WHAT IF OIL IS LESS SUBSTITUTABLE? A NEW-KEYNESIAN MODEL WITH OIL, PRICE AND WAGE STICKINESS INCLUDING CAPITAL ACCUMULATION

Verónica Acurio Vásconez, Université Paris 1 Panthéon – Sorbonne, Paris School of Economics, 0033 6 27 52 75 82,
Veronica.Acurio-Vasconez@malix.univ-paris1.fr

Overview

The recent literature has stated that energy is a critical input in industrialized economies, and that it is not perfectly substitutable to other production factors. In Fouré et al. (2012), Hassler et al. (2012), van-der Werf (2008) and Kander & Stern (2012) among others, energy (or fossil energy) is introduced in the production function through a constant elasticity of substitution (CES) function with two factors: energy and a Cobb-Douglas combination of capital and labor. Each of these papers exhibits different estimations for the energy elasticity of substitution with respect to labor and capital in different combinations, with values ranging from 0.004 to 0.64. However, all papers reject the assumption of a substitution elasticity equals to one.

In Dynamic Stochastic General Models (DSGE) that include oil and focus on the macroeconomics effects of oil shocks, to my knowledge, either the models are calibrated as in Blanchard & Galí (2009), or estimated but oil and the other factors are considered easy substitutes for oil as in the model developed in Acurio-Vásconez et al. (2015), or estimated but oil is not considered as a factor of production as in Kormilitsina (2011), else imperfect substitutability is introduced but no estimation is performed as in Montoro (2012). In Blanchard & Riggi (2013) model, an estimation using minimum distance estimation techniques is performed for some of the model parameters in two cases, assuming a Cobb-Douglas and a Leontief production function. Capital however is not included in Blanchard & Riggi (2013). Moreover, none of these DSGE models is able to recover four of the well known stylized facts which followed the oil shocks of the 2000s': the absent of recession, coupled with a low but persistent increase in inflation rate, a decrease in real wages, and a low price elasticity of oil demand in the short term, all at the same time.

In order to shed some new light onto these questions, this paper enlarges the model developed in Acurio-Vásconez et al. (2015), where oil is incorporated into a DSGE model through a Cobb-Douglas function in the consumption flow and in the production function of intermediate firms. The production function I use here is an integrated CES function, constructed as in Hassler et al. (2012) and re-normalized as in Cantore & Levine (2012). This function includes oil, which is fully imported from a foreign economy, and a Cobb-Douglas combination of labor and capital. On the household's side, I use a basic CES function that integrates final goods and oil to define the consumption flow.

The model is estimated using Bayesian methods, with quarterly U.S. data over the period 1984:Q1 - 2007:Q1. The estimated oil's elasticity of substitution are 0.14 in production and 0.51 in household consumption. These values exhibit the fact that oil is weakly substitutable to other quantities in both sectors, especially in the production sector. Another significant result of estimation is the posterior mean of oil's output elasticity at steady state, which is estimated at 0.06.

The impulse response function analysis shows that the model is able to recover and explain four well-known stylized facts after an oil price shock in the 2000s' detailed before. Thus this paper identifies yet another channel to explain why we did not observe the stronger impact on GDP after the oil shock of the 2000s'. If oil is not easily substitutable and if it is fully imported, an increase in its price causes firms to produce more in order to pay for the oil bill, in that way most of the domestic production and oil importation cancel each other out. Then the reaction of GDP to an oil shock could be nearly nil. It could even be positive, depending on the reaction of the rental rate of capital, which in turn depends on the endogenous reaction of monetary policy to an oil shock.

A sensitivity analysis shows that a decrease in nominal wage rigidity in the estimated model, ceteris paribus, could lead to an increase in real wages, which then leads to higher prices, confining households to a worse trade-off between consumption and investment, in favor of investment. Then a stronger increase in domestic output takes place, but because of the low substitutability, oil should increase as well. This oil increase should not be problematic as long as the U.S. economy can import as much oil as it wants. However, in a world where oil supply has entered a period of increased scarcity, the consequences could be a loss of output as shown in Kumhof & Muir (2014), Bezdek et al. (2005), Reynolds (2002), among others.

Methods

The model is constructed in a New-Keynesian framework. It assumes a small open economy where oil is imported from a foreign country at an exogenous price. The model consists of three sectors: Households, Firms and Government.

A typical household, consumes both oil and domestic goods, tied together by a CES function. It also supplies a differentiated service to the production sector, invests in government bonds and capital, pays taxes, and receives profits from the firms in the economy. In the sector of the firms there is a representative final good firm that will use the intermediate goods, produced by the intermediate firms, in order to create the final good that will be sold to the consumers. For the sake of simplicity no oil is needed for the creation of the final good. The intermediate firms use oil, capital and labor in order to create the intermediate good. The production function is a CES, which includes oil and a composite factor formed by a Cobb-Douglas combination of labor and capital. The model also includes a Government sector with spendings and a Central Bank that sets the nominal short-term interest rate by a monetary policy. Finally the model is estimated using 8 macro series and 8 shocks, which are: real oil price, real capita price, government expending, TFP, oil productivity, wage markup and price markup shock.

Results

Regarding the estimated of the main behavioral parameters, it turns out that the mean value for the oil's elasticity of substitution is equal to 0.14 in production and 0.51 in consumption. This result confirms the fact that the elasticity of substitution of oil and other factors in US is very low, in both sectors. In addition, the estimated steady state for the output elasticity is 6.8%. Turning to the estimated processes for the exogenous shock variables a number of observations are worth making.

The impulse response function analysis recovers four well-known stylized facts after an oil price shock in the 2000s': the absent of recession, coupled with a low but persistent increase in inflation rate, a decrease in real wages, and a low price elasticity of oil demand in the short term, all at the same time. This paper identifies another channel to explain why we did not observe the stronger impact on GDP after the oil shock of the 2000s': Domestic output increases in order to pay for the increased oil bill. Finally, a sensitivity analysis shows that a decrease in nominal wage rigidity, ceteris paribus, could lead to an increase in real wages, which then leads to an increase in inflation and so a decrease in domestic consumption.

Conclusions

In recent years, the inclusion of energy or oil into theoretical models has seen a rapid development, but still some questions and factors have not yet been taken into account. One of these factors is oil substitutability. To my knowledge, no DSGE model that includes energy or oil has been able to recover at the same time most of the effects that the 2000's oil shock generated in the U.S. economy. My assumption is that one possible reason for the lack of understanding is the assumption of a perfectly substitutable oil. Using a DSGE model this factor is now taken into account through the introduction of oil in the production and in the consumption sides. Using Bayesian techniques and U.S data from 1984:Q1 to 2007:Q3, it can be proved that the elasticity of substitution in U.S between oil and other factors is weak, results that are in line with empirical studies on the subject. On the other hand, once the low substitutability has been introduced, the model is able to recover four well-known stylized facts after an oil price shock in the 2000s': the absence of recession, coupled with a low level of inflation rate, a decrease in real wages and a low price elasticity of oil demand. It also shows that with a less persistent monetary policy, GDP could suffer a contemporaneous slight decrease after an oil shock. Finally, a reduction of wage rigidity amplifies the response of the economy to an oil shock in terms of inflation and consumption and shows that the increase obtained in GDP is possible under the assumption that there exists the possibility to import as much as oil as needed.

References

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