THE INTERDEPENDENCIES OF ELECTRICITY MARKET REGULATION AND ELECTRICITY SUPPLY SECURITY

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ABSTRACT

This paper assesses the effects of the introduction of electricity market regulation on the reliability of the electricity system in Europe. In particular, the implemented regulatory schemes, which differ substantially across 19 member states of the European Union (EU), are analysed with regards to their effects on annual power outage durations for the period from 1999 to 2010. In general, the trend of electricity supply security in these years has been positive (decreasing annual interruption durations) with less improvements in recent years. Applying different regression models, rate-of-return regulation schemes are found to be beneficial to electricity supply security when compared to output-based regulation. Furthermore, statistic evidence suggests that incentive (or cost-) based regulation has led to lower levels of electricity supply security in Europe. This however strongly depends on the assessment models and assumptions applied as is demonstrated in a model comparison approach.

In addition to the analysis of regulation's effects, we evaluate the empiric evidence of reverse causation in regulation. The question if lobbying activities can potentially influence electricity market regulation resulting in altered levels of supply security is relevant for policy making.

INTRODUCTION

The years from 1999 to 2010 are particularly relevant for the European electricity system as they were characterized by various paradigm shifts such as market deregulation, extraordinary growth of Trans-European power exchange, and the increasing use of renewable energy sources (henceforth RES). The liberalization of electricity markets in Europe, which to a large part took place during the period under consideration, had far reaching consequences for the national power systems. During this time, regulatory schemes were introduced. In most cases they aim at achieving - among others - two goals at the same time:

- lower electricity costs for consumers and
- higher levels of service reliability

However, although even directive 2003/54/EC [15] highlights the fact that electricity supply security (henceforth ESS) related aspects of electricity market regulation always have to be considered in conjunction with price effects, little is known about the empiric interaction of regulation and service reliability.

We aim at closing this gap by - among others - providing a thorough ex-post analysis of regulatory decisions and their effects on the level of service reliability in the EU.

The economic literature provides some insights into the different aspects of regulation and its welfare economic ramifications.

Ref. [21] analyzes the first evidences on regulation's effects for the case of Austria. As expected, electricity pricing has become more competitive after regulation was introduced.

Ref. [24] identifies a strong effect of regulation on the network costs charged and finds that grid tariffs decreased by almost 250m € between 2001 and 2003.

Ref. [23] and [19] analyze different schemes for electricity market regulation and provide insights in some countries' experiences with their introduction.

[33] finds, that incentive regulation potentially threatens service reliability. Using a comprehensive empirical analysis of quality of supply in electricity networks in the USA, the main finding is that quality needs to be addressed explicitly in regulatory regimes.

ELECTRICITY MARKETS AND SERVICE RELIABILITY IN EUROPE

Most European countries experienced service availability in the range of 99.80 to 99.99 per cent [2]. This is extraordinary high also in a historic context. However, due to increasing vulnerability of businesses and residential customers in the case of power outages, even small changes in reliability have enormous (economic and social) effects. Finding the socio-economic optimal level of reliability is paramount in the discussion of energy market regulation.

Common ways of measuring reliability includes the assessment of minutes lost per year or counting of the number of interruptions per year.

The utilized reliability indicator (The System Average Interruption Duration Index or SAIDI, which measures the average interruption duration per installed capacity in kilovolt-ampere kVA per year) varies significantly across Europe and over time. For instance in 2009, the average German citizen experienced 14.63 minutes without power supply per year, whereas Rumanian customers were disconnected for 638 minutes on average. The mean outage duration across Europe in 2009 amounted to 117 minutes [9].

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In Ref. [9] a strong correlation between supply security and underground cable rate is found. The presence of a high share of underground cables and consequently low interruption duration indices (SAIDI averaged over 3 years) is particularly strong for the medium voltage (MV, usually covering the voltage range from 1 to 36 kV) networks (R^2 of 7,134 when excluding Austria, Estonia, Finland, Poland and Spain).

ELECTRICITY MARKET REGULATION

Directive 96/92/EC [14] initiated the liberalization of energy markets with tremendous impact on hitherto vertically integrated utility companies and their business models.
Electricity market regulation cannot be exclusively assessed based on the desired (lowering) effects on consumer prices; rather assessments of regulatory schemes ought to also analyze their ramifications on ESS. However, despite some evidence in the economic literature, little is known about the precise interaction of regulation with regards to service reliability.
Thus, in this paper, a classification of different regulatory schemes in a binary panel data set was compiled at the first stage of this analysis (following a methodology from [1], [4], and [34]. The four categories involve:

- No regulation (no_reg)
- Rate-of-Return regulation (ror)
- Incentive regulation ((i)ncentive)
- Quality- or output-based regulation (o-b)

DATA

The adjusted data set with 135 of originally 504 observations (cases with missing observations are not implemented) was transformed into a time series panel data for this analysis, which is equivalent to an average of 7.1 observations per country.
Regulation of electricity markets usually follows a certain pathway, which (based on empiric evidence) leads from ”No Regulation”, to ”Rate-of-Return Regulation”. In various countries this regulatory regime was superseded by ”Incentive Regulation” . The introduction of ”Quality or Output-Based Regulation” is currently conducted in many countries. The year 1999 was defined as the base year. A trend variable (count land) was included to account for technological change and technical progress in maintaining the electricity grid.

METHODOLOGY

In order to isolate the effects of electricity market regulation on service reliability, whilst controlling for country-specific and time parameters the dependent variables (SAIDI) and a set of explanatory variable were analyzed by means:

- an ordinary least square analysis (OLS),
- a random effects estimation (RE),
- a fixed effects estimation (FE) as well as two and three stage least square analysis (2-SLS and 3-SLS, respectively).

For the best possible analysis of the impact of regulatory schemes on the annual interruption duration index, an analysis by means of fixed effect (FE) estimation, which takes into account the extent of structural differences in each country and their effects on the period of interruption of the power supply, proved to be well suited.

The originally applied FE regression for each year was not applied in the second step. This would imply that e.g. disasters winter occur simultaneously across Europe and affects all countries in a similar way. The country fixed effect was replaced by a trend variable which takes into account the technological progress which again positively affects the level of electricity supply security.

The main purpose of the basic econometric model (OLS estimator) is to identify the causal effect of the type of regulation applied on the dependent variable (”log_min lost”). In order to account for a higher absolute change over time due to higher initial minutes not supplied, the logarithm of these data was applied. This logarithm of minutes lost was utilized as dependent variable in the regressions incorporating the type of regulation which had been applied by the specific country and year and a set of other explanatory variables. The types of regulation were introduced as binary dummy data - 1 for regulation applied during the determined year, 0.5 if there were different types of regulation for the transmission and the distribution grid. As the output-based regulation is the most applied type of regulation, it was determined as the baseline model. To measure the effect of the regulation on the minutes lost, an OLS estimator with fixed effects was utilized (see Eq. (3) and (4) in table 1).
Even though a random effects model (Eq. (2) in table 1) might have been preferable in terms of efficiency, the endogenous nature of the data applied and the uncertainty about country-specific characteristics which were not controlled by the included set of explanatory variable made a fixed effects model necessary. This was also supported by a conventional Hausman-test. Due to presence of sufficient variance with regard to the regulation schemes applied throughout the observed time period, the utilization of a fixed effects model was possible.
In order to improve the efficiency of the model, several control variables were added. These control variables are qualitatively and quantitatively selected time varying factors which may also influence the security of supply. A detailed description of these explanatory variables which deal with domestic energy-specific characteristics, demographic data, climate and weather aspects as well as electricity prices for different consumer groups and descriptive statistics can be obtained from the authors.

ESTIMATION RESULTS

As can be seen in Table 2, the presence of rate-of-return regulation is statistically significant with regards to higher levels of electricity supply security. The impact of incentive regulation on ESS is negative in the first four models (i.e. incentive regulation fares worse than output-based regulation with regards to the annual duration of power outages).

DISCUSSION

The need for a stronger link between quality (reliability of supply) and regulation is widely accepted. According to the recommendations suggested by the 5th benchmark report [9], pg. 58, there exists the urgent necessity to exchange information on continuity of supply and its regulation (recommendation 8) and to investigate continuity of supply trends for a periodic review of regulation (recommendation 3). The changes over the last two decades in the structure of the European energy markets were significant in a historic context. The results of the empiric cross country analysis of regulatory effectiveness provide insights for efficient energy policy decisions with regard to service reliability

With regard to the effects of lobbying activities, it is particularly hard to assume the possible benefits grid operators with high minutes lost rates face from a rate of return regulation over an incentive regulation or vice versa. Nevertheless, the future trend of regulation is going to have at least some minimal quality criteria. Thus, it is a plausible assumption that grid operators, especially with high minutes lost rates will prefer rate of return regulation for as long as possible, to have their investments in grid improvement financed. This assumption has been used throughout our analyses, which has been supported by the analysis of the empiric data used.

The presence of rate-of-return regulation has statistically significant influence on the level of electricity supply security. This is potentially due to above-average investment incentives. However the analysis of how regulation finds its way into investment decisions are not subject of this study. They can be found among others in Ref. [4] as well as in Ref. [25]. Nevertheless, as utilities tend to be able to invest more in their infrastructure under this framework, the possible improvements must be weighed against the potentially higher costs to consumers. The economic importance of regulation is significant from a macroeconomic standpoint given the fact that the value of uninterrupted electricity supply is calculated to be considerably high. It was shown in this analysis that a reduction of the annual outage duration- can be supported by adequate regulatory frameworks. A theoretic reduction of the power outage duration in a country like Austria of one hour would result in macroeconomic benefits of about 148m €, which is equivalent to 0.05 % of the Austrian GDP [32]. Thus, regulation, which incorporates electricity reliability measures, is crucial in order to keep the currently excellent level of energy supply security and to prevent significant damages to the economy and society. Further research on the issue is urgently needed in order to allow a future improvement of regulatory frameworks. In addition, this would enable cost-benefit analyses which are needed to assess (regulatory) measures that aim at improving service reliability.

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Figure 1: Unplanned interruptions excluding exceptional events in minutes per year.

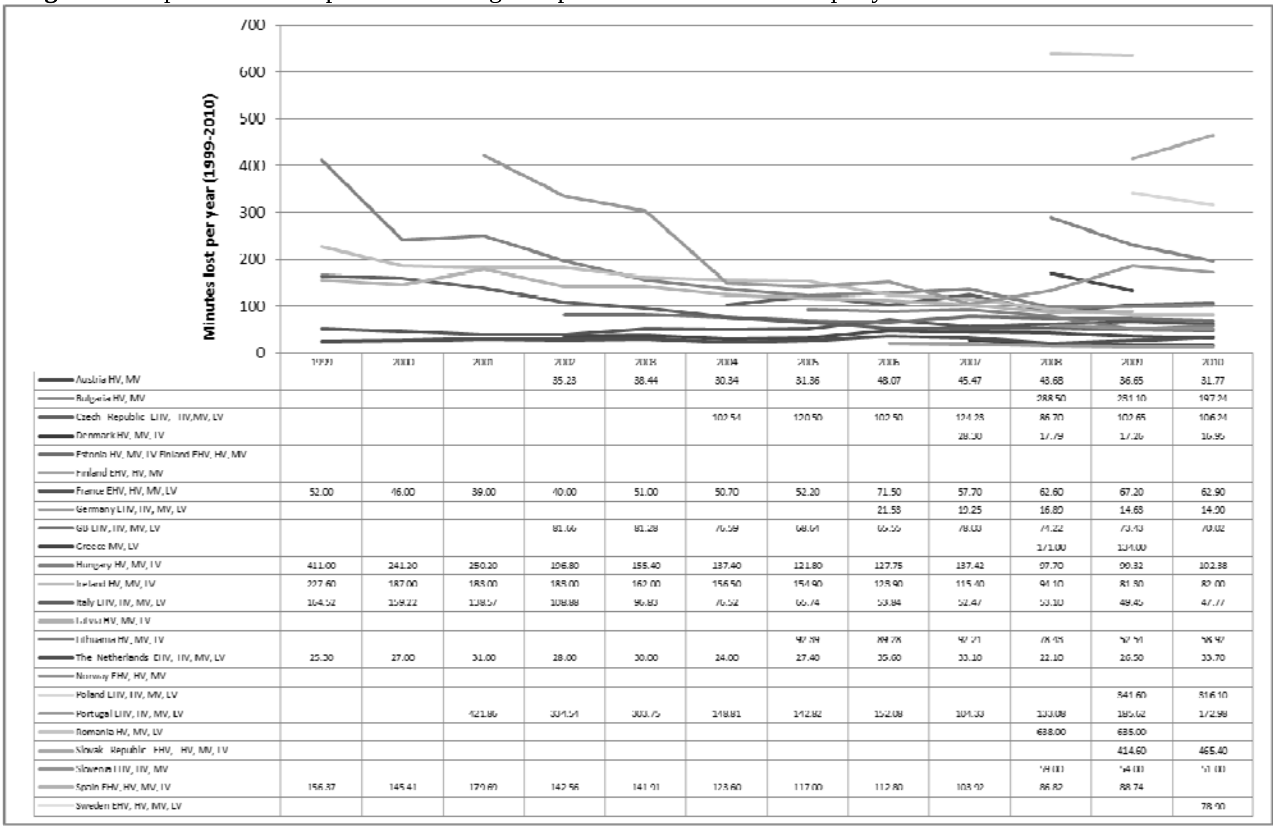

Table 1: Comparison of Regression Models

log minlost	(1) OLS	(2) Random_Effects	(3) FE_c	(4) FE_ct
ror	−0.144 (0.152)	−0.0896***	−0.0866***	−0.0777***
		(0.000)	(0.000)	(0.003)
incentive	0.144**	0.0968***	0.0969**	0.102**
	(0.043)	(0.007)	(0.015)	(0.016)
price industry	−0.00938	−0.0234*	−0.0236	−0.0341*
	(0.621)	(0.098)	(0.123)	(0.068)
public ownership	−0.00128	0.0000946	−0.000200	0.0000509
	(0.196)	(0.972)	(0.948)	(0.985)
vertical integration	−0.0209	0.00643	0.00616	0.00285
	(0.442)	(0.554)	(0.562)	(0.816)
entry regulation	0.0957***	0.0423***	0.0418***	0.0363***
	(0.001)	(0.000)	(0.000)	(0.004)
warmspellduration	−0.00110	0.00221***	0.00228***	0.00259**
	(0.523)	(0.001)	(0.003)	(0.012)
coldspellduration	−0.00666***	0.000376	0.000686	0.000279
	(0.001)	(0.631)	(0.448)	(0.755)
wind photo	−0.0172**	−0.0140***	−0.0128***	−0.0131**
	(0.027)	(0.001)	(0.006)	(0.010)
time trend	0.00367	0.00305	0.00175	
	(0.751)	(0.739)	(0.854)	
N	135	135	135	135
R^2	0.334		0.648	0.681
adj. R^2	0.281		0.620	0.625

robust standard errors are used for all regressions [Huber-White-Sandwich Estimator]
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; RE *Random Effects*; *FE Fixed Effects*
c(t) controlling for country (and time) fixed effects