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Re-examining uranium supply and demand: New insights

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ABSTRACT

In this paper, we derive a simultaneous system of equations which aims at analysing the uranium supply and demand. In addition to reviewing and updating previous studies dealing with the uranium market analysis, in particular Amavilah (1995), the contribution of the paper lies in putting attention to some questions which are still either controversial or unanswered. They are especially related to the controversial hypothesis of the interdependence between uranium market and other commodities markets, both, with respect to the demand side, *i.e.* oil and coal markets, and the supply side, *i.e.* gold market. The paper also casts lights on electricity and uranium price effects on uranium demand as well as on the simultaneous interdependencies that may exist between nuclear consumption and nuclear installed capacity.

The model is estimated for three different time periods which takes into account the major events that have influenced the nuclear-uranium development, that is, that have constrained the growth rate of nuclear generating capacity, *i.e.* oil crisis and nuclear accidents. This permits to show if uranium market reaction is independent or it is correlated with specific events associated with each time periods. The model was estimated by using the 3SLS method that correct for the presence of contemporaneously error terms correlation and for the existence of simultaneity bias in the model.

Main results give evidence of significant correlation between uranium price and competing fossil fuel prices. They also point-out that uranium price is significantly correlated with the supply forces where supply is significantly dependent on gold prices. Moreover, results show that the electricity prices have a significant effect on the uranium demand only in the post-1990 period, probably following the worldwide electricity prices increasing trend. Further, our estimations show that uranium demand is significantly correlated with uranium price only in the period of nuclear major expansion. As for the nuclear electric consumption and the nuclear installed capacity, results show that they are simultaneously correlated and that the uranium demand depends on both of them, but only for the pre-1990 period. Interestingly, our results give evidence of low elasticities and inelastic reaction of independent model variables to exogenous variables fluctuations, except for the uranium price equation.

Based on these results, some policy implications related to, first, the competitiveness of the uranium market and, second, to the supply–demand policy and the associated pricing mechanisms on the uranium market are discussed.

1. Introduction

The first oil crisis and the subsequent debates about energy security issues were the first crucial drivers for putting interest into nuclear energy potential as one alternative energy option giving the possibility for significant baseload power production.[1] Such interest was revived within the framework of recurrent debates about climate change issues owing to the fact that nuclear energy is a non-carbon-emitting energy option. As a consequence, several studies have been interested in analysing the prospectives for a worldwide nuclear expansion and the possible environmental consequences and energy security implications of such an expansion, especially in terms of reducing CO_2 emissions and enhancing nations own energy independence (see for example Chae et al., 1995; Barré, 1998; Sato et al., 1998; Sailor et al., 2000; Van der Zwaan, 2002, 2004, 2008; Uyterlinde et al., 2009; Esposto, 2008; Chakravorty et al., 2009).

However, owing to the high capital cost of nuclear energy,[2] a particular attention was given in those studies to discuss its

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[1] In order to maximize the return on high fixed capital cost of nuclear plants, reactors are usually operated over as many hours of the day as possible. Thus, they are generally used in order to provide baseload power rather than peak power.

[2] In fact, the most important feature of nuclear energy is that nuclear power plants have high capital cost but low operating costs. WNA (2003), MIT (2003), WNA (2008) and OECD/NEA (2008) argue that the capital costs contribute typically about 60% to the total cost of nuclear power generation, while operation and maintenance

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Table 1
Summary of empirical studies on uranium market.

Reference	Model characteristics		Focus of analysis	Major results
	Market scale	Time period		
Basheer Ahmed (1979)	US	1977–2000	Modelling the uranium mining and milling industry behaviour, and forecasting for uranium prices and outputs for the period going from 1977 to 2000.	The lagged uranium price has no significant effect on exploratory drilling. Drilling efforts exert a positive effect on addition to uranium discovery. Uranium price is significantly and negatively correlated with uranium reserves. Nuclear installed capacity does not exert a significant effect on uranium price. Uranium prices are expected to double during the period 1980–2000, but without causing any exponential increase in costs of nuclear electricity.
Owen (1984)	US	1966–1981	Explaining uranium consumption, forward commitments, mine production, contract prices and spot prices, and forecasting for the period going from 1984 to 1986.	The short-run uranium supply response to price variations is significant but inelastic. No significant correlation between uranium price and uranium demand can be correlated. Uranium spot price significantly depends on the ratio of inventories to consumption, whereas the contract price depends significantly on spot price. The latter is, however, insensitive to the ratio of forward commitments to total generating capacity indicating the proportion of future requirements which have been satisfied. The total generating capacity determines the forward commitments.
Trieu et al. (1994)	Global	1977–1991	Analysing the price formation in the uranium spot market, generating projections for prices and Australian uranium export, and simulating the effect of change in market conditions on Australian uranium exports.	Uranium spot prices are very sensitive to variations in the excess of supply. Uranium stocks were expected to reduce in a way which may lead to a gradual price increase after 1993. The magnitude of such increase were expected to depend on the new supply entering from non-traditional markets.
Amavilah (1994)	Global	1965–1989	Analysing effects of oil and coal prices on uranium demand.	Uranium prices are significantly correlated to coal prices but not to oil prices. Uranium prices as well as uranium lagged value have no significant effect on the uranium demand. However, the latter seems to be significantly correlated to nuclear generating capacity.
Amavilah (1995)	Global	1965–1989	Analysing effects of competing fossil fuels prices and nuclear electric consumption on the supply–demand behaviour.	The uranium prices are significantly correlated to coal prices but not to oil prices. The uranium prices as well as the uranium lagged value have no significant effect on the uranium demand. However, the latter seems to be significantly correlated to nuclear electricity consumption as well as to nuclear generating capacity.

competitiveness and possible prospectives for cost decrease (see for example WNA, 2003; Tolley and Jones, 2004; OECD/IEA/NEA, 2005; WNA, 2008; Yangbo and Parsons, 2009). Several other issues inherent in nuclear energy development have also been usually analysed such as waste management, proliferation risk and safety constraints. Nevertheless, a less discussed question deals with the uranium market.

The uranium supply and demand research has been -and is still- limited. Only a small number of studies[3] have been interested in the uranium supply–demand modelling although the uranium market stability is one crucial factor for successful nuclear energy expansion, mainly within the current framework of recurrent debates about "nuclear renaissance". As well as we know, other than empirical studies performed by Basheer Ahmed (1979), Owen (1984, 1985), Trieu et al. (1994) and Amavilah (1994, 1995), there is no more recent empirical papers analysing issues inherent to the uranium supply and demand interdependencies as well as their relationships with nuclear installed capacity and nuclear electricity consumption (*cf.* Table 1 for a summary of main features of these papers). Indeed, the uranium physical availability, the small contribution of uranium price to the total cost of nuclear power generation,[4] the long low and stable uranium price period from the beginning of the 1980s until the beginning of 2000s, the decline of the nuclear installed capacity growth rate after the Tchernobyl accident in 1986, and the subsequent everlasting controversial debates about future nuclear expansion have acted in a way to limit the empirical analysis of uranium supply–demand issues.

To revive the interest in uranium supply–demand analysis, we propose in this paper to derive and estimate a simultaneous system of equations which aims at analysing the uranium supply–demand. In addition to reviewing and updating previous studies on the uranium market, in particular (Amavilah, 1995), the contribution of the paper lies in the estimation of the model and the comparison of results for three different time periods which takes into account the major events that have influenced the nuclear-uranium development and, as a consequence, that have constrained the growth rate of nuclear generating capacity.

In particular, the first time period goes from 1970 to 2007 and aims at giving an overall retrospective sight on the uranium market. The second time period goes from 1970 to 1990 and corresponds to the nuclear major growth period. During this time period, several events have deeply disturbed the uranium market and, accordingly, the nuclear development. Indeed, in 1973 the OPEC oil embargo, combined with the prospect of an increasing oil

(*footnote continued*)
(O&M) and fuel cycle costs contribute about 20–25% and 15–20%, respectively. In particular, the levelized cost of nuclear electricity (LCOE) distribution is quite different from those of other energy sources. For instance, while the capital costs are the most significant component of the nuclear LCOE, for gas and coal LCOE, it is fuel costs. Typically, they represent between 50 to 80% of the total cost. In this context, MIT (2003) and Tolley and Jones (2004) show that the capital cost contribution per kW h to the total nuclear electricity cost ranges from 1500$/kW h to 2000$/kW h, while it, respectively, ranges from 500$kW h to 590$/kW h and from 1189$kW h to 1300$/kW h for gas and coal electricity. DGEMP (2003), Tarjanne and Luostarinen (2004), RAE (2004) and Ayres et al. (2004) give results which are sensitively similar.

[3] Uranium market issues are usually discussed in the annual world nuclear association symposium held each year in London. For symposium proceedings collection (starting from 1997), interested reader can refer to: http://www.world-nuclear.org/sym/subindex.htm.

[4] This contribution does not go beyond 5–7% (IEA, 2005; OECD/NEA, 2008; Percebois, 2008).