Measuring the effect of government interventions: evidence from restructuring the U.S. nuclear power sector

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(1) Abstract

The dominating empirical strategy when measuring the effect of endogenous government interventions is to represent the intervention by a dummy variable and to use continuous exogenous shocks as instruments. This modelling strategy assumes that if the net instrumental effect changes sign after the implementation of the intervention, one would expect the post-intervention conditions to reverse to their original state. In reality market conditions are often subject to inertia with the probability of reversal being close to 0 in the time periods preceding an intervention. We evaluate government interventions in the U.S. nuclear power market by creating instruments for interventions based on proportional hazard models. This procedure reduces the instrument variability to 0 after the intervention when the likelihood of reversed conditions was low. We find that divesture reduces the unavailability factor substantially more than previously found.

(2) Methods

The purpose of this paper is to measure the effect of market interventions when post-intervention conditions will persist for a reasonable long period. Such interventions will pose two distinct empirical challenges. First, the ideal instrument is one that varies prior to the intervention but has substantially reduced variability after the intervention. Searching for instruments that naturally have those properties is one obvious option. If such instruments are unavailable, one can instead create an instrument where restrictions are imposed on the post-intervention variability. In this paper we use a proportional hazard model where the breakdown of the current market conditions is represented by a regulatory change imposed by a state level government. Since, in our situation, we claim that it is unlikely that the regulatory adjustment is reversed to its initial state during our (relatively long) sample period, we take the final value of the survival model to persist indefinitely into the future. The predicted values of this model are then used as an instrument for the regulatory change in a standard 2SLS model. Conceptually this resembles what has been suggested by Wooldridge (2002, pp. 623-625) as he proposes to use the prediction from a non-linear model as instruments in a linear, two-stage model. However, we are not aware of any other study that has used the predicted values from a survival model to conceptually capture the reduced (or eliminated) risk of further policy changes in later periods.

The second empirical challenge is how to define the counterfactual, i.e. the state (completely) unaffected by the intervention(s). This can be problematic since effects from an

intervention might not be realised instantaneously and actors that appear to be unaffected can acquire experiences directly from affected actors, e.g. through joint stakeholders, and indirectly, e.g. through industry associations and labour movements. Conclusion must therefore be robust to different counterfactuals.

We implement our method on the U.S. nuclear power sector where a number of states decided to introduce wholesale electricity markets and where some vertically integrated utilities were forced to divest their assets during the 1990s and 2000s. We use yearly data on the reactor level between 1994 and 2011. Our primary focus is to investigate how the unavailability factor was affected by the creation of wholesales markets and the divestiture of nuclear reactors.

Previous empirical studies that have looked at the effects from market interventions in nuclear markets have focused on a single intervention. For example, Zhang (2007) studied the effects from the introduction of wholesale markets on outages, Pollitt (1996) looked at the response from privatisation of nuclear power plants in several countries and Davis and Wolfram (2012) investigated the effects of utility divestiture on outages.[1] The general conclusion based on these studies is that both the introduction of wholesale markets and divestiture have improved the economic performance of nuclear reactors and that this improvement has not been achieved at the detriment of safety. However, two potential problems can be observed while reviewing this literature. On the state level, the timing of different interventions tends to be correlated. This means that if only one intervention is included in the econometric model it is difficult to establish which specific intervention contributed to the estimated effect. Additionally, the previous literature, apart from Zhang (2007), does not fully address the endogeneity concerns.[2] Kwoka (2008) points out that this has blurred the understanding of how restructuring of the U.S. electricity market has affected economic performance.

Because interventions are treated as endogenous in this paper, it is also relevant to identify what factors influence energy market restructuring. Two studies use data from the U.S. electricity market and they both implement survival models using actual or intended implementation of competition in the retail market as the dependent variable (Ando and Palmer, 1998; Damsgaard, 2003). While in this paper we do not investigate what caused the establishment of retail markets, we assume that the fundamental drivers for all deregulatory activities were similar. Ando and Palmer (1998) find that the strength of the dominating interest group is positively related to deregulation when the potential efficiency gains are large. High electricity prices and large price differences with neighbouring states also increased the likelihood for deregulation. Damsgaard (2003) largely supports these conclusions. In addition he finds some support for that the share of independent power producers increase the likelihood of deregulation.

[1] Other studies in the broader field of electricity market restructuring have looked at the impact on the electricity price (Fabrizi et al. (2007), the heat rate for fossil plants (Craig and Savage, 2013), and productive efficiency (Delmas and Tokat, 2005). Under the assumption that explanatory variables are strictly exogenous, frontier methods have also been applied (Hiebert, 2002; Knittel, 2002). Moreover, Hausman (2012) has looked at whether electricity market restructuring impact safety performance and Verna et al., (1999) look at the economic and safety impacts of some performance based incentive programs prior to deregulation.

[2] Other papers, such as Fabrizio et al. (2007) or Craig and Savage (2013), deal with other endogeneity problems related to electricity generation such as entry and exist following policy change and the simultaneity between demand and input choice, which are not relevant for our analysis.

(3) Results

Foreshadowing our main results, we find that the introduction of wholesale markets had no significant effect on the nuclear unavailability factor. Divested assets, on the other hand, have reduced the unavailability factor and the reduction is both statistically and economically significant. When predictions based on both probit and survival models are used as instruments, they turn out to be substantially stronger than when individual instruments are inserted directly (i.e. not as predicted values) in a two-stage IV-model. The restrictive set of instruments used in previous studies is not strong enough to identify any significant effect from the interventions. Importantly, our initial hypothesis that survival-based instruments are more precise than instruments without restrictions on post-intervention variability is confirmed by data.

(4) Conclusions

A general claim proposed in this study is that instruments based on proportional hazard models are conceptually more appropriate when measuring the effect(s) of government interventions that persist over time, leading to substantially stronger instruments. Because the treatment of endogeneity often represents a shortcoming of many empirical studies dealing with electricity market restructuring (Kwoka, 2008), we argue that this approach could be replicated in the context of many structural policy interventions where policy inertia substantially reduces the risk of reversal following the reform, but also in the context of other economic decisions with the same properties (e.g., mergers, investment decisions).

Building on this approach, our findings show that the divestiture of nuclear reactors in the US has led to a substantial improvement in the economic performance of the US nuclear power sector. Taking into account potential increase in operation and maintenance costs associated with divestiture, our back of the envelope estimates show that, at wholesale market prices, divestiture has led to a $ 4.5 billion annual increase in profit for the US nuclear sector. In addition, considering the merit order of nuclear plants compared to fossil fuel plants in the US, this improvement in performance has also a significant impact on CO_2 emissions.

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