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Modelling the world oil market: Assessment of a quarterly econometric model

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Abstract

This paper describes a structural econometric model of the world oil market that can be used to analyse oil market developments and risks. Oil demand depends on domestic economic activity and the real price of oil. Oil supply for non-OPEC producers, based on competitive behaviours, is constrained by geological and institutional conditions. Oil prices are determined by a "price rule" that includes market conditions and OPEC behaviour. Policy simulations indicate that oil demand and non-OPEC supply are rather inelastic to changes in price, while OPEC decisions about quota and capacity utilisation have a significant, immediate impact on oil prices.

Keywords: Oil market; Econometric modelling; Forecasting

1. Introduction

The oil shocks of the 1970s and 1980s prompted theoretical advances in energy economics (Griffin, 1993), many of which were used to model the world oil market. Standard structural energy models that simulated energy flows in physical terms remained important for international organisations (see e.g. Cozzi, 2004; European Commission, 1995), but the bulk of oil price-related studies conducted in the 1990s analyzed the links between oil prices and macroeconomic activity by applying new econometric techniques (e.g. VAR and VECM models).

Recent price increases for oil combined with—and partly due to—geopolitical pressures and high demand have re-ignited interest in structural explanations of oil price formation based on market equilibrium (Krichene, 2002). Standard practice models the world oil market in terms of a supply–demand equilibrium schedule (e.g. Bacon, 1991; Al Faris, 1991). This approach has proved difficult due to characteristics specific to the oil market. Although a demand curve that relates quantities to prices can accurately represent oil demand, modelling supply is more difficult because oil is supplied by both a set of independent producers (non-OPEC nations) that act as price takers and an organization (OPEC) that uses a myriad of factors to determine levels of production and installed capacity. These aspects of OPEC production, along with changes in market conditions and OPEC behaviour, affect real oil prices (Kaufmann et al., 2004).

Here, we address these particularities with a quarterly model for the world oil market that includes a pricing rule and demand and supply schedules for different regions of the world. To model supply, we distinguish between non-OPEC and OPEC production behaviours. Non-OPEC behaviour is assumed to be competitive (but subject to geological and institutional constraints), while OPEC production is modelled using various behaviours that are described in an extensive literature (see Smith, 2005 for a brief review). Among the behaviours described, two can be identified as corner solutions: a cartel model, in which OPEC is the price maker, and a competitive model, in which OPEC is a price taker. Efforts to choose among these behaviours focus in part on identifying the slope of OPEC's supply curve. A negative relationship between price and production has been interpreted as a backward bending supply curve, which indicates that OPEC sets

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production based on some type of non-competitive behaviour. Econometric analyses of these relationships indicates that production by individual OPEC nations and OPEC as a whole "Granger causes" oil prices but prices generally do not "Granger cause" production (Kaufmann et al., 2004). More recent research indicates that individual OPEC nations do increase production in response to higher prices, but this response can be overwhelmed by changes in OPEC quotas and production sharing behaviours (Kaufmann et al., in review). In other words, OPEC functions somewhere between the two corner solutions. To simulate this intermediate degree of "real-world" control over the world oil market, the effect of both market conditions and OPEC behaviour on oil prices often is modelled with a "price rule." Such a rule gives the price at which OPEC is ready to act as a swing producer, given new demand conditions and market indicators that reflect the effect of behaviour by the dominant producer.

The rest of this paper is organised as follows. Section 2 describes the general structure of the model. Section 3 discusses the econometric methodology and reports estimation results for the demand, supply and price equations. Section 4 assesses the model in terms of forecast performance and simulation properties. The final section summarises the major findings.

2. General structure of the model

The present model for world crude oil consists of three blocks given by equations for demand, supply, and prices (Fig. 1). In this section, we present the general structure of the model, details of the econometric estimates are described in the next section. Specifically, this section does not describe the stochastic structure of the model.

2.1. Oil demand

Oil demand equations are estimated for ten main trading partners of the euro area; the US, Japan, UK, Euro area, Switzerland, other developed economies, non-Japan Asia, Transition economies, Latin America, and rest of the world. For each region, oil demand is a log-linear function of real *GDP*, real oil prices, and a time trend that represents technical changes, which affect energy efficiency.

The general specification for the econometric equations of oil demand is given by

$$DEM_i = \Phi\left(Y_i, \frac{POIL}{P_i^D} E_i, time\right) \quad (1)$$

in which DEM_i is oil demand in physical units for each country/region i, Y_i is real *GDP*, *POIL* is the oil price in USD, E_i the exchange rate vis-à-vis the US dollar and P_i^D is an index for domestic prices. All variables are in logarithms. As described in the estimation section, specification (1) represents the long-term determinants of demand. The regression errors from Eq. (1) are used to estimate error-correction models, in which lagged effects and short-term dynamics determine quarterly changes in demand.

2.2. Oil supply

We distinguish between the supply behaviour of OPEC and non-OPEC nations. The former can be modelled using either a cooperative behaviour, in which OPEC matches production to demand or a competitive behaviour, in which OPEC produces oil commensurate with its operable capacity. Non-OPEC production has a significant effect on OPEC's share of the world oil supply and, as a consequence, on OPEC's ability to influence prices. Production by non-OPEC countries is modelled using a technique that assumes competitive behaviour is constrained by geological and institutional factors.

2.1. OPEC supply

The model is set up to simulate two forms of OPEC production behaviour: cooperative and competitive production. Cooperative behaviour can be used to describe OPEC production since the third quarter of 1986 (Kaufmann, 1995). During that period, OPEC generally set production to match the difference between world oil demand and non-OPEC production. This behaviour can be simulated with the following equation:

$$PROD^{\text{opec}} = \sum_i DEM_i + \Delta S\text{tocks}^{\text{oecd}} - \text{NGLS} - \sum_j PROD^{\text{non-opec}} - \text{PG} \quad (2)$$

in which $\text{Stocks}^{\text{oecd}}$ is the level of stocks reported by OECD, NGLS the natural gas liquids, and PG the processing gains.

Alternatively, the model can simulate competitive behaviour by OPEC nations. Following this behaviour, OPEC nations compete among themselves and with non-OPEC producers for market share. To compete for market share, OPEC increases production to rates that are consistent with operable capacity. To account for competitive production behaviours, OPEC production is simulated using the following equation:

$$PROD^{\text{opec}} = 0.95 * Capacity^{\text{opec}} \quad (2')$$

in which *Capacity* is operable capacity (million barrels per day) of OPEC.[1] As described in the next section, OPEC capacity is exogenous. Competitive behaviour described by Eq. (2′) implies that production does not match demand. Oil produced in excess of demand is put into stocks, which depresses oil prices via the price rule that is described in the next section. When the model is simulated assuming competitive behaviour by OPEC, the price rule does not use the 95 percent rate of capacity utilisation that is dictated by Eq. (2′). Instead, the rate of capacity utilisation used by the price rule is calculated based on the call for OPEC oil that is given by Eq. (2).

[1]Data from Erik Kreil from the US Department of Energy.