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OPEC's Oil Exporting Strategy and Macroeconomic (In)Stability*

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Abstract

Aguiar-Conraria and Wen (2008) argued that dependence on foreign oil raises the likelihood of equilibrium indeterminacy (economic instability) for oil importing countries. We argue that this relation is more subtle. The endogenous choices of prices and quantities by a cartel of oil exporters, such as the OPEC, can affect the directions of the changes in the likelihood of equilibrium indeterminacy. We show that fluctuations driven by self-fulfilling expectations under oil shocks are easier to occur if the cartel sets the price of oil, but the result is reversed if the cartel sets the quantity of production. These results offer a potentially interesting explanation for the decline in economic volatility (i.e., the Great Moderation) in oil importing countries since the mid-1980s when the OPEC cartel changed its market strategies from setting prices to setting quantities, despite the fact that oil prices are far more volatile today than they were 30 years ago.

Keywords: Equilibrium indeterminacy; Oil; OPEC Strategy; Great Moderation

JEL Codes: E3, F4, L1, Q4

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1 Introduction

The empirical literature has suggested that oil price shocks have an important effect on economic activity (see, e.g., Hamilton, 1983, 1996, and 2003; Burbidge and Harrison, 1984; Gisser and Goodwin, 1986; Aguiar-Conraria and Wen, 2007; and Kilian, 2008). It is also known that there was a structural change for the macroeconomic impact of oil, which occurred at some point in the mid-1980s (see, e.g., Mork, 1989; Hooker, 1996; Hamilton, 1996 and 2003; and Aguiar-Conraria and Soares, 2011). This has been interpreted as evidence of a nonlinear or time-varying relationship between oil prices and economic activity.

We do not dispute these interpretations. However, we do call attention to a change in the behavior of the Oil Price Exporting Countries (OPEC) that occurred in the mid-1980s. On their official website, it is written that "OPEC did in fact set crude oil prices from the early 1970s to the mid-1980s", but that they stopped doing so thereafter. We also read that OPEC imposes production quotas to its members and meets twice a year to define their oil production policies. This change in OPEC's behavior is not unexpected. Deneckere (1983), Majerus (1988), Rothchild (1992) and Lambertini and Schultz (2003) argue that, as long as the produced goods are substitutes for each other, a quantity-setter cartel is more stable than a price-setter. Given that crude oil extracted in any particular country is a perfect substitute for crude oil extracted in other countries, it is optimal for the cartel to rely on quantities as the control variable.

It is known that tariffs and quotas are not equivalent instruments; unless perfect competition is assumed everywhere in both domestic and foreign markets (see Bhagwati, 1965). From the perspective of the exporters, it is also known that setting prices and setting production quotas are not equivalent (e.g. see Weitzman, 1974; and Cooper and Riezman, 1989). Given that 60% of the crude oil traded internationally comes from OPEC members, their strategic decisions are bound to have important implications. In this paper we study the implications of such behavior on equilibrium indeterminacy.

Aguiar-Conraria and Wen (2008) argued that dependence on foreign oil raises the likelihood of equilibrium indeterminacy. In this paper, we show that this result depends crucially on the cartel's choice of the control variable: price or quantity. To be more precise, we show that different cartel strategies create different macroeconomic propagation mechanisms for oil shocks. If the exporting cartel fixes the price of oil, then the likelihood of macroeconomic indeterminacy in the importing country is dramatically increased, while exactly the reverse happens if the cartel chooses to fix the quantity of oil production.

2 The Importance of Equilibrium Indeterminacy

Dynamic Stochastic General Equilibrium (DSGE) models are one of the modern workhorses in macroeconomics. In standard DSGE models with perfect competition and constant returns, there exists a unique rational expectations equilibrium. Therefore, there is no independent role for beliefs to influence the economic fundamentals. However, the pioneering work of Benhabib and Farmer (1994) has shown that a standard neoclassical growth model with externalities or increasing returns to scale may exhibit a continuum of rational expectations equilibria — equilibrium indeterminacy. In such models, beliefs can be self-fulfilling and affect resource allocations in equilibrium, thus can serve as an independent source of the business cycle. However, this first generation of belief-driven business cycle models was considered empirically implausible because they required externalities larger than empirical estimates. Subsequent works have shown that features such as additional sectors of production, durable consumption goods, small open economy, variable capacity utilization, high elasticity of substitutions between capital and labor can reduce the degree of externalities required for indeterminacy to an empirically plausible range (see, e.g., Wen, 1998; Benhabib, Nishimura and Meng, 2000; Weder, 2001; Meng and Velasco, 2003; Meng, 2003; Bian and Meng, 2004; Pintus, 2006; and Wang and Wen, 2008; among many others).[1]

[1]For a general analysis of this class of models regarding mechanisms giving rise to local indeterminacy, see Wen (2001). For the broader literature on sunspots and self-fulfilling propechies, please see Shell (1977, 1987), Cass and Shell (1983), Shell and Smith (1992), Azariadis (1981), Azariadis and Guesnerie (1986), and Woodford

Equilibrium indeterminacy implies that optimism and pessimism about the future can be self-fulfilling. In such a model, a fear or speculation of an increase in the imported oil price, say due to political instability in the foreign country, can trigger pessimism, generating a recession (Aguiar-Conraria and Wen, 2008). Economies with equilibrium indeterminacy will, ceteris paribus, exhibit higher volatility than an economy with equilibrium determinacy.

It is now a well-received stylized fact that the volatility of GDP has significantly decreased since the mid-1980s in the United States and other industrialized countries (e.g. see McConnell and Pérez-Quirós, 2000; Blanchard and Simon, 2001; and Gallegati and Gallegati 2007; among others). If one could make a case arguing that developed economies had equilibrium indeterminacy before the mid-1980s, then this would be an intriguing explanation for the Great Moderation after the mid-1980s.[2]

There is a second important implication of equilibrium indeterminacy. Aguiar-Conraria and Wen (2007) showed that the macroeconomic propagation mechanism for oil shocks was quite different in a model with indeterminacy from a standard model. In fact, an endogenous multiplier-accelerator mechanism can emerge, giving rise to persistent and hump-shaped fluctuations in aggregate output. For example, after a negative oil-price shock, output not only decreases in the impact period but also continues to decrease over time until a turning point, leading to a deeper and U-shaped slump. However, after the turning point the propagation mechanism reverses itself, leading to a cumulative process of recovery and expansion. This type of fluctuations is not to be expected in a model with equilibrium determinacy. Given that the propagation mechanism is so different from that of standard DSGE models, optimal monetary policy is also expected to be different. Nakov and Pescatori (2010) provide some evidence that oil shocks may have had a prominent role in explaining the 'Great Moderation'. Our argument in this paper provides yet another explanation for why this might be the case.

(1986a, 1986b, 1991).

[2] A related point was made by Lubik and Schorfheide (2004), who concluded that the U.S. monetary policy before 1982 was consistent wity indeterminacy, while after 1982 it was consistent with a unique rational expectations equilibrium.

3 The Model

Our baseline model is a continuous time version of Aguiar-Conraria and Wen (2007 and 2008). In the model a representative agent[3] chooses a trajectory of consumption (c_t), working hours (n_t), capacity utilization (u_t), quantity of oil demand (e_t), and capital accumulation ($\dot{k}_t$) to solve:

$$\max_{c,n,u,e,k} \int_0^\infty \exp(-\rho t) \left(\log(c_t) - \frac{n_t^{1+\gamma}}{1+\gamma} \right) dt \tag{1}$$

subject to

$$\dot{k}_t = -\delta_t k_t + y_t - c_t - p_t e_t \tag{2}$$

$$y_t = \Phi_t (u_t k_t)^{\alpha_k} n_t^{\alpha_n} e_t^{\alpha_e}, \qquad \alpha_k, \alpha_n, \alpha_e \geq 0, \text{ and } \alpha_k + \alpha_n + \alpha_e = 1 \tag{3}$$

$$\delta_t = \frac{1}{\theta} u_t^\theta, \;\; \theta > 1; \tag{4}$$

where p_t denotes oil price and e_t the quantity of imported oil. The agent pays $p_t e_t$ in terms of output to foreigners to receive oil imports. Note that this is not a model of international trade. The international trade balance is always zero. Foreigners are paid in goods. This is clear in the budget constraint, according to which domestic production is divided between consumption, investment and oil imports. So part of what is produced domestically is used to pay for the imports ($p_t e_t$). This is the interpretation of Finn (2000), Wei (2003) and Aguiar-Conraria and Wen (2007 and 2008) in similar models. The rate of capital depreciation, δ_t, is time varying and is endogenously determined in the model by equation (4), which states that capital depreciates faster if used more intensively. Agents take as given the aggregate productivity Φ_t:

$$\Phi_t = (u_t k_t)^{\alpha_k \eta} n_t^{\alpha_n \eta} e_t^{\alpha_e \eta}. \tag{5}$$

[3] Our representative-agent model can be mapped into a decentralized Dixt-Stiglitz style model where heterogeneous firms are monopolists with increasing returns technology. For details of such a mapping, see Benhabib and Wen (2004).

With this assumption, note that the economy exhibits increasing returns to scale of degree $1+\eta$. From the standard first order conditions, we can obtain the optimal demand equation for oil:

$$p_t e_t = \alpha_e y_t. \tag{6}$$

To close the model, we consider two extreme assumptions (we will relax them later) about the oil producer's decision. Our first hypothesis states that the oil cartel is a quantity-setting cartel and, therefore, prices will adjust. In this scenario, the oil importing country will take the quantity of oil as given: $e_t = \bar{e}$. Our second hypothesis assumes that the cartel fixes prices: $p_t = \bar{p}$.

The first order conditions with respect to $\{c_t, n_t, e_t, u_t, k_t\}$ and the budget constraint can be simplified to the following system:

$$\frac{\dot{c}_t}{c_t} = \left(\frac{\theta-1}{\theta}\alpha_k\frac{y_t}{k_t} - \rho\right) \tag{7}$$

$$\dot{k}_t = \left(\alpha_k\frac{\theta-1}{\theta} + \alpha_n\right) y_t - c_t \tag{8}$$

$$c_t = \alpha_n\frac{y_t}{n_t^{1+\gamma}} \tag{9}$$

$$u_t = \left(\alpha_k\frac{y_t}{k_t}\right)^{\frac{1}{\theta}} \tag{10}$$

$$y_t = Ak_t^{(1+\eta)\tau_k\alpha_k} n_t^{(1+\eta)\tau_n\alpha_n} e_t^{(1+\eta)\tau_e\alpha_e}, \tag{11}$$

where, $\tau_k \equiv \frac{(\theta-1)}{(\theta-(1+\eta)\alpha_k)}$, $\tau_n = \tau_e \equiv \frac{\theta}{(\theta-(1+\eta)\alpha_k)}$, and A is a constant.

Assuming that $e_t = \bar{e}$, and substituting this into equation (11), we derive the reduced-form production function:

$$y_t = B(\bar{e})k_t^{\tau_k(1+\eta)\alpha_k} n_t^{\tau_n(1+\eta)\alpha_n}, \tag{12}$$

where the coefficient $B(\bar{e})$ depends on and increases with $\bar{e}$.

If we assume $p = \bar{p}$ instead and substitute $e_t = \frac{\alpha_e y_t}{\bar{p}}$ in the production function (11), we can derive an alternative reduced-form production function:

$$y_t = C(\bar{p}) k_t^{\frac{\alpha_k(1+\eta)\tau_k}{1-\alpha_e(1+\eta)\tau_n}} n_t^{\frac{\alpha_n(1+\eta)\tau_n}{1-\alpha_e(1+\eta)\tau_n}}, \tag{13}$$

where $C(\bar{p})$ depends negatively on $\bar{p}$. In both cases, solving the above system of equations in the steady state gives the following steady-state values and ratios:

$$\frac{y^*}{k^*} = \frac{\rho}{\alpha_k} \frac{\theta}{\theta - 1} \tag{14}$$

$$\frac{c^*}{y^*} = \alpha_k \left(\frac{\theta - 1}{\theta}\right) + \alpha_n \tag{15}$$

$$\frac{c^*}{k^*} = \frac{\rho \left(\left(\theta - 1\right) \alpha_k + \theta \alpha_n\right)}{\left(\theta - 1\right) \alpha_k} \tag{16}$$

$$n^* = \left(\frac{\theta \alpha_n}{\left(\theta - 1\right) \alpha_k + \theta \alpha_n}\right)^{\frac{1}{1+\gamma}} \tag{17}$$

$$\delta^* = \frac{\rho}{\theta - 1}. \tag{18}$$

The results are formalized in the following proposition:

Proposition 1 *The cartel strategy does not affect the steady-state values.*

The intuition behind this proposition is simple: in a world without aggregate uncertainty (shocks), the cartel's behavior is irrelevant. However, the picture changes if we consider the dynamics of the model away from the steady state.

3.1 Dynamic Analysis I: Fixing Quantity

Taking the imported quantity of oil, $\bar{e}$, as given, the reduced-form production function is given by equation (12). Note that the higher the share of oil, the lower the effective returns to scale on capital and labor: $\tau_k \left(1 + \eta\right) \alpha_k + \tau_n \left(1 + \eta\right) \alpha_n$. It is known from the literature that higher increasing returns facilitate the existence of indeterminacy, therefore one would expect that the larger the share of imported oil the larger the necessary true returns to scale $(1+\eta)$ in order to have indeterminacy. We formalize this in the following proposition:

Proposition 2 *If the quantity of imported oil is taken as exogenous, the necessary and sufficient conditions for local indeterminacy are given by*

$$\frac{1-\alpha_k}{\alpha_k} > \eta > \frac{\theta\left(1+\gamma\right)-\alpha_n\theta-\alpha_k\left(1+\gamma\right)}{\alpha_n\theta+\alpha_k\left(1+\gamma\right)}. \tag{19}$$

Proof. Linearizing the first order conditions around the steady-state and simplifying, we get a system of two linear differential equations,

$$\begin{pmatrix} \dot{c}_t \\ \dot{k}_t \end{pmatrix} = M_Q \begin{pmatrix} c_t \\ k_t \end{pmatrix}. \tag{20}$$

The model exhibits local indeterminacy if and only if the real part of the eigenvalues of M_Q are both negative. This is true if and only if the determinant of M_Q is positive and the trace of M_Q is negative. For the determinant, after some algebra one concludes that

$$\det\left(M_Q\right) > 0 \quad \iff \quad \frac{\left(1-\tau_k\left(1+\eta\right)\alpha_k\right)\left(1+\gamma\right)}{\tau_n\left(1+\eta\right)\alpha_n-\left(1+\gamma\right)} > 0. \tag{21}$$

Which, in turn, is equivalent to

$$\frac{1-\alpha_k}{\alpha_k} > \eta > \frac{\theta\left(1+\gamma\right)-\alpha_n\theta-\alpha_k\left(1+\gamma\right)}{\alpha_n\theta+\alpha_k\left(1+\gamma\right)}. \tag{22}$$

For the trace, one gets that

$$Tr\left(M_Q\right) = \frac{-\left(\left(\theta-1\right)\left(1+\gamma\right)\alpha_k+\theta\alpha_n\gamma\right)\left(1+\eta\right)\rho}{\alpha_n(1+\eta)\theta-\left(1+\gamma\right)\left(\theta-\left(1+\eta\right)\alpha_k\right)}. \tag{23}$$

The numerator is negative, so $Tr(M) < 0$ if the denominator is positive. This is the case if and only if

$$\eta > \frac{\theta(1+\gamma) - \alpha_n\theta - \alpha_k(1+\gamma)}{\alpha_n\theta + \alpha_k(1+\gamma)}, \tag{24}$$

which is the same as the second inequality of (19). ■

For any set of realistic values, the binding constraint is this second inequality. An increase in α_e, holding either α_n or α_k constant, will increase the term on the right hand side, making indeterminacy harder to occur.

3.2 Dynamic Analysis II: Fixing Prices

Take the price of oil, $\bar{p}$, as given. Introducing equation (5) and $u = \left(\alpha_k \frac{y}{k}\right)^{\frac{1}{\theta}}$ into the production function, we get the reduced-form production function in equation (13). We can see there that reliance on imported oil amplifies the true returns to scale. Formally, we have:

Proposition 3 *If the price of imported oil is exogenous, the necessary and sufficient conditions for local indeterminacy are given by*

$$\frac{\alpha_n}{1-\alpha_n} > \eta > \frac{\theta(1+\gamma)(1-\alpha_e) - \alpha_n\theta - \alpha_k(1+\gamma)}{\alpha_n\theta + (\alpha_k + \alpha_e\theta)(1+\gamma)}. \tag{25}$$

Proof. See Aguiar-Conraria and Wen (2008). ■

For plausible parameter values the first inequality on the left-hand side of the above equation is not binding. Based on the inequality on the right-hand side, we conclude that, keeping either α_n or a_k constant, the larger the share of imported oil the smaller the required externalities for the model to exhibit local indeterminacy.

3.3 Calibration Exercise

Propositions 2 and 3 tell us that whether a country's reliance on imported oil increases or decreases its probability of indeterminacy depends crucially on the market strategy of the oil producers: if the cartel fixes oil prices, then the required externalities for local indeterminacy is lowered, while the reverse happens if the cartel fixes quantity of oil supply. We calibrate the model to check the magnitude of such effects. We set the inverse labor supply elasticity $\gamma = 0$ (Hansen's indivisible labor), the rate of time preference $\rho = 0.01$, $\theta = 1.4$ (implying $\delta^* = 0.025$), and the labor elasticity of output $\alpha_n = 0.65$.

Table 1. Required Returns to Scale for Indeterminacy

Oil Share (α_e)	Price Setting Cartel	Quantity Setting Cartel
0%	1.111	1.111
5%	1.094	1.157
10%	1.077	1.207

The cost share of imported oil in GDP is between 2% to 8% for several western economies (see Aguiar-Conraria and Wen 2008). Returns to scale in many industrial countries are around 1.1. For example, Laitner and Stolyarov (2004) found a value of between 1.09–1.11 for the United Sates; Inklaar (2007) estimated 1.16 for Germany and 1.12 for France; Hansen and Knowles (1998) found 1.105 for high income OECD countries; Miyagawa et al. (2006) found 1.075 for Japan; and Kwack and Sun (2005) 1.1 for South Korea.

Table 1 shows that, depending on the cartel's market strategies of price setting or quantity setting, reliance on imported oil can significantly change a country's likelihood of indeterminacy, thereby making the country more (or less) susceptible to sunspots-driven fluctuations and to having a hump-shaped propagation mechanism under oil shocks. For example, the middle row in Table 1 shows that a country with returns to scale in the order of 1.1 and with oil imports that account roughly for 5% of GDP (like the Netherlands or Portugal) will have equilibrium indeterminacy if the cartel sets the price, and will have a unique rational expectations equilibrium if the cartel sets the quantity.

3.4 Intermediate Case

In reality, there is no oil cartel that controls the entire production of oil or natural gas in the world. Even if it were the case, it is one thing to control the total amount of oil exports and another to define the amount of oil that each country can import. Our previous results were based on extreme assumptions about the cartel behavior. In one case, we assumed that the quantity was fixed and that the price would freely adjust. This assumption implies zero price elasticity for oil. In another case, we assumed that price was fixed and that quantities would freely adjust, which implies an infinitely elastic supply curve for oil. Now, we relax these extreme assumptions and allow for an imperfectly elastic supply of oil. This is probably a more realistic assumption which should give the reader more confidence in our results.

To incorporate an imperfectly elastic supply, we assume that oil is supplied by a monopolist whose objective function is to maximize profit:

$$\Pi^f = p_t e_t - \frac{d}{1+z} e_t^{1+z}, \tag{26}$$

where the cost function of oil is convex ($z \in [0, \infty]$). Given the demand function of oil from the home country, $p_t e_t = \alpha_e y_t$, profit maximization implies that the supply curve for oil is given by

$$p_t = \frac{d}{\alpha_e} e_t^z, \tag{27}$$

where $1/z$ measures the elasticity of supply.

Proceeding as before, it is easy to show that when supply meets demand, the home country's reduced-form production function becomes:

$$y_t = D k_t^{\frac{\alpha_k (1+\eta)\tau_k}{1-\frac{\alpha_e}{1+z}(1+\eta)\tau_n}} n_t^{\frac{\alpha_n (1+\eta)\tau_n}{1-\frac{\alpha_e}{1+z}(1+\eta)\tau_n}}, \tag{28}$$

with D depending negatively on the cost parameter d.

The two extreme cases we studied above are the limiting cases of the above production function either as $z \to 0$ (fixed price) or as $z \to \infty$ (fixed quantity). Therefore, the exact relationship between oil's cost share in GDP and the likelihood of indeterminacy depends on the value of the elasticity of supply.

Proposition 4 *If oil is supplied by a monopolist, the necessary and sufficient conditions for local indeterminacy are given by*

$$\frac{1-\left(\frac{\alpha_e}{1+z}+\alpha_k\right)}{\left(\frac{\alpha_e}{1+z}+\alpha_k\right)} > \eta > \frac{\theta\left(1+\gamma\right)\left(1-\frac{\alpha_e}{1+z}\right)-\alpha_n\theta-\alpha_k\left(1+\gamma\right)}{\alpha_n\theta+\left(\alpha_k+\frac{\alpha_e}{1+z}\theta\right)\left(1+\gamma\right)}. \tag{29}$$

Proof. The proof is similar to proofs of Propositions 2 and 3. ■

Again, for realistic values, the first inequality on the left-hand side of the above equation is not binding. Looking at the second inequality, we can see that the share of imported oil on local indeterminacy depends on parameter z.

Assuming that foreign oil is mainly a substitute for capital, hence when α_e increases, α_n remains constant and α_k decreases, then for $z > \theta - 1$ an increase of α_e will increase the term in the right hand side of equation (29), so indeterminacy is harder to arise. If $z < \theta - 1$, then indeterminacy becomes easier to arise. If $z = \theta - 1$, the impact is null. If we assume that imported oil is mainly a substitute for labor, the threshold value for z is γ. So the larger is α_e the harder is for indeterminacy to occur, as long as $z > \gamma$.

Therefore, the main implications of propositions 2 and 3 survive: if oil supply is less elastic then indeterminacy is less likely to occur. The result is reversed for a more price elastic supply curve.

4 Conclusion

This paper studies the consequence of reliance on foreign oil for macroeconomic (in)stability. We showed that the likelihood of equilibrium indeterminacy is a function of the market strategy of the oil exporting countries. In particular, indeterminacy arises more easily for oil importing countries if the oil cartel sets prices and the reverse is true if it sets quantities.

We are perfectly aware that our model is highly stylized, at least in four aspects. (i) It does not model international trade. Instead it assumes balanced trade (imports are fully paid in goods). This simplification avoids dealing with exchange rates and endogenous demand for the exported goods of oil importing countries. (ii) It does not model the behavior of the oil exporting cartel in a game theoretic framework. (iii) There is no endogenous oil supply or production in the oil-importing country. (iv) The mobility of labor and capital across borders is not considered. Our results may hinge on these assumptions. Extending the model to include standard features of an open economy and allow domestic production of oil and factor mobility is left as a future research topic.

In spite of these simplifications, we believe that our results are sufficiently interesting. We showed that the relation between oil-dependence and equilibrium indeterminacy is more subtle than what was described in Aguiar-Conraria and Wen (2008). Aguiar-Conraria and Wen (2008) concluded that the stronger the dependence on foreign oil the larger the likelihood of indeterminacy. In this paper we showed that this is true only if one assumes that oil exporters act like a cartel that fixes the price of oil (or at least if the supply curve is very price elastic). If, instead, oil exporters fix the quantity then the result is completely reversed — indeterminacy becomes much more unlikely. Using the information provided by OPEC, we know that OPEC's market strategy has changed in the 1980s. Combining that information with the implications of our model, it is possible that the U.S. economy has moved from a state of equilibrium indeterminacy to a state of equilibrium determinacy. This implication provides an alternative explanation to the Great Moderation.

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