ENDOGENOUS MODELING APPROACHES FOR A LONG-TERM COAL MODEL

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Overview

Since autumn 2006 European steam coal prices have more than doubled. Between October 2007 and July 2008 steam coal prices rose from 100 United States Dollars [USD] to 170 [USD] per tonne (CIF ARA). Similar price evolutions could also be observed in the other fossil fuel markets and in the energy market. With these figures it is quite clear that a short-term model to forecast steam coal prices is interesting and useful. A short-term model has been developed named World Coal Model (WCM). The horizon of WCM is between 2000 and 2010. The model is based on a bottom-up approach. A linear programming method is used to calculate the minimum of a cost function consisting of production costs and transport as well as port and loading costs and constrained by production, transport and port capacities. Discount rate, exchange rate and inflation rate have been taken into account. The outputs of the model are mainly the marginal costs in different areas of the world (Japan, South Africa, Australia, Indonesia, Europe, etc.) and the quantities transported. WCM does not take into account any investment. The production capacities of the different mines located around the world are fixed figures. New capacities cannot be developed if a huge peak of demand appears. Therefore the development of a long-term Capacity Expansion Model (CEM) is required. The CEM will have to be capable to calculate new capacities and long-term marginal costs. The software tool will be integrated in a chain of decisions to shape the future optimal power generation system.

Methods

The horizon of CEM is between 2000 and 2035. For the first release of the CEM we wished to keep the same economical (a perfectly competitive market assumption), mathematical and computational framework used for the short-term model WCM. This implied to keep a determinist and linear framework with a GAMS environment. GAMS (General Algebraic Modelling System) is an open source software developed by GAMS Development Corporation in the USA. New capacities are created by minimizing a cost function composed of production and investment costs. The production costs are attached to the produced quantities (variable q) while the investment costs are attached to the new capacities (variable k). The variable q is constrained by the existing capacities and the new ones (variable k) that will be found by the model during the calculation. The CEM module produces long-term marginal costs, coal volumes produced and transported and the new capacities build (investment to face the demand). The new capacities calculated by the CEM module can be sent to the WCM module in order to get short-term marginal costs.

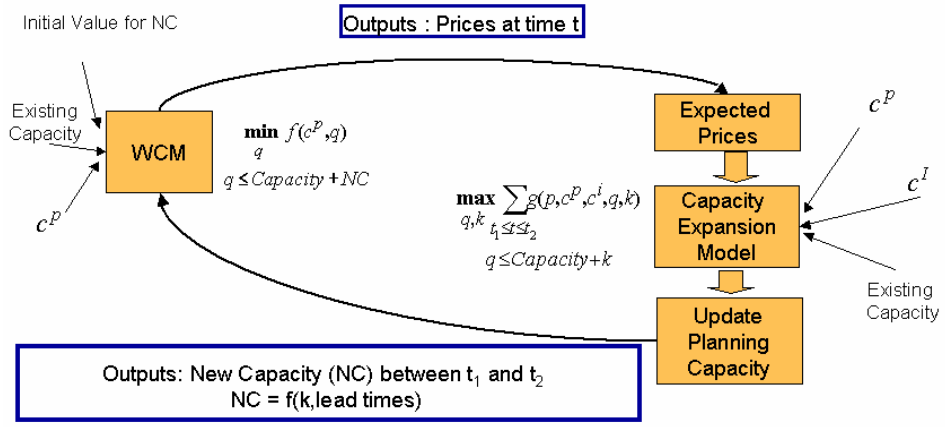

Figure 1: Short-Term WCM and Long-Term CEM model interaction

From the macro-economical point of view, this first approach is based on the rational price expectations theory [1] initially developed by John Muth [2] in 1961 followed by Robert Lucas [3] in 1972. The model always produces perfect foresight results. Realistic lead times are difficult to simulate. To get more realistic results a second model has been developed. The second approach (Figure 1) is based on the adaptive price expectation theory developed by Milton Friedman [4] and Edmund Phelps [5] in the sixties. An iterative loop over the time is defined between the CEM module (providing the new capacities) and the WCM module (providing the short-term marginal costs). Two new modules are added. The Price Expectation Module (PEM module) computes the expected prices for a period between t_1 and t_2 (typically 5 years) with a linear regression. A Capacity Planning

module has been developed to take into account the lead times. One loop of the algorithm starts with the WCM module where a price for a single period in time is computed. The calculated price (marginal cost) is sent to feed into the PEM module. The PEM module uses a list of historic and calculated prices to forecast the price for the next five years. In the CEM module the profit is maximized using the price signal coming from the PEM module. The CEM provides new capacities by taking into account investments. For the last step of the loop the new capacities calculated by the CEM module are send to the ST WCM module. Before an update of the capacity planning in order to simulate the lead times in a more realistic way is performed in the planning capacity module.

Results

Different demand scenarios have been designed to test the adaptive price expection and the rational price expectation models. Figure 2 shows a demand scenario with some demand spikes. Demand remains flat at 258 mt over all 35 years of the time horizon except of the years 2006, 2008 and 2020 where demand volumes rise by 98 mt, 48 mt and 198 mt respectively (cf. figure 2). The scenario has been used with the adaptive price expectation approach. Short term demand spikes (2006 and 2008) provoke capacity increases. In 2020 capacities do not increase due the ephemerality of the demand spikes as mine investments do not generate a return on investment.

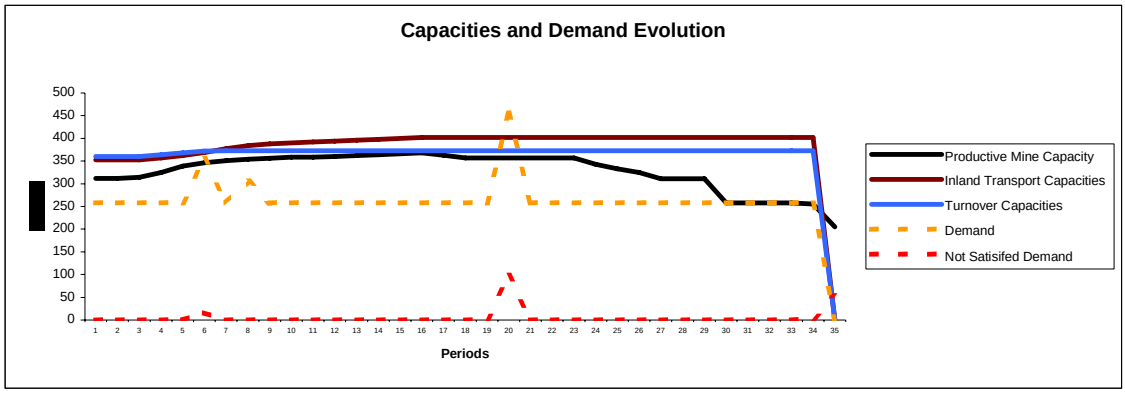

Figure 2: Capacities evolution for a specific demand scenario with some spikes

The main difference in the results between the rational and the adaptive approaches appears in the capacity expansion module. The adaptive approach overestimates the volume of new capacities compared to the rational model.

Conclusions

We present in this paper two approaches to simulate the mine investments. The first approach is based on rational expectations while the second one is based on adaptive expectations. Our models have been tested on an academic data set because at this time our data bought from the providers was not yet complete. The adaptive approach enables to deliver very realistic results taking into account various phenomena linked to demand behaviour, reserves and lead times. However, this method is difficult to be implemented and it is time consuming in the GAMS context. The PEM module based on a linear regression to forecast the prices can be contested. It is well known that prices cannot be forecasted with a linear regression. This is due to the nature of a price signal. A price signal is a random walk leading to spurious coefficients in a linear regression approach. We finally have adopted the rational approach because it offers an optimal compromise between robustness and realism

References

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