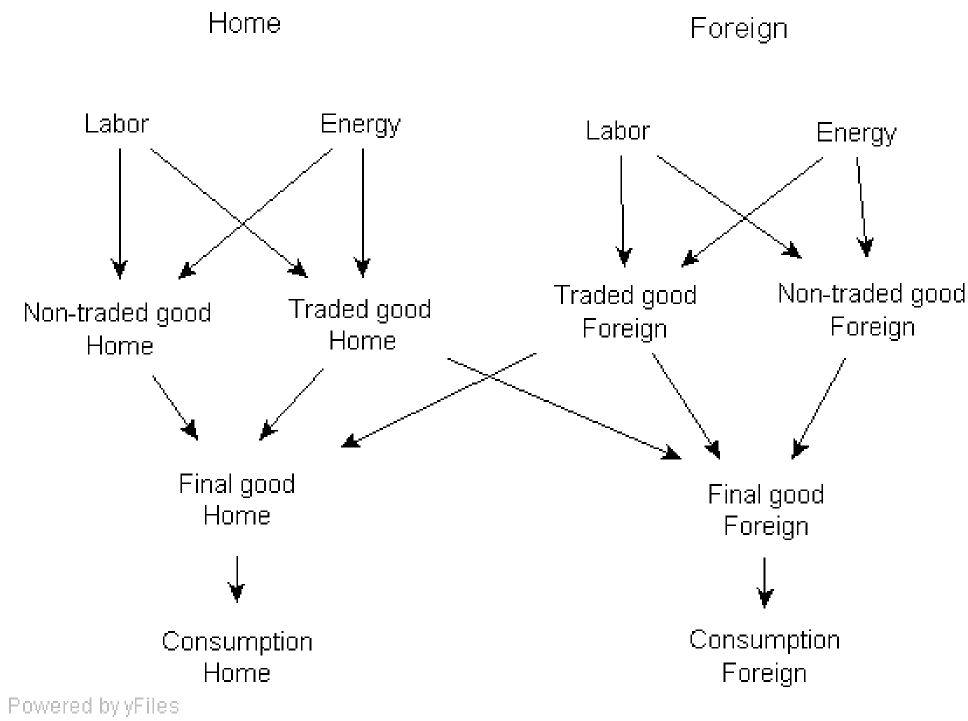

Figure B.2.1 - Structure of the model

The world economy consists of two identical countries denominated Home and Foreign. In each country the economic agents are households and firms. Variables with an asterisk denote prices and quantities in the Foreign country.

Households

Households consume a non-traded consumption good, supply labor in a perfectly competitive labor market and trade in Arrow Debreu contingent assets (full consumption risk-sharing). In each country the population size is normalized to one so that per capita and aggregate variables coincide. Households within the same country share the same preferences and budget constraint, so that for each country there is a representative agent.

The structure of the supply side.

The supply side of the economy is split into a perfectly competitive final good sector and an imperfectly competitive intermediate good sector. In each country the intermediate good sector is composed of a traded good and a non-traded good sector.

Firms in the intermediate good sector produce differentiated varieties of traded and non-traded goods through a Cobb Douglas technology which uses labor and energy as inputs. Firms have a monopoly power over the supply of their product and in absence of nominal rigidities set prices as a markup over marginal costs. The varieties of each sector are then aggregated into intermediate good aggregators: the Home-produced traded goods aggregators(H/H^*), the Foreign-produced traded goods aggregators ($F\ /F^*$), and the country specific non-traded goods aggregators(N/N^*), which are then used in the final good sector to produces the consumption good (C/C^*).

Utility function

$$U\left(C_t(j), L_t(j), \frac{M_t(j)}{P_t}\right) = \ln C_t(j) - \kappa L_t(j) + \chi \frac{M_t(j)}{P_t}$$

$$C = \left[(\xi \beta_C)^{\frac{1}{\theta}} H_t^{1-\frac{1}{\theta}} + ((1-\xi)\beta_C)^{\frac{1}{\theta}} F_t^{1-\frac{1}{\theta}} + (1-\beta_C)^{\frac{1}{\theta}} N_t^{1-\frac{1}{\theta}} \right]^{\frac{\theta}{\theta-1}},$$

$C(j) = Consumption\ good\ consumed\ by\ Households\ (j)$
$L(j) = Number\ of\ hours\ worked\ by\ Households\ (j)$
$\frac{M_t(j)}{P_t} =\ Real\ Balances\ holdings\ by\ Households\ (j)$
$H_t = Aggregator\ of\ Home - produced\ varieties\ of\ traded\ goods$
$F_t = Aggregator\ of\ Foreign - produced\ varieties\ of\ traded\ goods$
$N_t = Aggregator\ of\ Home - produced\ varieties\ of\ non - traded\ goods$
P_t= Price of one unit of the consumption good

Parameters in the utility function:

$\kappa > 0$,disutility of labor,
$\chi > 0$,utility.of real balances,
$\beta_C \in (0,1)$ weight of the domestic traded good in C,
$\xi \in (0,1)$ proportion between Home traded and non-traded good in C,
$\theta > 0$ elasticity of input substitution in C,
$\beta \in (0,1)$, discount rate.

Budget constraint

$$\begin{aligned} & P_t C_t(j) + M_t(j) + \sum_{s_t} Q(s_{t+1}, s_t) B_t(j, s_t) + \varepsilon_t \sum_{s_t} Q^*(s_{t+1}, s_t) B_t^*(j, s_t) \\ \leq \ & M_{t-1}(j) + W_t L_t(j) + \Pi_t(j) + B_{t-1}(s_{t,} j) + \varepsilon_t B_t^*(s_{t,} j) \end{aligned}$$

ε_t=Nominal exchange rate.
$Q(s_{t+1}, s_t)/Q^*(s_{t+1}, s_t)$ = the price of a Home/Foreign Arrow-Debreu security.
$B_t(j, s_t)/B_t^*(j, s_t)$ = Quantity of a Home/Foreign Arrow-Debreu security.
W_t = Nominal wage
$\Pi_t(j)$ = Share of profits from the intermediate sector held by Household (j).

Aggregators

$$H_t = \left[\int_0^1 H_t(h)^{1-\frac{1}{\psi_H}} dh \right]^{\frac{\psi_H}{\psi_H - 1}} \; ; \; F_t = \left[\int_0^1 F_t(f)^{1-\frac{1}{\psi_F}} df \right]^{\frac{\psi_F}{\psi_F - 1}} \; ; \; N_t = \left[\int_0^1 N_t(n)^{1-\frac{1}{\psi_N}} dn \right]^{\frac{\psi_N}{\psi_N - 1}} .$$

$H_t(h)$ =Differentiated variety h in the industry H

$F_t(f)$ =Differentiated variety f in the industry F

$N_t(n)$ =Differentiated variety n in the industry N

Parameters

$\psi_H > 1$ elasticity of substitution among varieties in the industry H,

$\psi_F > 1$ elasticity of substitution among varieties in the industry F,

$\psi_N > 1$ elasticity of substitution among varieties in the industry N

Intermediate sector

$$\begin{aligned} Y_t(h) &= Z_H L_t^{\alpha}(h) \; E_N^{(1-\alpha)}(h) \\ Y_t(h) &= H_t(h) + H_t^*(h) \\ N(n) &= Z_N L_t^{\alpha}(n) \; E_N^{(1-\alpha)}(n) \end{aligned}$$

$Y_t(h)$ / $N(n)$= output of the firm producing the variety h / n

$H_t(h) + H_t^*(h)$ =Demand of the variety $Y_t(h)$

$L_t(h)$ = labor input employed by firm $Y(h)$

$E_{N,t}(h)$= energy employed by firm $Y(h)$

Z_H / Z_N= Total Factor Productivity common to all the industries in the traded good sector / non traded good sector

$\alpha \in (0, 1)$ is the share of labor in the production function(common to all firms).

Monetary Policy

The stance of monetary policy is given by $\mu_t = P_t C_t$,it reflects the effect of monetary policy on the aggregate nominal spending, independently on the specific instrument that it adoptes.

The real price of oil

I assume that the real price of oil in Home unit of consumption is exogenous, so that $p_{e,t} = \frac{P_{e,t}}{P_t}$ is exogenous. I also assume that the law of one price holds $P_{e,t} = \varepsilon_t P_{e,t}^*$. It is then possible to link the the real price of oil in terms of Foreign unit of consumnption to $p_{e,t}$ as follows:

$p_{e,t}^* = \frac{1}{\Xi_t} p_{e,t}$
$p_{e,t}^* = \frac{C_t^*}{C_t} p_{e,t}$

2.C: Symmetric equilibrium

I consider a symmetric equilibrium where $\xi = (1-\xi^*)$, $\beta_C = \beta_C^*$, $\theta = \theta^*$, $\beta = \beta^*$, and α is common across countries and sectors.

Consumption and Labor in equilibrium

$$C_t = p_e^{\frac{(\alpha-1)}{\alpha}} \alpha(1-\alpha)^{\frac{(1-\alpha)}{\alpha}} \left[\begin{array}{c} (\xi\beta_C) \left(\frac{\psi_H}{\psi_H - 1} \frac{\kappa^\alpha}{Z_H}\right)^{1-\theta} + (1-\xi)\,\beta_C \left(\frac{\psi_F}{\psi_F - 1} \frac{(\kappa^*)^\alpha}{Z_F}\right)^{1-\theta} \\ + (1-\beta_C) \left(\frac{\psi_N}{\psi_N - 1} \frac{(\kappa)^\alpha}{Z_N}\right)^{1-\theta} \end{array} \right]^{\frac{1}{\alpha(\theta-1)}}$$

$$C_t^* = p_{e,t}^{\frac{(\alpha-1)}{\alpha}} \alpha(1-\alpha)^{\frac{(1-\alpha)}{\alpha}} \left[\begin{array}{c} ((1-\xi^*)\beta_C^*) \left(\frac{\psi_H}{\psi_H - 1} \frac{(\kappa)^\alpha}{Z_H}\right)^{1-\theta} + (\xi^*\beta_C^*) \left(\frac{\psi_F}{\psi_F - 1} \frac{(\kappa^*)^\alpha}{Z_F}\right)^{1-\theta} \\ + (1-\beta_C^*) \left(\frac{\psi_N^*}{\psi_N^* - 1} \frac{(\kappa^*)^\alpha}{Z_N^*}\right)^{1-\theta} \end{array} \right]^{\frac{1}{\theta-1}}$$
$$\left[\begin{array}{c} (\xi\beta_C) \left(\frac{\psi_H}{\psi_H - 1} \frac{\kappa^\alpha}{Z_H}\right)^{1-\theta} + (1-\xi)\,\beta_C \left(\frac{\psi_F}{\psi_F - 1} \frac{(\kappa^*)^\alpha}{Z_F}\right)^{1-\theta} \\ + (1-\beta_C) \left(\frac{\psi_N}{\psi_N - 1} \frac{(\kappa)^\alpha}{Z_N}\right)^{1-\theta} \end{array} \right]^{\frac{(1-\alpha)}{\alpha(\theta-1)}}$$

$$L_H = \xi\beta_C \left(\frac{(1-\alpha)}{p_{e,t}}\right)^{(\alpha-1)(1-\theta)} \left(\frac{\alpha}{\kappa}\right)^{(1-\alpha)+\theta\alpha} Z_H^{\theta-1} \left[1 + \left(\frac{C_t^*}{C_t}\right)^{1-\theta}\right] C_t^{\alpha(1-\theta)}$$

$$L_F = \xi\beta_C \left(\frac{(1-\alpha)}{p_{e,t}}\right)^{(\alpha-1)(1-\theta)} \left(\frac{\alpha}{\kappa^*}\right)^{(1-\alpha)+\theta\alpha} Z_F^{\theta-1} (C_t^*)^{\alpha(1-\theta)} \left[1 + \left(\frac{C_t^*}{C_t}\right)^{1-\theta}\right]$$

$$L_{N,t} = (1-\beta_C)\, Z_{N,t}^{\theta-1} \left(\frac{\alpha}{\kappa}\right)^{(1-\alpha)+\alpha\theta} + \left(\frac{1-\alpha}{p_{e,t}}\right)^{(1-\alpha)(\theta-1)} \left(\frac{\psi_N}{\psi_N - 1}\right)^{-\theta} C_t^{\theta(1-\alpha)}$$

$$L_N^* = (1-\beta_C^*)\,(Z_N^*)^{\theta-1} \left(\frac{\psi_N^*}{\psi_N^* - 1} \frac{(\kappa^*)^\alpha (p_{e,t})^{1-\alpha}}{\alpha^\alpha (1-\alpha)^{(1-\alpha)}}\right)^{-\theta} (C_t)^{\theta(1-\alpha)} (C_t^*)^{1-\theta}$$

$$\varepsilon_t = \frac{\mu_t}{\mu_t^*}.$$

Flexible price Equations

$$P_{H,t} = \frac{\psi_H}{\psi_H - 1} \frac{(\kappa\mu_t)^{\alpha} P_e^{(1-\alpha)}}{Z_H \alpha^{\alpha}(1-\alpha)^{(1-\alpha)}}$$

$$P_{H,t}^* = \frac{1}{\varepsilon_t} \frac{\psi_H}{\psi_H - 1} \frac{(\kappa\mu_t)^{\alpha} P_e^{(1-\alpha)}}{Z_H \alpha^{\alpha}(1-\alpha)^{(1-\alpha)}}$$

$$P_{F,t} = \varepsilon_t \frac{\psi_F}{\psi_F - 1} \frac{(\kappa^*\mu_t^*)^{\alpha} P_e^{*(1-\alpha)}}{Z_F \alpha^{\alpha}(1-\alpha)^{(1-\alpha)}}$$

$$P_{F,t}^* = \frac{\psi_F}{\psi_F - 1} \frac{(\kappa^*\mu_t^*)^{\alpha} P_e^{*(1-\alpha)}}{Z_F \alpha^{\alpha}(1-\alpha)^{(1-\alpha)}}$$

$$P_{N,t} = \frac{\psi_N}{\psi_N - 1} \frac{(\kappa\mu_t)^{\alpha} P_e^{(1-\alpha)}}{Z_N \alpha^{\alpha}(1-\alpha)^{(1-\alpha)}}$$

$$P_{H,t} = \frac{\psi_N^*}{\psi_N^* - 1} \frac{(\kappa\mu_t^*)^{\alpha} P_e^{*(1-\alpha)}}{Z_N^* \alpha^{\alpha}(1-\alpha)^{(1-\alpha)}}$$

2.D: The effect of unbalanced productivity growth on GDP composition

It is easy to define the GDP share of the non-traded goods sector in equilibirum

$$\frac{P_N N}{PC} = (1-\beta_C)\,\alpha^{\alpha}(1-\alpha)^{(1-\alpha)} \left[\begin{array}{c} (\xi\beta_C)\left(\frac{\frac{\psi_H}{\psi_H-1}}{\frac{\psi_N}{\psi_N-1}}\frac{Z_N}{Z_H}\right)^{1-\theta} + (1-\xi)\,\beta_C\left(\frac{\frac{\psi_F}{\psi_F-1}}{\frac{\psi_N}{\psi_N-1}}\frac{(\kappa^*)^{\alpha}}{\kappa^{\alpha}}\frac{Z_N}{Z_F}\right)^{1-\theta} \\ +(1-\beta_C) \end{array} \right]^{-1}$$

Proposition 2.1 *If the total factor productivity of either the Home traded good sector (Z_H) or the Foreign traded good sector (Z_F) increases relatively to the total factor productivity of the domestic non-traded goods sector (Z_N), then, a sufficient condition for the Home GDP share of the non traded good sector to increase is that the elasticity of substitution between traded and non-traded goods in C is below unity ($\theta < 1$).*

Proof. By taking the first difference of $\frac{P_N N}{PC}$ with respect to either $\frac{Z_H}{Z_N}$ or $\frac{Z_F}{Z_N}$ I obtain

$$\frac{\partial\left(\frac{P_N N}{PC}\right)}{\partial\left(\frac{Z_H}{Z_N}\right)} = -\left(1-\beta_C\right)\alpha^{\alpha}(1-\alpha)^{(1-\alpha)}\left(\xi\beta_C\right)(\theta-1)\left(\frac{\frac{\psi_H}{\psi_H-1}}{\frac{\psi_N}{\psi_N-1}}\frac{Z_N}{Z_H}\right)^{\theta-2}\frac{\frac{\psi_H}{\psi_H-1}}{\frac{\psi_N}{\psi_N-1}}\cdots$$
$$\left[\begin{array}{c}\left(\xi\beta_C\right)\left(\frac{\frac{\psi_H}{\psi_H-1}}{\frac{\psi_N}{\psi_N-1}}\frac{Z_N}{Z_H}\right)^{1-\theta}+(1-\xi)\,\beta_C\left(\frac{\frac{\psi_F}{\psi_F-1}}{\frac{\psi_N}{\psi_N-1}}\frac{(\kappa^*)^{\alpha}}{\kappa^{\alpha}}\frac{Z_N}{Z_F}\right)^{1-\theta}\\ +\left(1-\beta_C\right)\end{array}\right]^{-2},$$

which implies that $\frac{\partial\left(\frac{P_N N}{PC}\right)}{\partial\left(\frac{Z_H}{Z_N}\right)} > 0 \ if \ \ \theta < 1.$ ■

2.E: The oil-price elasticity of real GDP

The oil-price elasticity of output $\left(\eta_{C,P_e}\right)$ tells us in what direction and by how many percent points the real GDP (C) changes when the real price of oil increases by 1 percent. I can then use this measure to analyse how an increase in TFP affects the response of GDP to oil price shocks.

Proposition 2.2 *With Cobb-Douglas production functions the oil price elasticity of GDP is unaffected by changes in total factor productivities.*

Proof. By computing η_{C,P_e} I find that with a Cobb Douglas technology it is constant , as it depends only on α.

$$\eta_{C,P_e} = \frac{\left(\frac{dC}{dp_e}\right)}{\left(\frac{C}{p_e}\right)} = \frac{(\alpha-1)}{\alpha} < 0$$

It follows that any increase in the TFP does not change the output elasticity of the price of oil, that is, the change in the TFP does not affect the sensitivity of the economy to the real price of oil.

$$\frac{d\left(\eta_{C,P_e}\right)}{dZ} = 0$$

■

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CHAPTER 3

EXPLAINING THE 'LARGE' IMPACT OF OIL PRICE SHOCKS ON GDP

3.1 Introduction

The way oil price shocks affect the economy, namely GDP, has been widely investigated by the literature since the oil crisis of the early 1970s, when the empirical estimates of the effects of oil shocks on GDP appeared to be larger that the oil share. Indeed, before that episode the traditional argument that was used to explain the effects of oil shocks on GDP was the factor share argument, according to which the oil price elasticity of GDP should be equal to the oil share.

This paper analyses the impact of oil price shocks on GDP in an open economy framework and develops a mechanism which is able to amplify them beyond the oil share. For these purposes, I set up two theoretical models. I first set up a basic two-country model whose analytical tractability allows me to obtain the following results on the 'oil-macroeconomy' relationship. First, I show that the introduction of nominal rigidities considerably modifies the way oil shocks affect the economy with respect to the flexible price regime. In the flexible price regime the effect of oil shocks on economic activity is symmetric across countries and the oil price elasticity of both GDP and price level is constant. Instead, with the introduction of nominal rigidities oil shocks turn to have asymmetric effects across countries and the oil price elasticity of both GDP and price becomes an increasing function of the size of oil shocks. Second, I show analytically that a small open economy model, in comparison to a general equilibrium model, underestimates the effect of oil price shocks on GDP. Third, I show that the use of either the nominal or the real price of oil has different implications as to the impact of oil shocks on the economy, even though both measures lead to similar results as long as the oil share is small.

The basic model has a limited explaining power for the 'large' effect of oil shocks on GDP, where by 'large' I mean an oil price elasticity of GDP greater than the oil share. I then show that in an extended two-country, two-sector model with sector specific capital, oil price shocks can cause a 'large' effect on GDP even with flexible prices. Differently from former multi-sector models that have been developed to analyse the 'oil-macroeconomy' relationship, I do not assume different technologies across sector, namely I assume that the two sectors have the same oil intensity. Indeed, the model may produce 'large' effects of oil price shocks on GDP even with an identical technology across sectors as long as consumption and investment have a different composition in terms of sectorial intermediate goods. Finally, the introduction of nominal wage rigidities then further amplifies the effects of oil price shocks on GDP with respect to the flexible price regime. In particular, oil shocks do not only cause a larger impact on GDP but also their effect on economic activity become more persistent.

Section 2 presents some evidence and a survey of the relevant literature on the effects of oil shocks on GDP. Section 3 describes the basic theoretical model and presents results. Section 4 describes the extended model and presents results. Section 5 concludes.

3.2 The 'large' effect of oil shocks: evidence and theory

Exogenous Disruption in world Petroleum Supply

Date	Event	Drop in world production	Drop in U.S. GDP
Nov. 1956	Suez Crisis	10,10%	-2,50%
Nov.1973	Arab-Israel War	7,80%	-3,20%
Nov. 1978	Iranian Revolution	8,90%	-0,60%
Oct. 1980	Iran-Iraq war	7,20%	-0,50%

Source: Hamilton (2003)

Table 3.1 - The estimated drop in US GDP after large oil shocks

Table 3.1 shows the effects of oil shocks on US GDP estimated by Hamilton in correspondence to exogenous events which caused a relevant drop in the world oil supply. For each episode it is reported the date of the month in which the largest drop has been registered, the relative drop in world petroleum supply and the estimated amount by which US GDP declined between the date of the oil shock and the trough of the subsequent recession, which usually is reached four quarters after the oil shock. Thus, the estimated declines of GDP relative to trend are above 0.4%, which is the GDP drop that would be predicted by the factor share argument for a 10% drop in the world oil supply.

In what follows I report the theoretical channels which the literature has put forward to explain the effects of oil shocks on GDP.

3.2.1 The supply-side channel

The supply-side channel, pointed out by Rasche and Tatom (1977), Barro (1984) and Bruno and Sachs (1985), explains the recessive effect of positive oil price shocks as an effect of its scarcity, which causes a lower use of oil in the production so that both the GDP and the productivity of the other factors decline. Accordingly, the NAIRU and the interest rate goes up, the latter signalling the fact that consumers save less (or borrow more) for consumption smoothing. The demand for real balances also falls for any given stance of monetary stock, as the output decreases and both the interest rate and the inflation rate rises. Finally, because the lower labor productivity commands lower real wages, the presence of nominal or real wage rigidities may further reduce GDP and employment.

3.2.2 The 'Income transfers' channel

Fried and Schulze (1975), Dohner (1981) and Bruno and Sachs (1985) note that the rise in the price of oil implies a resource shift from net oil-importing countries to net oil-exporting countries. As long as the extra income of oil-exporting countries is not spent into goods produced in oil-importing countries, the world aggregate demand will fall and the world supply of savings will increase. The increase in the world supply of savings might offset the recessive effect of oil shocks by mean of a lower world interest rate, which might push investments up to make up for the fall in consumption in the net oil-importing countries.

The effective relevance of this channel then depends on two factors: the development of international financial markets and the presence of nominal rigidities. However, even though theoretically relevant, this channel imply consequences that are conterfactual. Indeed, it cannot explain the fact that most recessions that have followed oil price shocks have been worldwide in nature (Ferderer 1999) and why countries that are more dependent on oil-imports did not necessarily suffer more during the crises. [1]

3.2.3 Oil shocks and monetary policy

The role of monetary policy in the propagation of oil shocks is somewhat debated in the literature. It has been recently reemphasized by Bohi (1991) and Bernanke, Gertler and Watson (1997), who argue that the tight response of monetary policy to the rise in the price of oil is the main responsible for the recession. However, this emphasis on the role of monetary policy has been challenged by Brown and Yücel (1995) and Hamilton and Herrera (2000).

Brown (2000) also argues that the monetary policy matters to evaluate the real effects of oil price shocks, but emphasizes that it is the specific monetary policy target to determine

[1] For example, the United Kingdom experienced a much more severe recession during the 1978–81 oil crisis than Japan did, despite the fact that the UK was a net oil exporter and Japan was an oil importer (see Bohi, 1991).

the trade-off between inflation and output which follows an oil price shock[2].

3.2.4 Non standard channels: Endogenous rate of capital depreciation, Countercyclical Markups, Uncertainty and Input Reallocation costs

Some authors moved away from standard assumptions of real business cycle models to find other channels which could reproduce the large impact of oil shocks on GDP. In particular, I consider four different alternative models. The first model is by Woodford and Rotemberg (1996). They move away from the hypothesis of perfect competition and explain the large impact of oil shocks on GDP through countercyclical markups. Indeed, the recessive effect of positive oil price shocks gets reinforced by the increase in markups which further reduce the aggregate demand.

The second model is by Finn (2000). She uses a neoclassical model of perfect competition with a variable capital depreciation rate and with energy as a complementary input to the service flow from capital. In her model, oil price shocks cause fluctuations in the energy usage which affect the production not only directly through the production function, but also indirectly through its effects on the depreciation and the capital utilization rate. Thus, oil price shocks, by inducing a lower use of energy in the production, also reduce the depreciation rate of capital, which in turn lowers the aggregate demand because of the lower level of investments.

The third class of models comprises multi-sector models with reallocation costs, where sectors differ among them for the energy intensity of the production function (Davis 1985, Loungani 1986). In these models, oil price shocks shift the demand towards products which are less energy-intensive, so that also inputs must be reallocated across sectors. The presence of input reallocation costs then amplifies the recessive effect of oil price shocks.

Finally, the fourth model is by Bernanke (1993), who highlights the role of uncertainty in a model with irreversible investments. In his model a rise in the price of oil increases the level of uncertainty in the economy and reduces the propensity to invest because the option value of delaying any kind of investment goes up.

[2] In particular Brown considers three monetary policy targets: a constant growth rate of nominal GDP, a constant growth rate of the monetary aggregate and a constant interest rate. To make an example on how the monetary target matter in affecting the effects of oil shocks on economic activity, we can consider that a positive oil price shock affects negatively the real GDP growth rate and tends to increase both the real interest rate and the velocity of circulation of money. If the monetary policy target is a constant nominal GDP growth, then the inflation rate will have to increase proportionally to the real GDP slowdown, the nominal growth of the monetary aggregate will be reduced, and so the real interest rate will be pushed further up. Instead, if the monetary policy target aims to keep constant the interest rate, it will be both the growth rate of the monetary aggregate and the inflation rate to increase.

3.3 A basic two-country framework to analyse the impact of oil shocks on macroeconomic performance

In this section I use a basic two country model to derive analytically some general results about the effect of oil price shocks on GDP in a two-country framework. The model builds on Corsetti and Pesenti (2005), but I extend it to comprehend oil as an additional input to labor.

3.3.1 The model

The world consists of two countries of equal size, Home and Foreign. In each country the economy consists of households and firms. Home households and firms are both defined over a continuum of unit mass, with indexes $i \in (0,1)$ and $h \in (0,1)$. Foreign households and firms are similarly defined over a continuum of unit mass, with indexes $i^* \in (0,1)$ and $f \in (0,1)$.

Oil is a Foreign-specific resource, which is the only source of asymmetry across countries.

In what follows I describe Home economy, but the case of Foreign is symmetric

Households Home population is normalised to one. Households have identical preferences, own national firms, derive utility from consuming the final good and disutility from supplying labor services to firms in exchange for wage income. The instant utility of household i is

$$U_t(i) = \ln C_t(i) - kl_t(i)$$

where $k > 0$ is a parameter which rules the disutility of supplying labor and $C_t(i)$ is a Cobb-Douglas basket of the Home $(C_{H,t}(i))$and Foreign goods $(C_{F,t}(i))$,both with a weight equal to $\frac{1}{2}$:

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

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

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

where $\theta > 1$ is the elasticity of substitution across varieties which I assume to be common across countries.

From expenditure minimization I obtain the price level (P) and household i demand for each variety h and f $(C_t(h,i), C_t(f,i))$

$$\begin{aligned} P &= \frac{1}{2} P_H^{\frac{1}{2}} P_F^{\frac{1}{2}} \\ C_t(h,i) &= \frac{1}{2}\left(\frac{P_t(h)}{P_{H,t}}\right)^{-\theta}\left(\frac{P_{H,t}}{P_t}\right)^{-1} C \\ C_t(f,i) &= \frac{1}{2}\left(\frac{P_t(f)}{P_{F,t}}\right)^{-\theta}\left(\frac{P_{F,t}}{P_t}\right)^{-1} C \\ P_H C_H &= P_F C_F = \frac{1}{2} PC. \end{aligned}$$

I assume no international financial markets and no fiscal policy. Households then choose consumption $(C_t(i))$and labor $(l_t(i))$ to maximise the present value of the stream of instant utilities subject to the stream of one-period budget constraints

$$P_t C_t(i) \leq W_t l_t(i) + \Pi_t(i)$$

Firms   Each firm uses a Cobb-Douglas technology to produce a variety of the national good $Y_t(h)$ which is an imperfectly substitute to all other varieties under conditions of monopolistic competition:

$$Y_t(h) = Z l^{\alpha}(h) E_N^{1-\alpha}(h),$$

where Z is the Total Factor Productivity common to all Home firms, $l(h)$ and $E_N(h)$ are the amount of labor and energy employed by the firm producing variety h and $\alpha \in (0,1)$ defines the share of labor income.

The aggregate demand for variety h is obtained by aggregating over Home and Foreign households demand, so that firm h faces the following demand schedule for its product:

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

Any Home firm then set the prices for its product to mazimise profits $\Pi_t(h)$:

$$\begin{aligned} \Pi_t(h) &= (P_t(h) - MC_t(h)) \int_0^1 C_t(i,h)di + (\varepsilon_t P_t^*(h) - MC_t(h)) \int_0^1 C_t^*(i^*,h)di^* \\ MC(h) &= MC = \frac{(k\mu)^{\alpha} P_{e,t}^{1-\alpha}}{Z\alpha^{\alpha}(1-\alpha)^{1-\alpha}} \end{aligned}$$

Where $MC(h)$ is the marginal cost of producing the marginal unit $Y(h)$ which results equal across h.

Monetary Policy The stance of monetary policy is given by $\mu_t = P_t C_t$, and reflects the effect of monetary policy on the aggregate nominal spending independently on the specific instrument that it adoptes.

The price of oil The nominal price of oil is denominated in Home currency and is exogenous. In alternative I could also consider as exogenous the real price of oil denominated in Home unit of consumption good.

The assume that the law of one price holds for the price of oil so that:

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

3.3.2 The flexible price case

In this section I focus on how the introduction of oil affects the equilibrium values of the model in both countries(nominal exchange rate, consumption and labor) as well as on the effect of oil price shocks on the two economies.

In the flexible price case the equilibrium nominal exchange rate is a function of the ratio between Home and Foreign monetary policy stance $\left(\frac{\mu_t}{\mu^*_t}\right)$, as in Corsetti and Pesenti, but also of a constant $\varphi > 1$ which depends on both the Home degree of monopolistic power $\left(\frac{\theta}{\theta-1}\right)$ and the Home share of oil income $(1-\alpha)$.

$$\varepsilon_t = \frac{\mu_t}{\mu^*_t}\left(\frac{1+\frac{\theta}{\theta-1}\frac{1-\alpha}{2}}{1-\frac{\theta}{\theta-1}\frac{1-\alpha}{2}}\right) = \frac{\mu_t}{\mu^*_t}\varphi \ , \ \alpha \in (0,1)\,, \ \theta > 1, \ \varphi > 1 \qquad (3.1)$$

The interpretation of the constant is related to the fact that oil is a Foreign specific resource. Thus, the more oil is required in the production $(1-\alpha)$the higher the value of Home imports, as the price of oil is exogenous in Home currency, and so the more the nominal exchange rate has to depreciate for Home to reach the trade balance. Indeed, as $(1-\alpha)$ tends to 0 φ goes to 1, and the equilibrium nominal exchange rate becomes completely determined by the ratio between Home and Foreign monetary policies, like in Corsetti and Pesenti.

As the nominal exchange rate is unaffected by oil price shocks and the technology is identical across countries, in the flexible price regime oil price shocks produce constant and symmetric effects across countries. However, the fact that oil is a foreign specific resource induces a wedge in the equilibrium GDP $\left(\frac{C^*_t}{C_t}\right)$ and labor ratio $\left(\frac{l^*_t}{l_t}\right)$. Indeed, in equilibrium Foreign households work less and consume more than Home households

$$\frac{C_t^*}{C_t} = \varphi \Longrightarrow C_t^* > C_t \;\; ; \;\; \frac{l_t^*}{l_t} = \frac{\left(1 - \frac{\theta}{\theta-1}\frac{1-\alpha}{2}\right)}{\left(1 + \frac{\theta}{\theta-1}\frac{1-\alpha}{2}\right)} \Longrightarrow l_t^* < l_t$$

To measure the impact of oil on the economy I compute the nominal and the real oil price elasticities of GDP and price for both countries. The nominal oil price elasticity of GDP $\left(\frac{el\_C}{el\_P_e}, \frac{el\_C*}{el\_P_e}\right)$ results to be equal to the oil share $(1-\alpha)$ in both countries, and lower than the real oil price elasticity $\left(\frac{el\_C}{el\_p_e}, \frac{el\_C*}{el\_p_e}\right)$, which is instead equal to $\frac{(1-\alpha)}{\alpha}$ in both countries.

$$\frac{el\_C}{el\_p_e} = \frac{el\_C^*}{el\_p_e} = \frac{(1-\alpha)}{\alpha} > \frac{el\_C}{el\_P_e} = \frac{el\_C^*}{el\_P_e} = (1-\alpha) \; , \; \alpha \in (0,1) \, .$$

This result highlights that when comparing the results on the effect of oil prices on GDP from different analysis, it should be taken into account whether the oil price which used in the analysis is nominal or real price of oil. However, in practice such a distinction is not crucial as long as the oil share is small, as in this case both measures would lead ti similar results.

I also compute the elasticity of the price level in the two countries

$$\frac{elP}{elP_e} = \frac{elP^*}{elP_e} = (1-\alpha)$$

To explain the effect of oil price shocks on Home and Foreign economy I can use with a graphical interpretation through the schedule of Aggregate Supply (AS) and Aggregate Demand (AD) on the space (C, L), like in Corsetti and Pesenti (figure 1) .

$$\begin{aligned} AS &: \;\; C = \tilde{\tau} L : \\ \tilde{\tau} &= \frac{1}{2}\left(\frac{1}{1+\varphi}\right)\frac{k\mu}{\alpha}\left(\frac{1}{\varepsilon^{\alpha}}\right)^{\frac{1}{2}}\left(\frac{1}{MC}\right) \\ AD &: \;\; C = \frac{\mu}{P} \end{aligned}$$

The first element of the AS is the term $\tilde{\tau}$, which considers both the terms of trade and the marginal condition for the intratemporal substitution between labor and energy. A positive oil price shock rotates the AS schedule from AS^0 to AS^1, but only because of the intratemporal marginal condition between labor and energy. Indeed, as the technology is symmetric and the nominal exchange rate is not affected by oil shocks, the terms of trade is unaffected by oil price shocks. The oil price shock also shifts downwards the AD schedule from AD^0 to AD^1 to as P increases. Thus, in the new equilibrium Home labor does not change, consumption decreases from C^0 to C^1 and the price level increases from P^0 to P^1.

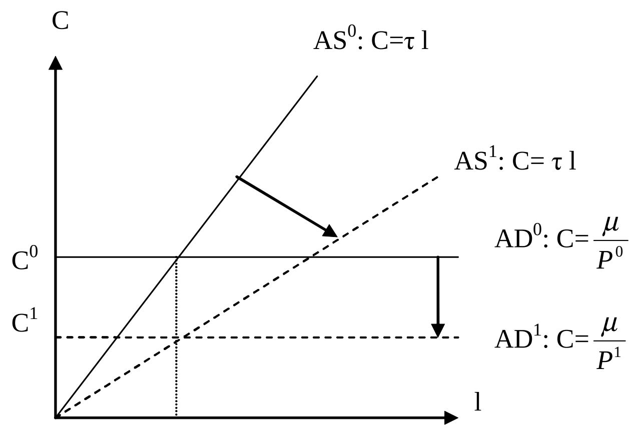

Figure 3.1 - The effect of oil price shocks on Home economy with flexible prices

The mechanism works symmetrically for the Foreign Country.

3.3.3 Nominal rigidities

The introduction of nominal rigidities changes the way oil shocks affect the economy. In particular, I show that with nominal rigidities oil shocks have asymmetric effects across countries, and may produce 'large' impact on the economy. For reasons of tractability I follow Corsetti and Pesenti and assume that prices are predetermined one period ahead.[3] Moreover, as nominal wages are determined by the stance of the monetary policy, nominal rigidities in the model make sense only in reference to price setting and not to wage setting.

Price setting in a two-country model implies that firms have to set a price for the domestic market and one for the foreign market. In general, if the price to be set in the foreign market is P_x^*, a firm will choose it to maximise profits with respect to $P_x \varepsilon^{\phi}$, where $\phi \in [0, 1]$ is the degree of pass through of nominal exchange rate on P_x. I take into account the two extreme cases, that is those corresponding to $\phi = 0$ and $\phi = 1$. The second case corresponds to the so-called Producer Currency Pricing (PCP), and implies full pass through so that the law of one price holds. The first case, instead, corresponds to the so-called Local Currency Pricing (LCP), and implies no pass through.

[3] Nominal rigidities may be introduced in many ways. For example, quadratic costs of price adjustment à la Rotemberg would introduce a more interesting dynamic, but would not allow me to get an analytical solution.

3.3.3.1 Nominal rigidities and Price Currency Pricing

Equilibrium values for the nominal exchange rate, prices, consumption and labor are reported in the appendix. Here I focus on how the oil-macroeconomy relationship is modified by the introduction of nominal rigidities. I first notice that the nominal exchange rate is no longer independent on the price of oil:

$$\varepsilon = \frac{\mu}{\mu^*}\left(\frac{E\left[MC\right]/MC + \frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}{E\left[MC\right]/MC - \frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}\right),$$

therefore oil shocks produce asymmetric effects across countries. It is useful to determine the elasticity of the nominal exchange rate with respect to the nominal oil price:

$$\frac{el\_\varepsilon}{el\_P_e} = \frac{\frac{1}{4}\frac{\theta}{\theta-1}E\left[MC\right]/MC}{\left(\left(E\left[MC\right]/MC\frac{\theta}{\theta-1}\frac{2}{(1-\alpha)}\right)^2-1\right)}.$$

It is possible to distinguish two cases: for oil price shocks which are small enough, that is such that $E\left[MC\right]/MC > \frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}$, the nominal exchange rate tends to depreciate, and the depreciation is the higher the larger the shock; for 'large' oil price shocks, that is such that $E\left[MC\right]/MC < \frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}$, the oil shock causes an appreciation of the nominal exchange rate. While both cases are theoretically possible, however, for plausible values of the degree of monopolistic power (θ), energy share ($1-\alpha$) and size of the oil price shock, only the first case is interesting. I therefore focus the analysis on oil shocks such that $E\left[MC\right]/MC > \frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}$ and define as the standard case the one in which this condition is satisfied.

I then compute the oil price elasticities of GDP and price of both countries in terms of $\frac{el\_\varepsilon}{el\_P_e}$:

$$\frac{el\_C}{el\_P_e} = -\frac{1}{2}\frac{el\_\varepsilon}{el\_P_e} \quad ; \quad \frac{el\_C^*}{el\_P_e} = \frac{1}{2}\frac{el\_\varepsilon}{el\_P_e}$$
$$\frac{el\_P}{el\_P_e} = \frac{1}{2}\frac{el\_\varepsilon}{el\_P_e} \quad ; \quad \frac{el\_P^*}{el\_P_e} = -\frac{1}{2}\frac{el\_\varepsilon}{el\_P_e}.$$

Because the oil price elasticities of the nominal exchange rate $\left(\frac{el\_\varepsilon}{el\_P_e}\right)$ is not constant, but the higher the larger is the oil price shock, it is possible that large oil price shocks cause a drop in GDP larger than the energy share.[4] Moreover, with a real oil price shock the

[4] In general the $\frac{el\_\varepsilon}{el\_P_e} > n(1-\alpha)$ for oil price shock such that $E\left[MC\right]/MC < \frac{\theta-1}{\theta}(1-\alpha)\left(\frac{1+(1+n)^{\frac{1}{2}}}{2n}\right) = \phi$, and $\frac{\partial\phi}{\partial n} < 0$

amplification effect is even larger:

$$\frac{el\_C}{el\_p_e} = \frac{\frac{el\_C}{el\_P_e}}{1+\frac{el\_C}{el\_P_e}} > \frac{el\_C}{el\_P_e}.$$

Another difference with respect to the flexible price case is that in equilibrium labor is not anymore constant. Thus, oil shocks now affect the value of labor, as it is shown by the oil price elasticities of labor:

$$\frac{el\_l}{el\_P_e} = (1-\alpha)\frac{E\left[MC\right]/MC}{E\left[MC\right]/MC - \frac{\theta}{\theta-1}\frac{(1-\alpha)}{2}} > (1-\alpha)\ if\ \frac{el\_\varepsilon}{el\_P_e} > 0.$$

Thus, in the standard case $\left(E\left[MC\right]/MC > \frac{\theta}{\theta-1}\frac{(1-\alpha)}{2}\right)$, Home labor will increase after the shock.

$$\begin{aligned} AS &: \quad C = L\tilde{\tau} \\ \tilde{\tau} &= \frac{k}{\alpha}\left(\mu\mu^*\right)^{\frac{1}{2}}\frac{E\left[MC\right]^{\frac{3}{2}}}{E\left[MC*\right]^{\frac{1}{2}}}\frac{\left(E\left[MC\right]/MC - \frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}\right)^{\frac{3}{2}}}{\left(E\left[MC\right]/MC + \frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}\right)^{\frac{1}{2}}} \\ AD &: \quad C = \frac{\mu}{P}. \end{aligned}$$

I can use the AD and AS scehdule to show graphically the effects of a positive oil price shock on Home and Foreign economies. In the standard case, a positive oil price shock will rotate the Home AS schedule downwards from AS^0 to AS^1, and will shift downwards the Home AD schedule AD^0 to AD^1; therefore, in the new equilibrium C decreases C^0 to C^1,l increases l^0 to $l^1$and P increases P^0 to P^1(figure 2).

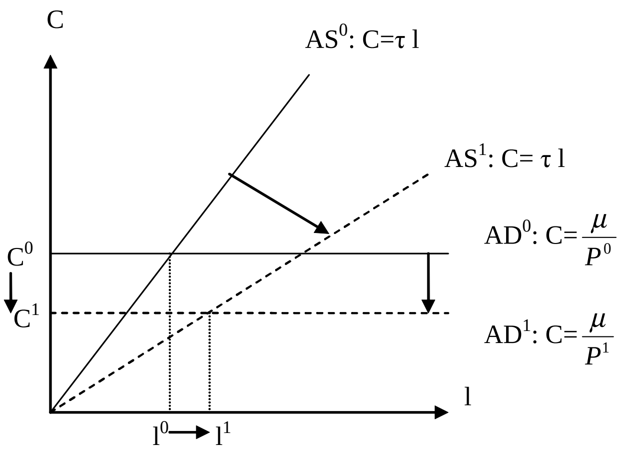

Figure 3.2 - The effect of oil price shocks on Home economy with nominal rigidities and PCP

$$
\begin{aligned}
AS &: \quad C^* = L^* \tilde{\tau}^* \\
\tilde{\tau}^* &= \frac{k}{\alpha}\left(\frac{\mu^*}{\mu}\right)^{1-\alpha} \frac{\theta-1}{\theta} \frac{\left(E\left[MC\right]/MC + \frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}\right)^{2-\alpha}}{\left(E\left[MC\right]/MC - \frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}\right)^{1-\alpha}} \left(\frac{E\left[MC^*\right]/\tilde{M}C^*}{E\left[MC\right]/MC}\right) L^* \\
AD &: \quad C^* = \frac{\mu^*}{P^*}
\end{aligned}
$$

With nominal rigidities, the effect of oil price shocks is not anymore symmetric across countries. Indeed, the depreciation of the nominal exchange rate, by making Home exports cheaper, lowers the foreign price level, so that the AD shifts upwards from AD^0 to AD^1. As to the AS schedule, it might take both directions, depending on the size of the oil shocks. If the size of the oil shocks is sufficiently small then the AS will rotate upwards from AS^0 to AS^1; otherwise it will rotate downwards from AS^0 to AS^2. Thus, the effect of oil price shocks on the equilibrium level of labor is ambiguous, as it falls to l_1^* for sufficiently small in size oil shocks while it increases to l_1^*otherwise. Instead, Foreign consumption increases always from C_0^* to C_1^* and the Foreign price level decreases from P_0^* to P_1^* (figure 3).[5]

[5]
$$
\frac{el\_L^*}{el\_P_e} = -(1-\alpha)\frac{1}{MC}\frac{2(1-\alpha)\frac{\theta}{\theta-1}\frac{(1-\alpha)}{2} - E\left[MC\right]/MC}{\left(E\left[MC\right]/MC - \frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}\right)\left(E\left[MC\right]/MC + \frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}\right)} \lesseqgtr 0.
$$

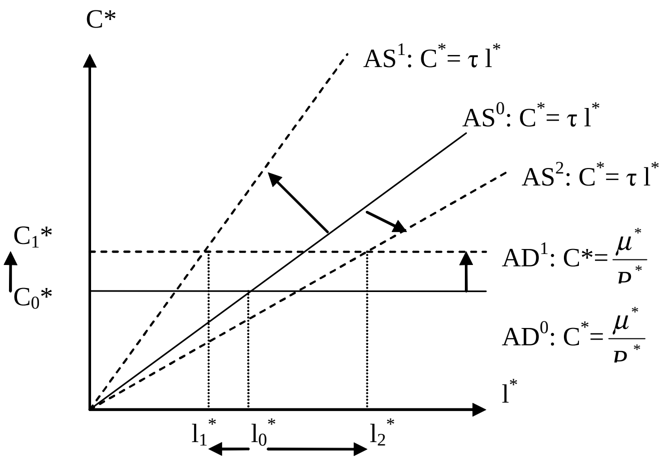

Figure 3.3 - The effect of oil price shocks on Foreign economy with nominal rigidities and PCP

3.3.3.2 Nominal rigidities and Local Consumer Pricing

With LCP and nominal rigidities the price indexes (P, P^*) are not affected by oil shocks, and the oil price elasticity of nominal exchange rate has an upward limit in the value of the oil share $(1-\alpha)$:

$$\varepsilon = \frac{\mu^*}{\mu}\left(1 + \frac{\theta}{\theta-1}\frac{1-\alpha}{2}\left(\frac{MC}{E\left[MC\right]} + \frac{\mu}{\mu^*}\frac{MC}{E\left[MC/\varepsilon\right]}\right)\right)$$

$$\frac{el\_\varepsilon}{el\_P_e} = (1-\alpha)\left[\frac{\frac{\theta}{\theta-1}\frac{1-\alpha}{2}\left(\frac{MC}{E[MC]} + \frac{\mu^*}{\mu}\frac{MC}{E[MC/\varepsilon]}\right)}{1 + \frac{\theta}{\theta-1}\frac{1-\alpha}{2}\left(\frac{MC}{E[MC]} + \frac{\mu^*}{\mu}\frac{MC}{E[MC/\varepsilon]}\right)}\right] \in [0, 1-\alpha)$$

Thus, while oil shocks still produce asymmetric effects across economies, as it can be easily shown with a graphical interpretation of the AS and AD schedule for both countries, it is not anymore possible for oil shocks to produce 'large' effect on th eeconomies.

$$AS \quad : \quad C_t = \frac{k}{\alpha}\frac{\mu_t}{MC_t}\left(\frac{\theta-1}{\theta}\right)^2\left(\frac{E\left[MC\right]^{\frac{1}{2}}E\left[MC/\varepsilon\right]}{E\left[\varepsilon MC^*\right]^{\frac{1}{2}}\left(E\left[MC/\varepsilon\right]+\frac{\mu^*}{\mu}E\left[MC\right]\right)}\right)L_t$$

$$AD \quad : \quad C_t = \frac{\mu_t}{P_t}$$

After an oil price shock, because of the increase in MC_t the AS schedule rotates downwards from AS^0 to AS^1, while the AD stays put. In the new equilibrium the level of Home consumption level is unchanged but the amount of labor supplied is higher (figure 4).[6]

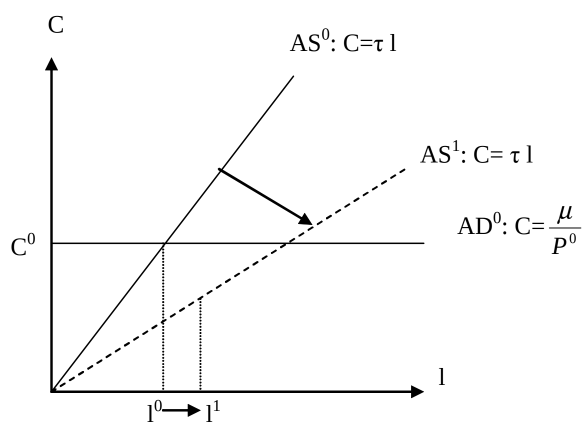

Figure 3.4 - The effect of oil price shocks on Foreign economy with nominal rigidities and LCP

The effect of oil shocks on Foreign is almost symmetric to that on Home economy. Indeed, even Foreign AD schedule is unaffected by oil price shocks, therefore there is no change in the equilibrium level of consumption. However, the AS schedule rotates downward but by less than for Home economy. In fact, while the increase in the price of oil tends to reduce the use of oil, the change in the nominal exchange rate, being the price of oil denominated in Home currency, reduces the size of the oil price shock for Foreign economy. Thus, in the new equilibrium the level of consumption stays put and the amount of labor increases, but by a less amount than for Home.

6

$$\frac{el\_C}{el\_P_e} = 0 \ ; \ \frac{el\_L}{el\_P_e} = (1-\alpha)\,.$$

$$\frac{el\_C^*}{el\_P_e} = 0 \ \ ; \ \ \frac{el\_L^*}{el\_P_e} = (1-\alpha)\left[1 - \frac{el\_\varepsilon}{el\_P_e}\right] < (1-\alpha)\,.$$

3.3.4 Using a Small open economy in the analysis of oil price shocks

In this section I show that a small open economy model tends to underestimates the impact of oil price shocks on GDP. This happens because small open economy models are unable to fully capture international spillovers, which in turn tend to amplify the effect of oil price shocks on economic activity. Indeed, as long as imports are used as intermediate inputs for domestic productions, the effect of oil shocks on GDP will pass not only through the supply side channel, but also through the interplay between imports and exports. In fact, after an oil shock foreign economies, by reducing their productions, will lower their demand of domestic imports, which thing implies a further reduction in the domestic aggregate demand.

It is straightforward to show it analytically by mean of small modifications to the model that have been developed in the previous section. In particular, I now assume that both the foreign currency value of Foreign imports and the foreign currency price of Foreign intermediate goods are exogenous. I consider only the flexible price regime and assume that Home and Foreign have a relative weight of the world economy equal to, respectively, β and $(1-\beta)$,where $\beta \in (0,1)$. I then compare the oil price elasticity of Home GDP computed with the small open economy model $\left(\frac{el\_GDP^{SOC}}{el\_P_e}\right)$ to that obtained in the general equilibrium model $\left(\frac{el\_GDP^{GE}}{el\_P_e}\right)$:

$$\frac{el\_GDP^{SOC}}{el\_P_e} = \beta\,(1-\alpha) < (1-\alpha) = \frac{el\_GDP^{GE}}{el\_P_e}$$

It is then evident that the use of a small open economy model, with respect to the general equilibrium model, underestimates the effect of oil prices on Home GDP the more the smaller is the weight of Home economy in the world (β).

3.4 Amplifying the effect of oil price shocks on GDP with a non-basic two-country model

The basic model that has been developed in the previous section can hardly explain how positive oil price shocks may cause GDP to fall by more than the oil share. In fact, for this to happen the basic model must assume nominal rigidities, a specific kind of price setting, and extremely large oil shocks.

In this section, I show that a two-country model, with a traded and a non-traded sector and sector specific capital, while does not allow me to get an analytical solution nonetheless allows me to obtain a 'large' response of GDP to oil price shocks even with flexible price. Differently from former multi-sector models that have been developed to analyse the oil-macroeconomy relationship, I do not assume a different technology across sectors. . Indeed, to explain the large effect of oil price shocks the crucial assumption is that the investment and the consumption good have a different composition in terms of traded and non-traded goods: consumption smoothing then causes input to reallocate across sectors, and the assumption of sector-specific capital amplifies the effect of oil shock on GDP and make it persistent.

The model I use is largely based on that I have already developed in chapter II, so that I remand to chapter II and the appendix for details about the introduction of nominal rigidities. In this section I briefly explain its main characteristics in reference to figure 5The model consists of two countries , Home and Foreign, inhabited by infinitely-lived households. The two countries are symmetric in every respect apart from the fact the oil is a Foreign-specific resource. Each country is represented by a competitive final good sector and a monopolistic competitive intermediate sector. The intermediate sector produces differentiated varieties of traded and non-traded goods through a CES production function which uses labor, capital and oil as inputs. The final good sector produces the consumption good by aggregating Home and Foreign traded goods and domestic non-traded goods. Labor is mobile within the country and immobile across countries. Capital is a sector-specific input complementary to oil (Finn 2000) whose price (P_e) is denominated in Home currency.

Households can trade in a country specific contingent bond, so that perfect risk sharing is assumed within each country. In addition, households share the same preferences and have the same initial level of wealth, therefore it is possible to assume a representative agent within each country. The characterization of the financial market is then completed with the introduction of an international one-period riskless bond denominated in Foreign currency.

3.4.1 Results

In what follows I present results for Home and Foreign GDP response to 1% positive shock to the real price of oil for different scenarios. In particular, I consider the flexible price case, the small open economy case and the nominal wage rigidities case.[7]

[7] The parametrization of the model is identical to that developed in chapter II section.

3.4.1.1 The flexible price case

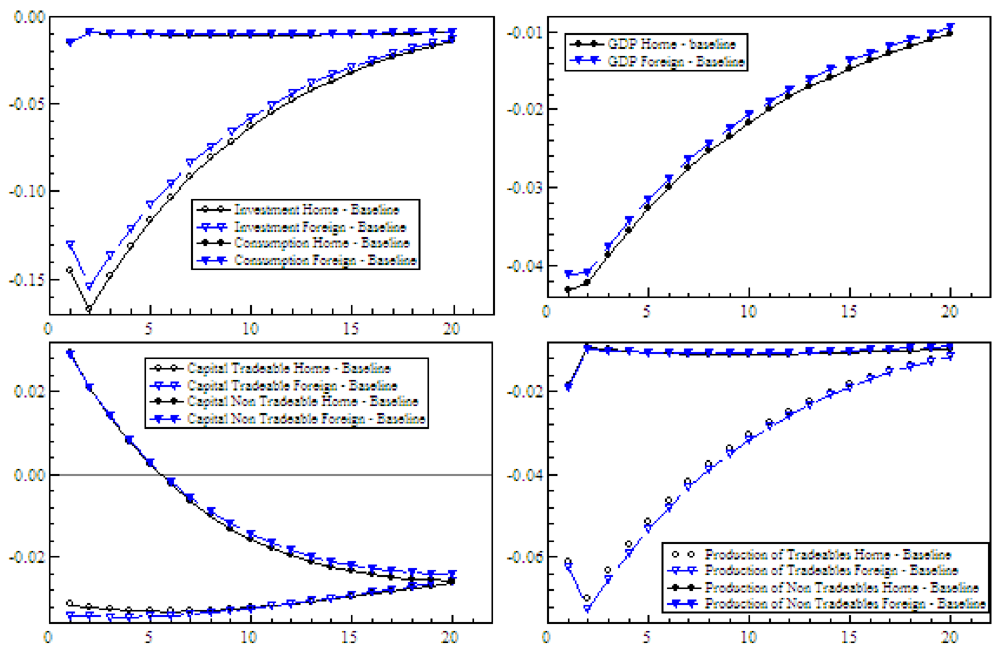

Figure 3.6 - IRFs to 1 % positive real oil price shock in the flexible price regime

The top right panel of Figure 3.6 shows Home and Foreign GDP response to a positive 1% shock to the real price of oil. In the basic model I have developed above, as well as in standard RBC models, without the introduction of ad-hoc mechanisms (i.e. endogenous markups, endogenous rate of depreciation) the maximum GDP fall predicted would be $\frac{1-oil\%}{oil\%}$, where $oil\%$ stands for the oil share in the economy. Given that in the model the oil share amounts to 2.7% of GDP, which is the average US energy share over the period 1947-2005, I would expect a maximum GDP fall equal to 2.78% after a 1% positive real oil price shock. I then observe that the model, even with flexible price, explains a fall in GDP which is 44% larger than that expected in basic models.

The other panels show how the mechanism through which the assumption of sector-specific capital amplifies the effect of oil shocks. The top-left panel shows how consumption smoothing implies a different reaction to oil price shocks of consumption and investment. As consumption and investments have a different composition in terms of traded and non-traded goods, also the production of traded and non-traded goods (bottom-right panel), and accordingly the amount of capital required in each sector (bottom-left panel), show different pattern in the reaction. Thus, as capital within any country cannot move freely from the traded to the non-traded good sector, the implied loss of efficiency in production in both sectors amplifies the fall of GDP beyond the oil share.

3.4.1.2 The response of GDP in the small open economy model

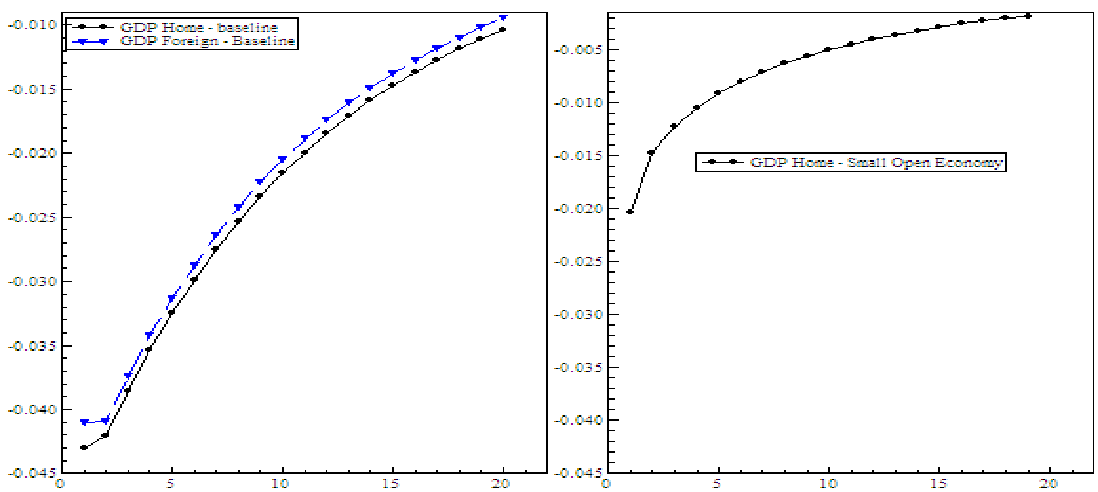

Figure 3.7 - IRFs to 1 % positive real oil price shock in the small open economy

Figure 3.7 compares Home GDP response to 1% positive oil price shock computed with the small open economy model to that obtained with the general equilibrium model. It is worth noting that the response of Home GDP is exactly halved with respect to the general equilibrium model, as it was predicted by the basic mode when the two countries have equal size.

3.4.1.3 The response of GDP with nominal rigidities

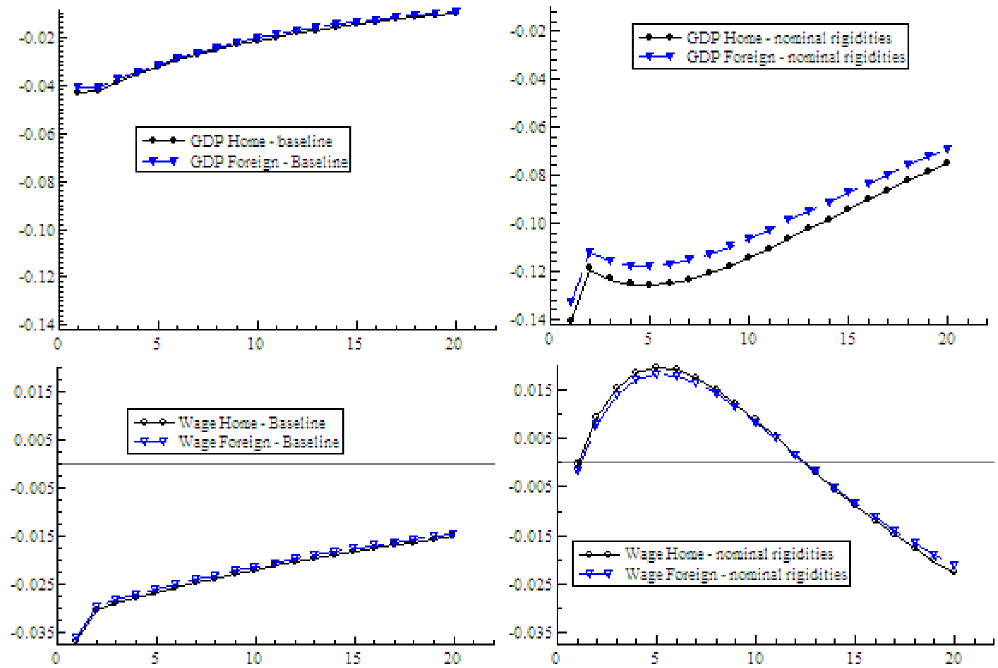

Figure 3.8 - IRFs to 1 % positive real oil price shock in the nominal wage rigidities regime

Figure 3.8 shows how the introduction of nominal wage rigidities dramatically amplifies the effect of oil price shock on GDP. In particular, I introduce in both countries quadratic costs of nominal wage adjustment à la Rotemberg. The response of Home and Foreign GDP to a 1% oil price shock with nominal rigidities (top-right panel) is then compared to that computed without nominal rigidities (top-left panel). It clearly emerges that with nominal rigidities the size of the through of GDP is three times as large as that with flexible price. But along with the size of the response of GDP it is also the persistence of the effects of the oil shock to be far larger.

The key of this results is on the response of real wage to oil price shock . Indeed, with flexible prices wage-setters find optimal to reduce nominal wage, and accordingly the real wage (bottom-left panel), and so buffer the recessive effects of positive oil price shocks. With nominal rigidities, instead, wage-setters find optimal to increase nominal wages in the first periods after the oil shock, and so also real wages (bottom-right panel), further amplifying the recessive effects of oil shocks. Finally, it is worth noticing that with nominal rigidities, even assuming an AR(1) for the real oil price, the reaction of real wages may imply, as in the case in figure 3.8, that the reaction of GDP be close to be hump-shaped, which is the standard pattern that is observed in empirical analysis.

3.5 Conclusion

In this paper I set up two theoretical models to analyse the effects of oil shocks on GDP in an open economy framework, and to show how a simple modification to standard modes may allowsfor oil price shocks to have the 'large' impact on GDP which is estimated in empirical analysis. The first model is a basic two-country model, which permits me to clearly describe the 'oil-macroeconomy' relationship in an open economy framework.

I notice that the basic model is able to capture some of the channels through which oil shocks affect the economy, namely the supply side channel, other than capturing the importance of international spillovers. However, the basic model is not able to explain an impact of oil shocks on GDP larger than the oil share in regime of flexible prices. I then consider the possibility of nominal rigidities, but result are ambiguous. On one side, nominal rigidities modify substantially the oil-macroeconomy relationship as the oil price elasticity of GDP becomes non-linear, so that the recessive effects of oil shocks become larger the larger the size of the oil shock. On the other side, the possibility for oil shocks to produce a 'large' impact on the economy is conditional on a specific price setting behaviours.

In the second model I show that a two country model with a traded and a non-tradedgoods sector and with sector specific capital is able to produce a 'large' effect of oil shock on GDP even in a regime of flexible prices. This results are based on a which hinges on the assumption of sector specific capital and on the working of consumption smoothing. Indeed, as consumption and investments have a different composition in terms of traded and non-traded goods, after an oil shock consumption smoothing will imply an input reallocation across sectors. Thus, as capital within any country cannot move freely across sectors, the implied loss of efficiency in production in both sectors causes a the GDP to fall beyond the oil share. Finally, I show that with the introduction of nominal wage rigidities the effect of oil shocks is even further amplified as wage setter do not find anymore optimal to reduce nominal wage to buffer the recessive effects of oil shocks.

Appendices

3.A: Equilibrium equations in the basic 2-country model

I report the equilibrium values of nominal exchange rate, consumption, labor and prices of both countries, under three different regime: flexible prices, nominal rigidities with PCP price setting and nominal rigidities with LCP price setting.

Set of equilibrium equations common to the three regimes

$$P_{H,t}H_t = P_{F,t}F_t = \frac{1}{2}P_tC_t \quad ; \quad P_H^{*,t}H_t^* = P_{F,t}^*F_t^* = \frac{1}{2}P_t^*C_t^*$$

$$P_t = 2P_{H,t}^{\frac{1}{2}}P_{F,t}^{\frac{1}{2}} \quad ; \quad P_t^* = 2P_{H,t^*}^{\frac{1}{2}}P_{F,t^*}^{\frac{1}{2}}$$

$$\mu_t = P_tC_t \quad ; \quad \mu_t^* = P_t^*C_t^*$$

$$Y_{H,t} = H_t + H_t^* = Z_tL_t^{\alpha}E_{N,t}^{1-\alpha} \quad ; \quad Y_{F,t} = F_t + F_t^* = Z_t^*L_t^{*\alpha}E_{N,t}^{*1-\alpha}$$

$$\frac{E_{N,t}}{L} = \frac{(1-\alpha)}{\alpha}\frac{k\mu}{P_e} \quad ; \quad \frac{E_{N,t}^*}{l^*} = \frac{(1-\alpha)}{\alpha}\frac{k\mu^*}{P_e^*}$$

$$\begin{aligned} MC &= \frac{(k\mu)^{\alpha}P_{e,t}^{1-\alpha}}{Z\alpha^{\alpha}(1-\alpha)^{1-\alpha}} \\ MC^* &= \varepsilon^{1-\alpha}\tilde{M}C^*;\ \tilde{M}C\frac{(k\mu^*)^{\alpha}P_{e,t}^{1-\alpha}}{Z^*\alpha^{\alpha}(1-\alpha)^{1-\alpha}} \end{aligned}$$

Equilibrium equations in the flexible price regime

$$\begin{aligned} P_t &= \left(2\frac{\theta}{\theta-1}\right)^{\frac{1}{\alpha}}\frac{k}{\alpha}\frac{\mu}{(1-\alpha)^{\frac{1-\alpha}{\alpha}}}\frac{p_{e,t}^{\frac{1-\alpha}{\alpha}}}{(Z_tZ_t^*)^{\frac{1}{2\alpha}}}\varphi^{\frac{1}{2}} \quad ; \quad P^* = \left(2\frac{\theta}{\theta-1}\right)^{\frac{1}{\alpha}}\frac{k}{\alpha}\frac{\mu^*}{\varphi^{\frac{1}{2}}(1-\alpha)^{\frac{1-\alpha}{\alpha}}}\frac{p_{e,t}^{\frac{1-\alpha}{\alpha}}}{(Z_tZ_t^*)^{\frac{1}{2\alpha}}} \\ P_t &= \left(2\frac{\theta}{\theta-1}\right)\left(\frac{k}{\alpha}\right)^{\alpha}\frac{\mu^{\alpha}}{(1-\alpha)^{1-\alpha}}\frac{P_{e,t}^{1-\alpha}}{(Z_tZ_t^*)^{\frac{1}{2}}}\varphi^{\frac{\alpha}{2}} \quad ; \quad P^* = \left(2\frac{\theta}{\theta-1}\right)\left(\frac{k}{\alpha}\right)^{\alpha}\frac{(\mu^*)^{\alpha}}{\varphi^{\frac{\alpha}{2}}(1-\alpha)^{1-\alpha}}\frac{P_{e,t}^{1-\alpha}}{(Z_tZ_t^*)^{\frac{1}{2}}} \end{aligned}$$

$$\varepsilon_t = \frac{\mu_t}{\mu_t^*}\left(\frac{1+\frac{\theta}{\theta-1}\frac{1-\alpha}{2}}{1-\frac{\theta}{\theta-1}\frac{1-\alpha}{2}}\right)$$

$$l_t = \frac{\alpha}{k}\frac{\theta-1}{\theta}\frac{1}{\left(1-\frac{\theta}{\theta-1}\frac{1-\alpha}{2}\right)} \quad ; \quad l_t^* = \frac{\alpha}{k}\frac{\theta-1}{\theta}\frac{1}{\left(1+\frac{\theta}{\theta-1}\frac{1-\alpha}{2}\right)}$$

$$E_{N,t} = (1-\alpha)\frac{\mu}{P_e}\frac{\theta-1}{\theta}\frac{1}{\left(1-\frac{\theta}{\theta-1}\frac{1-\alpha}{2}\right)} \;\; ; \;\; E_{N,t}^* = (1-\alpha)\frac{\mu}{P_e}\frac{\theta-1}{\theta}\frac{1}{\left(1+\frac{\theta}{\theta-1}\frac{1-\alpha}{2}\right)}\left(\frac{1+\frac{\theta}{\theta-1}\frac{1-\alpha}{2}}{1-\frac{\theta}{\theta-1}\frac{1-\alpha}{2}}\right)$$

$$C_t = \frac{(Z_t Z_t^*)^{\frac{1}{2\alpha}}\,\alpha\,(1-\alpha)^{\frac{1-\alpha}{\alpha}}}{kp_{e,t}^{\frac{1-\alpha}{\alpha}}\,\varphi^{\frac{1}{2}}}\left(\frac{\theta-1}{2\theta}\right)^{\frac{1-\alpha}{2}} \quad ; \quad C_t^* = \frac{(Z_t Z_t^*)^{\frac{1}{2\alpha}}\,\alpha\,(1-\alpha)^{\frac{1-\alpha}{\alpha}}}{kp_{e,t}^{\frac{1-\alpha}{\alpha}}}\varphi^{\frac{1}{2}}\left(\frac{\theta-1}{2\theta}\right)^{\frac{1-\alpha}{2}}$$

3.B: Equilibrium equations in the PCP nominal rigidities regime

$$\varepsilon = \frac{\mu}{\mu^*}\left(\frac{E[MC]/MC+\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}{E[MC]/MC-\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}\right).$$

$$C = \frac{1}{2}\frac{\theta-1}{\theta}\frac{(\mu\mu^*)^{\frac{1}{2}}}{(E(MC)\,E(MC^*))^{\frac{1}{2}}}\left(\frac{E[MC]/MC-\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}{E[MC]/MC+\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}\right)^{\frac{1}{2}}$$

$$C^* = \frac{1}{2}\frac{\theta-1}{\theta}\frac{(\mu\mu^*)^{\frac{1}{2}}}{(E(MC)\,E(MC^*))^{\frac{1}{2}}}\left(\frac{E[MC]/MC+\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}{E[MC]/MC-\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}\right)^{\frac{1}{2}}$$

$$l = \frac{\frac{\alpha}{k}\frac{\theta}{\theta-1}}{E[MC]/MC-\frac{\theta}{\theta-1}\frac{(1-\alpha)}{2}}$$

$$l^* = \frac{1}{2}\frac{\alpha}{k}\frac{(\mu)^{\frac{3}{2}-\alpha}}{(\mu^*)^{\frac{1}{2}-\alpha}}\frac{\left(E[MC]/MC-\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}\right)^{\frac{1}{2}-\alpha}}{\left(E[MC]/MC+\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}\right)^{\frac{3}{2}-\alpha}}\frac{(E[MC])^{\frac{1}{2}}}{(E[MC^*])^{\frac{3}{2}}}\frac{\tilde{M}C^*}{MC}$$

$$l^* = \frac{\theta}{\theta-1}\frac{\alpha}{k}\left(\frac{\mu}{\mu^*}\right)^{1-\alpha}\frac{\left(E[MC]/MC-\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}\right)^{1-\alpha}}{\left(E[MC]/MC+\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}\right)^{2-\alpha}}\left(\frac{E[MC]/MC}{E[MC^*]/\tilde{M}C^*}\right)C^*$$

The effect of oil shocks on the AS schedule

Proposition 3.1 *In the standard case* $\left(E\left[MC\right]/MC > \frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}\right)$ *a positive oil price shock tends to rotate downwards the Home AS schedule*

Proof. *To prove it is enough to show that* $\frac{\partial\tilde{\tau}}{\partial P_e} < 0$:

$$\begin{aligned}\frac{\partial\tilde{\tau}}{\partial P_e} &= -l\frac{k}{\alpha}\left(\mu\mu^*\right)^{\frac{1}{2}}\frac{E\left[MC\right]^{\frac{3}{2}}}{E\left[MC^*\right]^{\frac{1}{2}}}\frac{(1-\alpha)}{P_e}\frac{E\left[MC\right]}{MC}\left(\frac{E\left[MC\right]/MC-\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}{E\left[MC\right]/MC+\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}\right)^{\frac{1}{2}} \\ &\quad \underbrace{\left(\frac{3}{2}-\frac{1}{2}\underbrace{\left(\frac{E\left[MC\right]/MC-\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}{E\left[MC\right]/MC+\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}\right)}_{A}\right)}_{B}\end{aligned}$$

The term $A\left(\frac{E[MC]/MC-\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}{E[MC]/MC+\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}\right)$ *is in (0,1) because I assume* $E\left[MC\right]/MC > \frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}$. *Thus the sign of* $B\left(\frac{3}{2}-\frac{1}{2}\left(\frac{E[MC]/MC-\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}{E[MC]/MC+\frac{\theta-1}{\theta}\frac{(1-\alpha)}{2}}\right)\right)$ *is positive, and* $\frac{\partial\tilde{\tau}}{\partial P_e} < 0$. ■

3.C: Equilibrium equations in the LCP nominal rigidities regime

$$\begin{aligned}P_H &= \frac{\theta}{\theta-1}E\left[MC\right] \quad ; \quad P_{H^*} = \frac{\theta}{\theta-1}E\left[\frac{MC}{\varepsilon}\right] \\ P_F^* &= \frac{\theta}{\theta-1}E\left[MC^*\right] \quad ; \quad P_F = \frac{\theta}{\theta-1}E\left[\varepsilon MC^*\right]\end{aligned}$$

$$\varepsilon = \frac{\mu^*}{\mu}\left(1+\frac{\theta}{\theta-1}\frac{1-\alpha}{2}\left(\frac{MC}{E\left[MC\right]}+\frac{\mu}{\mu^*}\frac{MC}{E\left[MC/\varepsilon\right]}\right)\right)$$

$$l = \frac{1}{2}\frac{\alpha}{k}\frac{MC}{\mu}\frac{\theta}{\theta-1}\left[\frac{\mu}{E\left[MC\right]}+\frac{\mu^*}{E\left[MC/\varepsilon\right]}\right]$$

$$l^* = \frac{1}{2}\frac{\alpha}{k}\frac{MC^*}{\mu^*}\frac{\theta}{\theta-1}\left[\frac{\mu}{E\left[MC^*\right]}+\frac{\mu^*}{E\left[\varepsilon MC\right]}\right]$$

$$C = \frac{1}{2}\frac{\theta}{\theta-1}\left(\frac{1}{E\left[MC\right]^{\frac{1}{2}}E\left[\varepsilon MC^*\right]^{\frac{1}{2}}}\right)$$

$$C^* = \frac{1}{2}\frac{\theta}{\theta-1}\left(\frac{E\left[MC\right]^{\frac{1}{2}}E\left[MC/\varepsilon\right]}{E\left[\varepsilon MC^*\right]^{\frac{1}{2}}}\right)\frac{1}{\varepsilon^{\alpha}}$$

The effect of oil shocks on the AS schedule

Proposition 3.2 *A positive oil price shock tends to rotate downwards the Home AS schedule*

Proof. To prove it is enough to show that $\frac{\partial \tilde{\tau}}{\partial P_e} < 0:$ ■

$$AS: \; C = \frac{k}{\alpha}\frac{\mu}{MC}\left(\frac{\theta-1}{\theta}\right)^2 \left(\frac{E\left[MC\right]^{\frac{1}{2}} E\left[MC/\varepsilon\right]}{E\left[\varepsilon MC^*\right]^{\frac{1}{2}}\left(E\left[MC/\varepsilon\right] + \frac{\mu^*}{\mu}E\left[MC\right]\right)}\right) l = \tilde{\tau} l$$

$$\frac{\partial \tilde{\tau}}{\partial P_e} = -\frac{(1-\alpha)}{P_e}\tilde{\tau} \Longrightarrow \frac{el\_\tilde{\tau}}{el\_P_e} = -(1-\alpha) < 0$$

Proposition 3.3 *A positive oil price shock tends to rotate downwards the Foreign AS schedule but by a less amount than the Home AS schedule*

Proof. To prove it is enough to show that $\frac{el\_\tilde{\tau}}{el\_P_e} < \frac{el\_\tilde{\tau}^*}{el\_P_e} < 0:$ ■

$$AS: C^* = \frac{k}{\alpha}\mu^*\left(\frac{\theta-1}{\theta}\right)^2 \left(\frac{E\left[MC^*\right]^{\frac{1}{2}} E\left[MC^*\varepsilon\right]}{E\left[MC/\varepsilon\right]^{\frac{1}{2}}\left(E\left[MC^*\right] + \frac{\mu}{\mu^*}E\left[MC^*\varepsilon\right]\right)}\right) \frac{\varepsilon^{1-\alpha}}{M\tilde{C}^*} l^* = \tilde{\tau}^* l^*$$

$$\frac{\partial \tau^*}{\partial P_e} = \frac{k}{\alpha}\mu^*\left(\frac{\theta-1}{\theta}\right)^2 \left(\frac{E\left[MC^*\right]^{\frac{1}{2}} E\left[MC^*\varepsilon\right]}{E\left[MC/\varepsilon\right]^{\frac{1}{2}}\left(E\left[MC^*\right] + \frac{\mu}{\mu^*}E\left[MC^*\varepsilon\right]\right)}\right) \left[\frac{(1-\alpha)\,\varepsilon^{-\alpha}\frac{\partial \varepsilon}{\partial P_e}M\tilde{C}^* - (1-\alpha)\,\varepsilon^{1-\alpha}}{\left(M\tilde{C}^*\right)^2}\right.$$

$$= \tau^*(1-\alpha)\frac{1}{P_e}\left[\frac{\partial \varepsilon}{\partial P_e}\frac{P_e}{\varepsilon} - 1\right] \Longrightarrow \frac{el\_\tilde{\tau}^*}{el\_P_e} = -(1-\alpha)\left[1 - \frac{el\_\varepsilon}{el\_P_e}\right] > -(1-\alpha) = \frac{\partial \tilde{\tau}}{\partial P_e}$$

3.D: The Small Open Economy Case

In the small open economy case the Home economy has weight β and the consumption baskets is:

$$C = C_H^{\beta} C_F^{1-\beta}$$

From cost minimization I obtain the demand for the Home basket of intermediate good C_H and for the Foreign basket of intermediate goods C_F :

$$\begin{aligned}
& \min \; P_H C_H + P_F C_F \\
st\; C &= C_H^{\beta} C_F^{1-\beta} \\
C_H &= \left(\frac{P_H}{P}\right)^{-1} \beta C \; ; \; C_F = \left(\frac{P_F}{P}\right)^{-1} (1-\beta) C \\
\frac{C_H}{C_F} &= \frac{\beta}{1-\beta} \frac{P_F}{P_H} \\
P &= \frac{P_H^{\beta} \left(P_F\right)^{1-\beta}}{\beta^{\beta} \left(1-\beta\right)^{31-\beta}}
\end{aligned}$$

By taking the value of exports in foreign currency value as given, I assume that Foreign spends a fixed amount of foreign currency in imports from Home $P_H^* H^* = \bar{E}xp$

$$\varepsilon = \frac{P_F F + P_e E_N}{P_H^* H^*} = \frac{P_F F + P_e E_N}{\bar{E}xp}$$

The price of Foreign goods in Foreign country is also given

$$\begin{aligned}
P_F^* &= \bar{P}_F^* \\
P_F &= \varepsilon \bar{P}_F^*
\end{aligned}$$

It follows that GDP in equilibrium is equal to:

$$C^{SOE} = \frac{\beta^{\beta} \left(1-\beta\right)^{1-\beta} Z^{\beta}}{k^{\alpha\beta} \left(\varepsilon \bar{P}_F^*\right)^{1-\beta}} \left(\frac{\theta-1}{\theta}\right)^{\beta} \left(\frac{1}{P_e}\right)^{\beta(1-\alpha)}$$

Proposition 3.4 *A a small open economy approach induces to undervalue the effect of oil price shocks on GDP.*

Proof. By using the oil elasticity of GDP to measure the size of the impact of oil shocks I show that

$$\frac{el\_C^{SOE}}{el\_P_e} = \beta\left(1-\alpha\right) < \left(1-\alpha\right) = \frac{el\_C^{GE}}{el\_P_e}$$

■

3.E: The extended model with nominal rigidities

Households

Population is normalised to 1, and a generic household j must decide the flow of Consumption (C_{t+i}), Investment (I_{t+i}), sector-specific capital $(K_{H,t+1+i},\; K_{N,t+1+i})$, nominal wage

(W_{t+i}), domestic Bond (B_{t+1+i}) and international Bonds (B^*_{t+1+i}) to maximise the present value of the flow of instant utilities subject to the flow of intertemporal budget constraints and the laws of motion of sector-specific capital:

$$\underset{\{C_t,I_t,K_{t+1},W_t,B_{t+1},B^*_{t+1}\}}{Max} E_t\sum_{i=0}^{\infty}\beta^i\left[\frac{(C_{t+i}(j))}{1-\sigma}+\tau\frac{(1-L_{t+i}(j))^{1+\gamma}}{1+\gamma}\right],\ s.t.$$

$$\begin{aligned} & B_{t+i+1}(j)+\varepsilon_{t+i}B^*_{t+i+1}(j)-\varepsilon_{t+i}B^*_{t+i}(j)(1+i^*_{t+i})\left(1-\Sigma_{t+i}\right)-B_{t+i}(j)(1+i_{t+i}) \\ = \; & W_{t+i}(j)L_{t+i}(j)-P_{t+i}C_{t+i}(j)-P^I_{t+i}I_{t+i}(j)+R_{N,t+i}K_{N,t+i}(j)+R_{H,t+i}K_{H,t+i}(j) \\ & +\Pi^f_{t+i}(j)+\Pi^b_{t+i}(j) \end{aligned}$$

or, in case of nominal wage adjustment costs:

$$\begin{aligned} & B_{t+i+1}(j)+\varepsilon_{t+i}B^*_{t+i+1}(j)-\varepsilon_{t+i}B^*_{t+i}(j)(1+i^*_{t+i})\left(1-\Sigma_{t+i}\right)-B_{t+i}(j)(1+i_{t+i}) \\ = \; & W_{t+i}(j)L_{t+i}(j)\left(1-\Omega_t(j)\right)-P_{t+i}C_{t+i}(j)-P^I_{t+i}I_{t+i}(j)+R_{N,t+i}K_{N,t+i}(j)+R_{H,t+i}K_{H,t+i}(j) \\ & +\Pi^f_{t+i}(j)+\Pi^b_{t+i}(j) \\ \Omega_t(j) \; = \; & \frac{\phi_w}{2}\left(\frac{W_t(j)}{W_{t-1}(j)}-\pi\right)^2,\ \phi_w>0^8 \end{aligned}$$

$$\begin{aligned} K_{H,t+i+1}(j) &= K_{H,t+i}(j)(1-\delta)+I_{H,t+i}(j) \\ K_{N,t+i+1}(j) &= K_{N,t+i}(j)(1-\delta)+I_{N,t+i}(j). \end{aligned}$$

$\beta\in(0,1)$ is the intertemporal discount factor, $\sigma>0$ is the inverse of the intertemporal elasticity of substitution, $\gamma>0$ and $\tau>0$ characterize the labor disutility, $\delta\in(0,1)$ is the depreciation rate, $P_{t+i}$is the price of a unit of consumption good C_{t+i}, $P^I_{t+i}$is the price of a unit of investment good I_{t+i}, i_{t+i} and i^*_{t+i} are, respectively, the nominal interest rate set by Home and Foreign monetary policy authorities, $R_{H,t+i}$ and $R_{F,t+i}$ are the nominal rates of return on capital in the traded and non traded good sector, $B_{t+i+1}(j)$ is the value of the stock of Home contingent bond held by household j, $B^*_{t+i+1}(j)$ is the value of the stock of international bond held by household j, $\Pi^f_{t+i}(j)$ is the household share of profits from the intermediate sector. $\Pi^b_{t+i}(j)$ the household share of profits from the financial transaction sector. Financial transaction costs, Σ_{t+i}, are defined as follows:

$$\Sigma_{t+i}=\phi^1_\Sigma\frac{\exp\phi^2_\Sigma(\varepsilon_{t+i}B^*_{t+i}/P_{t+i-1})-1}{\exp\phi^2_\Sigma(\varepsilon_{t+i}B^*_{t+i}/P_{t+i-1})+1},$$

and depend on the real value of the stock of international bond held by Home at the beginning of the period $t+i$ $\left(\frac{B_{t+1}}{P_{t+1}}\right)$ and on the parameters $\phi_{\Sigma}^{1} > 0$ and $\phi_{\Sigma}^{2} \in [0, 1]$.

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