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# Effects of Privatization on Price and Labor Efficiency: The Swedish Electricity Distribution Sector

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# Effects of Privatization on Price and Labor Efficiency: The Swedish Electricity Distribution Sector

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### Abstract

I examine the effects of privatization, in the form of acquisitions, in the Swedish electricity distribution sector. As the majority of the distribution networks have remained publicly owned, I use a synthetic control method to identify the effects on price and labor efficiency. In comparison to their synthetic counterparts, I find that the acquired networks increased labor efficiency by 8-18 percent depending on model specification, while no effect is found on price. Thus, the evidence suggests economically meaningful efficiency gains but that these are not fed through to consumer prices. Robustness results using a conventional difference-in-differences estimator largely confirms the results, although the estimated efficiency gains are either comparable to or less pronounced than their synthetic control counterparts.

**JEL-Classification**: L33, L52, L94

**Keywords**: Incentive regulation; electricity distribution; natural monopoly; privatization; synthetic control method.

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# 1 Introduction

When a network industry is privatized, a fundamental controversy lies in the potential increase in productive efficiency due to increased incentives to minimize costs, vs. distortions in allocative efficiency and a subsequent redistribution from consumers to producers due to market power. The electricity distribution sector is particularly well suited for firm performance comparisons since electricity distribution is a homogenous good, and since data on the technical characteristics of the networks as well as accounting data are standardized and reported to a central regulator. At the same time, since the market is regulated, the possibility to extrapolate results to other markets should be done with care.

In this study, I examine the effects of private acquisitions of publicly owned networks in the Swedish electricity distribution sector. Specifically, I study the performance of 34 municipally owned networks that were acquired by private firms around the turn of the century. I focus on two outcome variables: price and labor efficiency. I find evidence of an increase in labor efficiency in the acquired networks by 8-18 percent compared to the control group depending on model specification, while no acquisition effect is found on the price. Thus, the evidence suggests economically meaningful efficiency gains but that these are not fed through to consumer prices. All acquisitions examined in the study were conducted by two firms, E.ON and Fortum. The qualitative effects on both outcome variables are similar across firms, although the increase in labor efficiency is both statistically and economically more significant in the networks acquired by Fortum.

To the best of my knowledge, this is the first study to use a synthetic control method to evaluate firm performance in the electricity distribution sector. For each acquired network, I create a synthetic control network from a weighted average of the control networks. The synthetic control network is constructed to have the same technical characteristics and pre-acquisition trend of the outcome variable as the acquired network. The effect of the acquisition is then estimated by comparing the factual post-acquisition trend of the outcome variable to that of its synthetic analogue. Conceptually, it is a generalization of the more commonly used difference-in-differences (DiD) estimator, and is particularly well suited to estimate the effect of an intervention when the number of potential control firms are large. Robustness tests using a conventional DiD estimator largely confirms the results from the synthetic control method, although the estimated efficiency gains are either less pronounced, or comparable to, the results using the synthetic control method. Further, the precision of the estimates are comparatively low under both methods for several of the specifications. Therefore, results should be interpreted with care.

Although it is beyond the scope of this paper to identify the specific mechanisms driving the efficiency gains, one plausible explanation is returns to scale, since each of the acquisitions involved bordering networks that were previously operated by each respective municipality. For example, the same administrative staff may be used for several networks, and the use of equipment may be optimized by transporting it across regions. It is also likely that some publicly owned firms prefer to offer higher wages relative to private firms *ceteris paribus*, in which case variations in labor efficiency also reflects how revenues are distributed between workers and owners. Still, it should be noted that since prices are regulated, also publicly owned firms are allowed to make profits that can be transferred to the general municipal budget.

The choice of the electricity distribution sector as a testing ground for studying privatization is not only motivated by the availability of data and the diversity of the ownership structure. Another important factor is the increased skepticism against private ownership in network industries that has developed during the last decade, which can be exemplified by the experiences in Sweden and Germany. Prior to electricity reform, distribution networks in Sweden and Germany were usually owned by the municipalities. In Sweden, the state-owned firm Vattenfall also owned a fair share of the networks, and continues to do so (NordReg, 2011; OECD, 2004). However, the last two decades have seen a transition towards consolidation and privatization of the network ownership structure. In Sweden, the new entrants Fortum and E.ON now have a market share of around 20 percent each. Consumer groups claim that the sharp price increases during the last decade are mainly driven by the largest firms (SABO, 2011), and some municipalities have expressed an interest in buying back their networks (Dalarna's newspaper, 2014). Germany has seen a similar development, where the four largest firms acquired shares in numerous local distribution networks during the privatization wave initiated by the municipalities around the turn of the century. However, in contrast to Sweden, there has been a reverse trend in network ownership during recent years. Municipalities, often guided by the will of the local people, have started to repurchase the networks (the so-called *Rekommunalisierung*, or remunicipalization). The two most notable events were the referendums in the two largest German municipalities, Berlin and Hamburg, which in 2013 both voted for the remunicipalization of the electricity, gas, and district heating networks (although the referendum in Berlin failed due to insufficient voter turnout). Similar skepticism towards private ownership of network industries has also been raised elsewhere. For example, the website www.remunicipalisation.org collects data on remunicipalization projects of water provision services throughout the world, recording 180 cases during the last 15 years, impacting 100 million people. The recent years' remunicipalization trend further highlights the importance of examining the effects of privatization in network industries.

Previous studies on the relationship between ownership and efficiency in Swedish electricity distribution are not conclusive. Using a stochastic frontier model analyzing panel data during 2000-2007, Söderberg (2011) finds that private ownership is associated with relatively lower costs than public ownership. However, the economic significance of the effect is rather modest and the sample is different from the present study since networks that changed ownership status during the sample period are excluded from the analysis. Using data from 1970-1990, Kumbhakar and Hjalmarsson (1998) find that private ownership is associated with relatively higher labor efficiency in terms of cross-sectional variation, but there is no conclusive evidence that labor efficiency increased more within the privately owned networks during the sample period.

International experience also does not provide any clear cut predictions, although most evidence suggests that private ownership is associated with increased efficiency. In the UK, Domah and Pollitt (2001) find that privatization improved efficiency, but costs and prices did not fall until about a decade after privatization, partly as a result of regulatory interventions. In line with this finding, Karahan and Toptas (2013) find that the privatization of electricity distribution companies in Turkey did not yield lower prices within the first 4 years of the program. Within the Ukrainian distribution sector, Berg et al. (2005) find that privatization is conducive to efficiency given that regulation is adequate. Borghi et al. (2016) study the interaction effects between quality of government and private ownership in determining the total factor productivity of electricity distribution firms using data from 16 EU countries. When the quality of government is poor, private ownership is associated with relatively higher productivity levels, while the opposite is true when the quality of government is good. In a study using data from 14 Latin American countries, Estache and Rossi (2005) find that the relative labor efficiency of private firms depend on the regulatory regime: private firms perform better under price cap regulation, but not under rate-of-return regulation. A common argument against privatization is that it may be accompanied by a deterioration in quality. For example, Kwoka (2005) finds that public ownership is associated with relatively higher quality of service, measured by the occurrence of service disruptions. Although quality of service is not the focus of the present study, I include a measure of service interruptions as a control variable to reduce the probability that this factor is driving the estimated efficiency gains.

# 2 Institutional background and data

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## 3.1 Regulatory framework

Traditionally, a majority of the Swedish distribution networks have been owned by the municipalities, or by private firms organized as economic associations owned by the electricity consumers in the area where they operated. Some distribution networks were also owned by the state-owned firm Vattenfall, which is also the largest electricity producer in the Nordic region. Before the liberalization of the wholesale market in 1996, a proper incentive regulation for the distribution sector was not considered necessary, although there was a general legal principle stating that publicly owned firms were not allowed to make profits (*självkostnadsprincipen*). The non-profit rule did not apply to private firms, that in theory were free to set their own prices. Shortly after the liberalization of the wholesale market, a new regulatory framework was introduced. It was a type of rate-of-return regulation, albeit without being any more precise than that prices should be fair (*skäliga*). Heden (2012) characterizes the evaluation of the tariffs as "pretty ad-hoc", noting that "There wasn't any well defined methods for valuation of the distribution firms' assets, or explicit principles for what would constitute a fair rate-of-return".

There are several reasons why a traditional rate-of-return regulation may fail to incentivize firms to minimize costs. The most well-known is attributed to Averch and Johnson (1962), showing that firms have incentives to engage in excessive amounts of capital accumulation in order to expand the volume of profits. Laffont and Tirole (1993) discuss how information asymmetries between the regulator and the firm under rate-of-return regulation can lead to several other inefficiencies. Even though the switch from rate-of-return to incentive regulation took place in tandem with the liberalization process in most countries, the insight that also public bureaucrats seek to maximize their own budgets suggests that a proper incentive regulation may increase efficiency also among publicly owned firms (Niskanen, 1968).

One of the ways to get around the misguided incentives provided by traditional regulation is to benchmark firms against each other, in order to achieve a type of artificial yardstick competition (Shleifer, 1985). In the electricity distribution sector, different forms of yardstick regulation have been adopted by countries such as Norway, Australia, and the UK. In these models, a best-practice frontier of real firms is identified, against which individual firms can be compared (Jamasb and Pollitt, 2008).

In 2003, Sweden also adopted a proper incentive regulation. However, instead of benchmarking costs against other firms, the allowed revenue was determined to reflect the cost of building and operating a hypothetical network with the same exogenous environmental and demand conditions as the real network. It was called the Network Performance Assessment Model (NPAM). The revenue of the actual network was then divided by the computed costs of the hypothetical reference network, obtaining the network's "charge rate". If a network was found to have a charge rate exceeding a certain threshold, the owner was subject to a detailed investigation. For a full description of the NPAM model, see Appendix A. Similar "reference firm" regulations have also been adopted by Chile and Spain (Jamasb and Pollitt, 2008). Sweden formally decided to abandon the NPAM in 2008, and adopted a revenue cap regulation that has been in place since 2012.

Although the long term goal of the NPAM was to make actual revenues contingent entirely on exogenous characteristics that the firms were unable to influence, in this respect the NPAM was not successful. Out of the 16 firms (including Fortum and E.ON) that were imposed to pay back customers after the first round of scrutiny, all of the firms appealed to a higher court. After a lengthy legal process, the firms agreed to pay back parts of their revenues in 2008, amounting to 140 million SEK (Heden, 2012).

## 3.2 Electricity distribution in Sweden

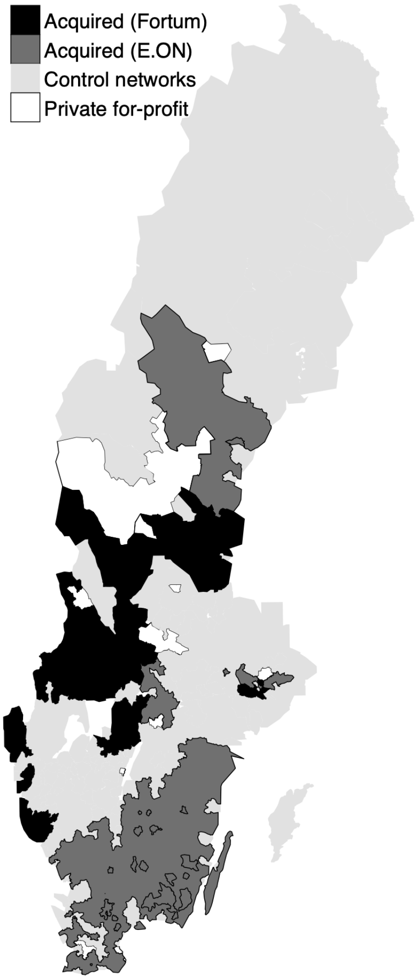
The Swedish electricity supply chain is physically divided into four vertically separated markets: generation, national transmission, regional transmission, and distribution. A schematic diagram is presented in Figure B1. The wholesale market for electricity is organized on the Nordic power exchange Nord Pool. E.ON and Fortum are important players in all markets except for national transmission, which is controlled by the state-owned transmission system operator Svenska Kraftnät. The scope of this paper is limited to the distribution network, which has the lowest voltage and connects end consumers to the system. However, the regional transmission network is subject to the same type of regulation as the distribution network, and is almost exclusively controlled by Vattenfall, E.ON, and Fortum. In a review of the empirical literature, Meyer (2011) documents a range of studies from several countries finding economies of scope between various stages in the supply chain. Although it is beyond the scope of this paper to quantify its importance in the present setting, one should bear in mind that the regulatory structure does not take economies of scope into consideration. This should provide E.ON and Fortum with a cost advantage compared to municipally owned networks that generally do not engage in generation or regional transmission. The acquirers may also use private information about bottlenecks in transmission or power line failures to predict price formation in the wholesale market, creating a strategic advantage compared to other firms active in the wholesale market.

The distribution network is geographically divided into *concession areas*, which legally define each local monopoly by its geographical boundaries. The concession areas are the relevant legal unit when computing the allowed revenues under the NPAM. Hence, technical and accounting data are available by concession area. Henceforth, I will simply refer to a concession area as a network. Each network can only be operated by one firm, but one firm can be the operator in several networks. If a firm acquires several bordering networks, they are usually merged into one. Therefore, although 34 publicly owned networks were acquired, complete panel data can only be constructed for five networks (four for Fortum and one for E.ON).

E.ON is a privately owned, publicly traded German energy firm. Fortum is also publicly traded, but the Finnish government owns 51 percent of the shares. As there is no reason to believe that the Finnish government would have preferences for Swedish consumer surplus, it is plausible that it behaves as a profit maximizer. E.ON entered the market in 2001, acquiring the majority share in the Swedish firm Sydkraft, which owned both distribution networks and generation. Prior to the acquisition, the combined ownership of the Swedish municipalities Malmö, Oskarshamn, Lund, Landskrona, and Halmstad constituted the greatest voting share in Sydkraft. In 2004 E.ON also acquired the firm Graninge. However, since Graninge was already privately owned, this concession area is excluded from the analysis. Fortum was already present in the Swedish market at the beginning of the sample period. However, it was only in 2002 that it became the majority owner in Birka Energy, which it previously co-owned together with Stockholm municipality. During the following two years, E.ON and Fortum also acquired a few more municipally owned networks, but those networks were minor in comparison to the ones owned by Sydkraft and Birka Energy. By the end of the sample period, E.ON and Fortum were the largest players on the market together with Vattenfall, who all had a market share of about 20 percent each (measured by the number of customers). The fourth largest player in the market is the municipally owned Göteborg Energi, with a market share of five percent. Vattenfall did not conduct any major acquisitions during the sample period. For a comprehensive review of all major M&As in the Swedish electricity market during 1997-2006, see Energy Markets Inspectorate (2006).

Figure 1 depicts the geographical locations of the networks owned by Fortum and E.ON in 2011. Both firms control parts of the distribution network in Stockholm, which is the capital and the most densely populated area. 30 percent of the remaining networks are operated by private firms. 70 percent of the private firms are non-profit economic associations (*ekonomiska föreningar*), owned by the electricity consumers themselves. Hence, they should not behave as profit maximizers, and are therefore included in the control group. In total there are 145 control networks in the control group, out of which

Figure 1: Network ownership by E.ON and Fortum in 2011



Note: Networks acquired by Fortum and E.ON, as well as control networks and private networks that are for-profit.

30 are operated by economic associations.

## 3.3 Data

The main data set has been compiled by the Energy Markets Inspectorate, and is available on a yearly basis for the years 2000-2011. It includes both accounting data and technical characteristics of the networks. To control for the impact of wind speed on the quality of service, I also construct a measure of wind speed using publicly available data from the Swedish Meteorological and Hydrological Institute (SMHI). Summary statistics of all variables are depicted in Table 1.

Table 1: Summary statistics

| | Control networks | | Acquired networks | |
|---|---|---|---|---|
| | mean | sd | mean | sd |
| Price | 4291 | 1195 | 4730 | 873 |
| Labor cost | 1683 | 778 | 1289 | 384 |
| In-house labor cost | 738 | 429 | 339 | 266 |
| Customer density | 78 | 109 | 120 | 242 |
| Underground line | 66 | 31 | 63 | 24 |
| Overhead line | 55 | 45 | 69 | 41 |
| Transformer capacity | 13 | 154 | 10 | 2 |
| Transformer stations | 36 | 24 | 44 | 24 |
| Minutes of service disruption (SAIDI) | 74 | 190 | 165 | 252 |
| Days above 15 m/s | 5 | 15 | 9 | 23 |
| Observations | 1740 | | 84 | |

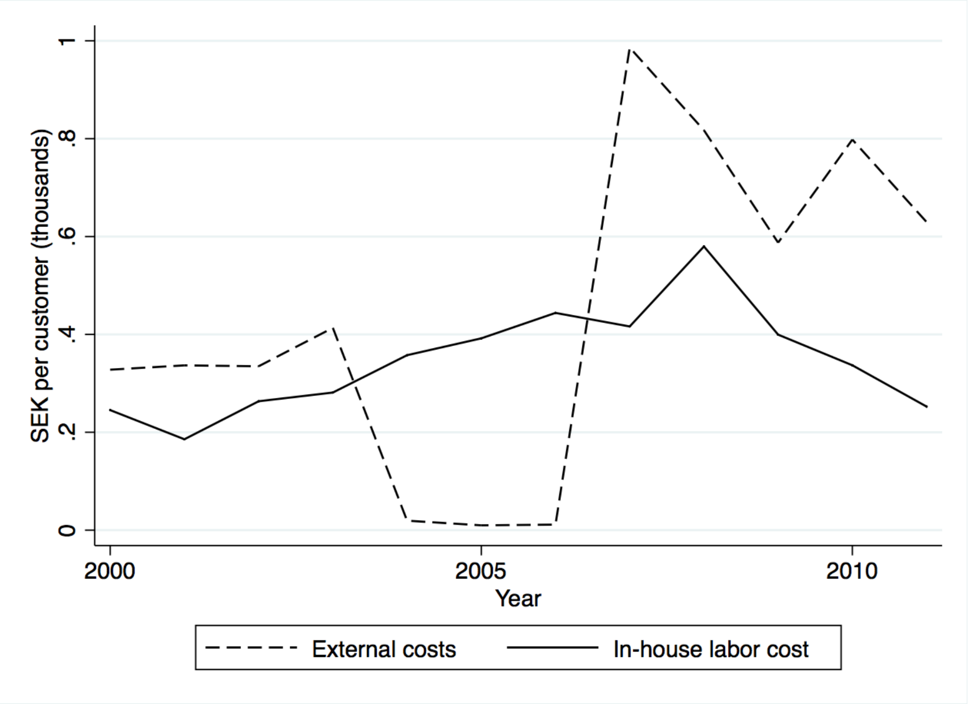
Note: Price, labor cost, and in-house labor cost are in SEK/customer. Customer density is in customers/km$^2$. Power lines are in meter/customer. Transformer stations are the nr of stations per 10 000 customers. Minutes of service disruptions is the System Average Interruption Duration Index (SAIDI).

### Outcome variables

The first outcome variable, price, is defined as revenue per customer and year (the only revenue source is payments from customers). The average price over the whole sample is 4,300 SEK/customer (10 SEK≈1 EUR). The mean nominal price increase during the sample period was 40 percent (20 percent in real terms). The greatest price increase was in 2010, which was on average 8 percent. The Energy Markets Inspectorate (2011) notes that the sharp increases during the later years in the sample are partly due to costs associated with two great storms in 2005 (*Gudrun*) and 2007 (*Per*). Tougher regulations to prevent outages, and obligations to offer hourly metering of consumption in 2009 are other possible contributing reasons. Further, the local distributors' fees to the national transmission network have increased due to a higher demand on the transmission lines as new wind power plants are incorporated in the system.

The second outcome variable, labor efficiency, is the number of customers per unit of labor. However, to make the outcome variables comparable, instead of labor efficiency I will henceforth refer to its inverse, labor cost, which is also expressed in SEK/customer. The mean labor cost for the whole sample was 1,600 SEK/customer and year, which is about 40 percent of the price. Examining accounting data, the accounted cost for "staff expenditures" only includes in-house labor costs, and not outsourced services. These services are instead accounted for as "external costs", according to the guidelines set by the regulator. Since outsourcing has become increasingly common, in the main specification I also include this entry in the labor cost, even though this entry may also include other costs that are not directly attributed to labor costs. For example, if the outsourced services instead would have been performed in-house, the wage cost of the service would be separated from the capital cost, such as renting maintenance equipment. In-house labor costs constitutes about half of the total labor costs for the control networks, but less for the acquired networks. However, the accounted value of "external costs" may also vary across years within a given network. As an illustrative example, Figure 2 depicts the

Figure 2: In-house labor cost and external costs in networks acquired by Fortum



Note: Mean accounted labor cost per customer in the networks acquired by Fortum, disaggregated into in-house labor cost and external costs.

trend in in-house labor costs and external costs in the networks acquired by Fortum.To account for this data issue, I perform several sensitivity tests that are described in detail in the robustness section below.

The rest of the costs are mainly capital costs, and costs for electricity to cover transmission losses. The mean accounted operating profit (not reported in the summary statistics) is 601 SEK/customer and year, which is about 14 percent of the price. Figure 3 depicts the trends in price and labor cost for acquired and control networks respectively. Two years, 2007-2008, experienced the highest labor costs in the acquired networks. This is partly due to the storm *Per* that swept through the south of Sweden in 2007 through several of the networks owned by E.ON and Fortum. Except for 2007-2008, the labor costs in the control networks increased comparatively more than in the acquired networks.

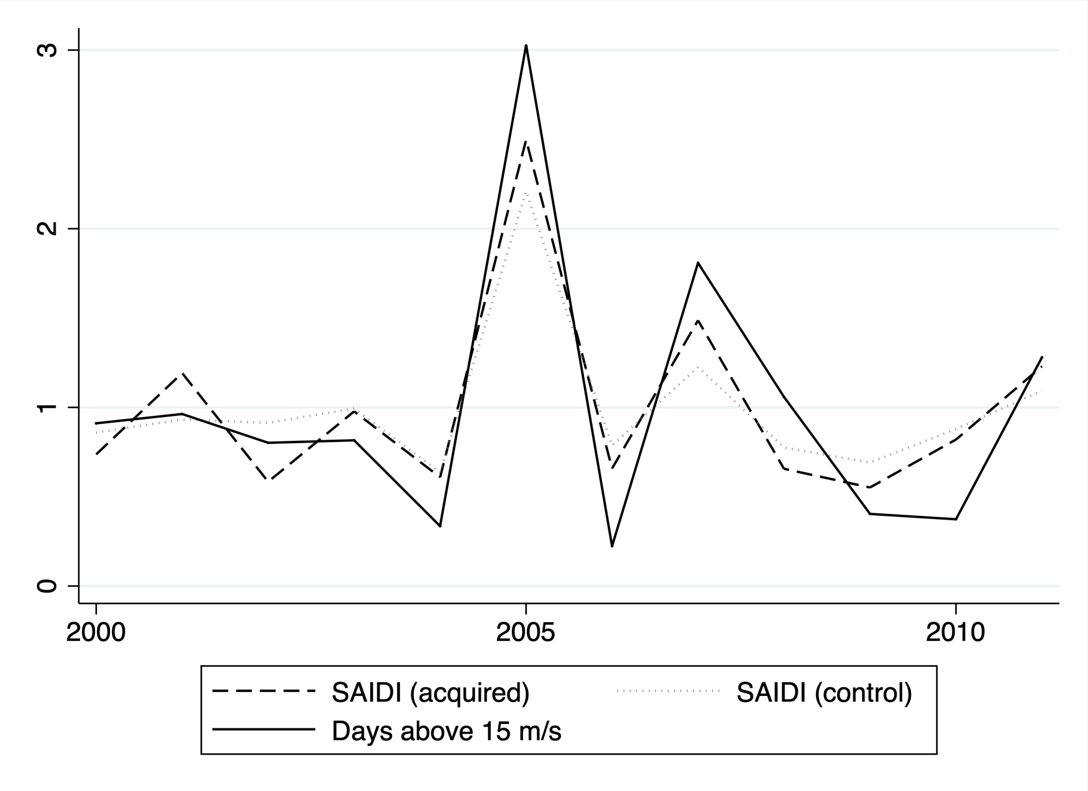
### Control variables

Customer density is measured by the number of customers/km$^2$ of the concession area. It is an important determinant of cost, given that it is less costly to serve customers in a high density area. In a fixed effects setting this variable also captures returns to scale, if there is variation across time in the number of customers within a specific concession area. More than 99 percent of the customers in all networks are residential low-voltage customers, and the mean within-network correlation between the number of low- and high voltage customers is above 0.93 for all years in the sample. Therefore I do not distinguish between the two groups, although the cost of serving a high-voltage customer is likely to differ from

Figure 3: Trends in price and labor cost

Note: Trends in price and labor cost per customer for the acquired networks and the control networks, respectively. The control networks consist of municipally owned networks that were not acquired, as well as privately owned non-profit networks. The gray shaded regions represent the range between the $25^{th}$ and $75^{th}$ percentile for the control networks.

Figure 4: Quality of service and wind speed



Note: Mean of the System Average Interruption Duration Index (SAIDI) for the acquired and control networks respectively, as well as the mean number of days with wind speeds above 15 m/s for the whole sample. Variables have been normalized by dividing with the concession area mean. The spike in 2005 is due to the storm *Gudrun*.

the cost of serving a low-voltage customer. Two related variables are underground- and overhead power lines, which are expressed in meter/customer. Although correlated with customer density, power line length is a more precise measure of network density, since it depends on the actual distance between customers. On the other hand, power line length does not capture returns to scale: even if previously unpopulated areas become populated, power line length per customer could remain constant. Overhead lines generally demand more maintenance, but incur a higher investment cost. The two remaining variables describing the technical characteristics of the grid are transformer capacity and the nr. of transformers per 10 000 customers, which both are cost drivers.

To account for the quality of service, I include the System Average Interruption Duration Index (SAIDI). It is the annual average outage duration (in minutes) per customer and year. Customers experiencing extended outages are entitled a repayment from the network owner. Since 2006, compensations are standardized: Any customer with an outage lasting 12-24 consecutive hours gets a compensation corresponding to 12.5 percent of that customer's annual distribution cost. After 24 hours the compensation is increased to 37.5 percent, and after each consecutive 24 hours an additional 25 percent is added, until the maximum annual compensation of 300 percent is reached. Since revenues from customers are computed net of refunds, SAIDI is also a determinant of the revenues.

Since strong wind is an important determinant of service interruptions, I also include a variable measuring the percentage of days when the maximum wind speed was at least 15 meter per second (m/s) at some point of the day. SMHI had about 150 weather stations operating continuously during the sample period. To construct the wind speed variable, the centroid of each network was computed, and matched with the closest station. To determine the threshold of 15 m/s, SAIDI was iteratively regressed on the wind speed variable, including network fixed effects, by varying the threshold between 5-25 m/s. The magnitude and precision of the coefficients are presented in Figure B3. For both the magnitude and precision, a threshold of 15 m/s performs best. It is also worth to note that both SAIDI and the wind speed variable is roughly twice as large for the acquired relative to the control networks throughout the sample period. Figure 4 depicts the trend in SAIDI for the acquired and control networks respectively, as well as the sample mean of the wind speed variable. By visual inspection, it is evident that SAIDI follows wind speed closely during the whole sample period for both groups.

# 4 Method

## 4.1 The synthetic control method

The most widely used method for assessing efficiency in the electricity distribution sector is stochastic frontier analysis. The goal is then to estimate each firm's distance to a production frontier, which is generated from data. However, in the present setting the relevant counterfactual is restricted to the trend in the outcome variable that would have prevailed if the acquisitions had not been carried out, i.e., the goal is to measure the "treatment effect" of the acquisitions. The conventional reduced form analysis when assessing treatment effects relies on the DiD estimator. However, this estimator rests on the so called "parallel trends" assumption. It requires that in the absence of treatment, the difference between the treatment and control group would have been constant over time. In the presence of time-varying unobserved confounders, this assumption may be violated. The synthetic control method addresses this problem by constructing a synthetic control network from a weighted combination of the control networks, such that the trajectory of the outcome variable and the mean of the control variables in the synthetic network match the acquired network during the pre-acquisition period. Hence, weights are static, and are constructed using pre-acquisition data only. Borrowing from the matching literature, the set of all control networks are usually referred to as the "donor pool". Since individual weights are restricted to be positive and sum to one, the synthetic control network is constructed without any extrapolation outside the convex hull of the data from the donor pool.

Formally, following the notation in Abadie et al. (2010), suppose that there are $J+1$ networks, and that only the first network is acquired. Since several networks were acquired, one could either construct a representative acquired network, or estimate the acquisition effects separately for each network. As the main results are qualitatively invariant to the choice of method, in the baseline estimation I construct a representative network in order to simplify the exposition, although I also report network specific effects. To construct the representative acquired network, I begin by merging all acquired networks into one large network, containing both E.ON's and Fortum's networks. Since the technical characteristics are expressed as fractions of the number of customers, the fact that the size of the merged network is very large does not matter.

Let $Y_{it}^{A}$ and $Y_{it}^{N}$ be the outcomes that would be observed for network $i$ at time $t$ given an acquisition, and in absence of an acquisition, respectively. Let $T_0$ be the number of pre-acquisition periods, with $1 \leq T_0 < T$. Let $D_{it}$ be an indicator that takes the value one if network $i$ has been acquired at time $t$, and zero otherwise. The observed outcome for the acquired network at time $t$ is then $Y_{1t} = Y_{1t}^{N} + \alpha_{1t}D_{1t}$. As the vector of interest is $\alpha_{1t}$, we need to estimate $Y_{1t}^{N}$ for all periods where we do not have observational data. Suppose that $Y_{it}^{N}$ is given by the factor model

$$Y_{it}^{N} = \delta_t + \boldsymbol{\theta_t}\mathbf{Z_i} + \boldsymbol{\lambda_t}\boldsymbol{\mu_i} + \varepsilon_{it} \tag{1}$$

where $\delta_t$ is an unknown common factor with constant factor loadings across networks (cf. a time fixed effects vector in a DiD setting), $\mathbf{Z_i}$ is a vector of observed technical characteristics not affected by the intervention, and $\boldsymbol{\theta_t}$ is a vector of unknown parameters. Further, $\boldsymbol{\lambda_t}$ is a vector of unobserved common characteristics, and $\boldsymbol{\mu_i}$ is a vector of unknown factor loadings. In a DiD setting, the "parallel trends" assumption is the identifying assumption ensuring that time-varying unobserved variables do not bias the results. By contrast, the synthetic control method takes advantage of the fact that there are several networks in the donor pool, and uses a matching algorithm that forces the parallel trends assumption to hold.

Ideally, the variables in $\mathbf{Z_i}$ should be completely exogenous. In the short run, exogeneity seems reasonable. However, in this case it is not possible to determine wether the choice of technical characteristics is compatible with long run cost minimization, but rather if labor use is efficient given the set of technical characteristics. If long run efficiency is of interest, it could be more suitable to instead match only on purely exogenous environmental and demand characteristics (such as the distance between consumers, size of the concession area, and land type). In the framework of the NPAM regulation, this would be equivalent to match on the variables collected in the "data collection" stage. However, an implicit assumption is then that network owners are free to change the physical constituents of the network, and that there is a unique optimal network for a given set of environmental and demand characteristics. These assumptions are questionable, and have been contested by Jamasb and Pollitt (2008). In another study of the Swedish NPAM regulation, Jamasb and Söderberg (2010) find that the reference networks are not adequate representations of the real networks. Taken together, it appears most suitable to keep the technical characteristics of the network as matching variables.

Consider a (J x 1) vector of weights $\mathbf{W} = (w_2,...,w_{J+1})'$ such that $w_j \geq 0$ for $j = 2, ..., J+1$ and $w_2$ +...+ $w_{J+1} = 1$. That is, each particular value of the vector $\mathbf{W}$ represents a potential synthetic control group. The value of the outcome variable for each synthetic control indexed by $\mathbf{W}$ is:

$$\sum_{j=2}^{J+1} w_j Y_{jt}^N = \delta_t + \boldsymbol{\theta_t} \sum_{j=2}^{J+1} w_j \mathbf{Z_j} + \boldsymbol{\lambda_t} \sum_{j=2}^{J+1} w_j \boldsymbol{\mu_i} + \sum_{j=2}^{J+1} w_j \varepsilon_{jt} \tag{2}$$

Suppose that there is a vector of weights $\mathbf{W}^*$ such that

$$\begin{aligned} \sum_{j=2}^{J+1} w_j^* Y_{j1} = Y_{1t} \qquad \forall t \leq T_0 \\ \sum_{j=2}^{J+1} w_j^* \mathbf{Z_j} = \mathbf{Z_1} \end{aligned} \tag{3}$$

i.e., the synthetic control group matches the acquired network both in terms of the pre-treatment trajectory of the outcome variable, and the observed technical characteristics. Then, Abadie et al. (2010) proves that under fairly standard conditions on the unobserved factors:

$$\hat{\alpha}_{1t} = Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} \tag{4}$$

is an unbiased estimator of $\alpha_{1t}$, and the mean estimated treatment effect is then computed according to $\overline{\alpha}_1 = \frac{1}{T-T_0} \sum\limits_{t>T_0} \hat{\alpha}_{1t}$. In practice, it is often the case that no set of weights exist such that (3) holds exactly. Then, weights are chosen to minimize the mean squared prediction error (MSPE) between the matrix of pre-acquisition characteristics and outcome variable trajectory of the real network, and the corresponding matrix of its synthetic control network.[1]

To determine the precision of $\hat{\alpha}_{1t}$, an inference method akin to the placebo tests used in the conventional DiD setting is employed. First, the synthetic control method is iteratively applied to every network in the donor pool. Then, the post-treatment MSPE (i.e. the mean squared estimated placebo effect) is divided by the pre-treatment MSPE for each network, and these ratios are then compared to the corresponding ratio for the treated network. The reason why the estimated placebo effects are not compared directly to the estimated treatment effect, is that the matching algorithm sometimes fails to find an appropriate synthetic control group. By scaling the estimated placebo effects by the pre-treatment MSPE, such networks are down-weighted in the ratio. Then, one can compute the probability of obtaining a MSPE ratio at least as high as the ratio obtained from the treated network. If, for example, 5 out of 145 control networks have a higher ratio than the treated network, the probability that a network picked at random would obtain at least as high ratio as the treated network is $6/145 \simeq 0.041$. Henceforth, I refer to this value as the $r$-value, to avoid confusion with the $p$-value usually employed in ordinary regression analysis.

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[1] I estimate the model using Stata's *synth* package (Abadie et al., 2011).

In the present setting, a potential caveat is that the number of pre-treatment periods are small. To increase the number of pre-treatment periods, I assume that acquirers could not influence the outcome variables until one year after the acquisitions took place. This is a plausible assumption, as prices are usually revised only once a year, and revisions do not come into effect until at least a couple of months after the decision. An analogous reasoning can be made in terms of labor costs. Therefore, I estimate the main model using 2003 as the year of treatment. In the network specific estimates, I use 2002 as the year of treatment for E.ON since these acquisitions were conducted in 2001.

## 4.2 DiD estimation

Despite its inability to account for unobserved time-varying characteristics when the parallel trends assumption is not met, the DiD estimator can account for observed time-varying characteristics both before and after treatment. Since the DiD estimator relies on regression analysis, the precision of the coefficients is also evaluated in a more conventional manner than under the synthetic control method. In principle, the magnitude of the DiD estimate on price should be comparable to that of the synthetic control method, since the pre-acquisition trend of the price for the acquired networks is very similar to that of the unweighted mean of the control group. On the contrary, the labor cost in the acquired networks experienced a somewhat different trend compared to the control group mean, leading to potentially different estimates.

Formally, the DiD estimator is identified by:

$$y_{it} = \alpha + \rho_a + \boldsymbol{\lambda}_t + \delta D_{at} + \mathbf{X}_{it}\boldsymbol{\gamma} + \boldsymbol{\eta}_i + \varepsilon_{it} \tag{5}$$

Where $y_{it}$ is the outcome variable in network $i$ in year $t$, and $\alpha$ is a constant. The dummy variable $\rho_a$ takes the value one if the network was acquired at some point, and $\boldsymbol{\lambda}_t$ is a vector of year fixed effects. The variable of interest is $D_{at}$, taking the value one for all acquired networks during the post-acquisition period and zero otherwise, with its associated coefficient $\delta$. $\mathbf{X}_{it}$ is a matrix of time-varying control variables with its associated coefficient vector $\boldsymbol{\gamma}$. $\mathbf{X}_{it}$ contains the same physical characteristics as $\mathbf{Z_i}$ in equation (1). Finally, $\boldsymbol{\eta}_i$ is a set of network fixed effects and $\varepsilon_{it}$ is the error term. In the estimation, standard errors are clustered by network.

A methodological issue within the DiD framework is that acquirers may opt for networks where the potential for efficiency improvements is large, e.g. networks where labor costs are high in relation to comparable networks. In that case, selection-into-treatment could overestimate the potential efficiency gains for the population as a whole. As a diagnostic test of the potential loss in external validity due to sample selection bias, I begin by constructing synthetic control networks using data on the control variables only. In effect, the synthetic networks are then (almost) identical to the acquired networks in all observable dimensions except for the outcome variables. Then, I compare pre-acquisition data on the outcome variables of the real and synthetic comparable networks.

Beginning with the labor cost depicted in Figure B8, it is evident that all of the acquired networks in fact had *lower* labor costs in relation to the comparable networks during the pre-acquisition period. Hence, there is no evidence that the acquired networks were disproportionately inefficient in this respect. Further, there is no sign of a systematic difference in the pre-acquisition trajectories, except for Fortum's network 2, where the synthetic network experienced a comparatively sharp drop during the pre-acquisition period. Hence, the test suggests that the acquired networks were not disproportionately inefficient, even if it is still possible that selection has been made based on unobservable characteristics.

Figure B9 depicts the corresponding graphs for the price. It is evident that the price was instead comparatively *high* in the acquired networks already during the pre-acquisition period, and there is no indication that the pre-acquisition trends differed in relation to the comparable networks.

## 4.3 Robustness

A disadvantage of relying on accounting data is that firms may have an incentive to misreport. In the present context, firms have an incentive to exaggerate their true costs in order to increase their allowed revenue. Even if the NPAM is based on exogenous variables only, there is still a possibility to renegotiate the allowed revenue with the regulator *ex post*. For firms that wish to cross-subsidize divisions that are not subject to regulation, incentives to misreport may be even stronger, e.g., by letting the administrative staff handle the tasks of the firm's retailing activities, or by letting maintenance staff perform maintenance on equipment owned by the firm's generation division. Even for firms with low charge rates, this may be a beneficial strategy if firms believe that regulation will be tightened if the regulator finds profits to be unreasonably high. For Fortum and E.ON, the possibility of cross-subsidization is further reinforced since they also operate the regional transmission networks. The regional transmission networks are also subject to the NPAM, and these networks are usually located in the same region as the distribution networks. Since the type of costs associated with regional transmission and distribution are similar, it should be relatively easy to transfer costs to the division with the lowest charge rate.

To take the issue of cross-subsidization into account, I also estimate the model by only including control firms who engage exclusively in electricity distribution, which applies to about 25 percent of all firms in the control group. Naturally, it would be preferable if such a test could be made also for the acquired networks, but since both E.ON and Fortum engaged in several activities on top of electricity distribution, this is not possible.

Further, to mitigate the possibility that the division between in-house and outsourced labor are driving the results, I perform two robustness tests: First, I estimate the model by restricting the labor cost to in-house labor. Second, I restrict the donor pool to firms that have a similar share (±5 percent) of in-house to total labor costs compared to the mean of the acquired networks. All robustness tests are applied to both the synthetic control method, as well as the DiD specification.

Last, it should also be noted that incentives to *understate* costs may arise among owners that are planning to divest their network, as higher profitability should appear more attractive to investors. In the present context this could have been relevant to Fortum, which in 2015 divested all its distribution and regional transmission networks to a consortium lead by the Canadian firm Borealis Infrastructure (SvD, 2015). The price tag was approximately 7,000 EUR per residential customer (or 6.6 billion EUR in total). To get a rough idea if the accounted profits appear reasonable in relationship to the price, back-of-the envelope calculations suggest that the highest discount rate that could justify the investment given a perpetuity corresponding to the accounted EBITDA is 2.7 percent[2]. This figure appears to be rather low, indicating that accounted costs could be overstated, and possibly that the acquirer was aware of this. By comparison, the benchmark repo interest rate set by the central bank of Sweden averaged at 3.46 percent during the last two decades.

# 5 Results

## 5.1 Synthetic control method results

Table 2 shows the pre-acquisition mean of all variables. Column (1) depicts the observed mean of the acquired networks, while columns (2)-(3) depict the corresponding figures for the synthetic networks. Since the matching algorithm is run separately for price and labor respectively, there are separate synthetic networks associated with each of the outcome variables. As seen in Table 2, the variables in the real acquired networks match the synthetic networks well. Importantly, both outcome variables are matched very well, with an absolute difference compared to the real network of less than one percent.

Table 3 presents the results, and the upper left diagram in Figure 5 compares the trajectory of the price in the acquired network to its synthetic analogue. Both the real and the synthetic network experience an increase in price of around 40 percent throughout the sample period, which is about the same as the industry average. In the first years following the acquisitions, the price in the acquired network was somewhat lower than the synthetic price. This indicates that the new owners kept prices low for a number of years after the acquisition, possibly to reduce the risk of being suspected of overcharging. In 2008, the price in the acquired network started to catch up with the synthetic price, and by the end of the sample period prices were almost identical. On average the price in the acquired network was 1.2 percent (63 SEK) above its synthetic analogue during the years following the acquisitions, an effect that is hardly economically significant. The trajectories of the placebo effects are depicted in Figure B4. The distribution of the placebo estimates also confirm that the effect is not statistically significant: 68 of the placebo networks had an post/pre-acquisition MSPE ratio higher than the estimated effect. Hence, if the intervention would be assigned at random in the data, the probability of obtaining

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[2] In 2011, Fortum's EBITDA was 190 EUR per residential customer (including the earnings on the regional transmission network). The highest discount factor that can justify the investment given a perpetuity of 190 EUR per year is 2.7 percent ($190/0.027 \approx 7,000$). Figures for later out-of-sample years were only slightly different compared to the figures for 2011.

Table 2: Matching of variables during the pre-acquisition period

| | (1) | (2) | (3) |
|---|---|---|---|
| | Acquired | Synthetic | |
| *Independent variables* | | *Price* | *Labor* |
| Customer density | 135 | 152 | 173 |
| Underground line | 45.2 | 43.1 | 46.2 |
| Overhead line | 67.2 | 64.2 | 68.2 |
| Transformer stations | 33.9 | 35.2 | 31.7 |
| Transformer capacity | 8.1 | 9.6 | 9.8 |
| SAIDI | 93.8 | 97.3 | 96.5 |
| Days above 15 m/s | 7.2 | 6.3 | 7.4 |
| *Outcome variables* | | | |
| Price | 4237.76 | 4242.48 | - |
| Labor | 1197.10 | - | 1203.20 |

Note: Mean of the independent and the outcome variables during the pre-acquisition period for the acquired and the synthetic networks.

Table 3: Synthetic control method results

| Model | Price (SEK) | % | Labor (SEK) | % |
|---|---|---|---|---|
| Main specification | 63 | 1.21 | -427** | -17.7 |
| Only in-house labor | - | | -50* | -8.74 |
| Control group only electricity distribution | 93 | -1.98 | -107* | -7.57 |
| Control group similar share in-house/external costs | 59 | 1.07 | -225** | -14.23 |

* $r < .10$, ** $r < 0.05$, *** $r < 0.01$

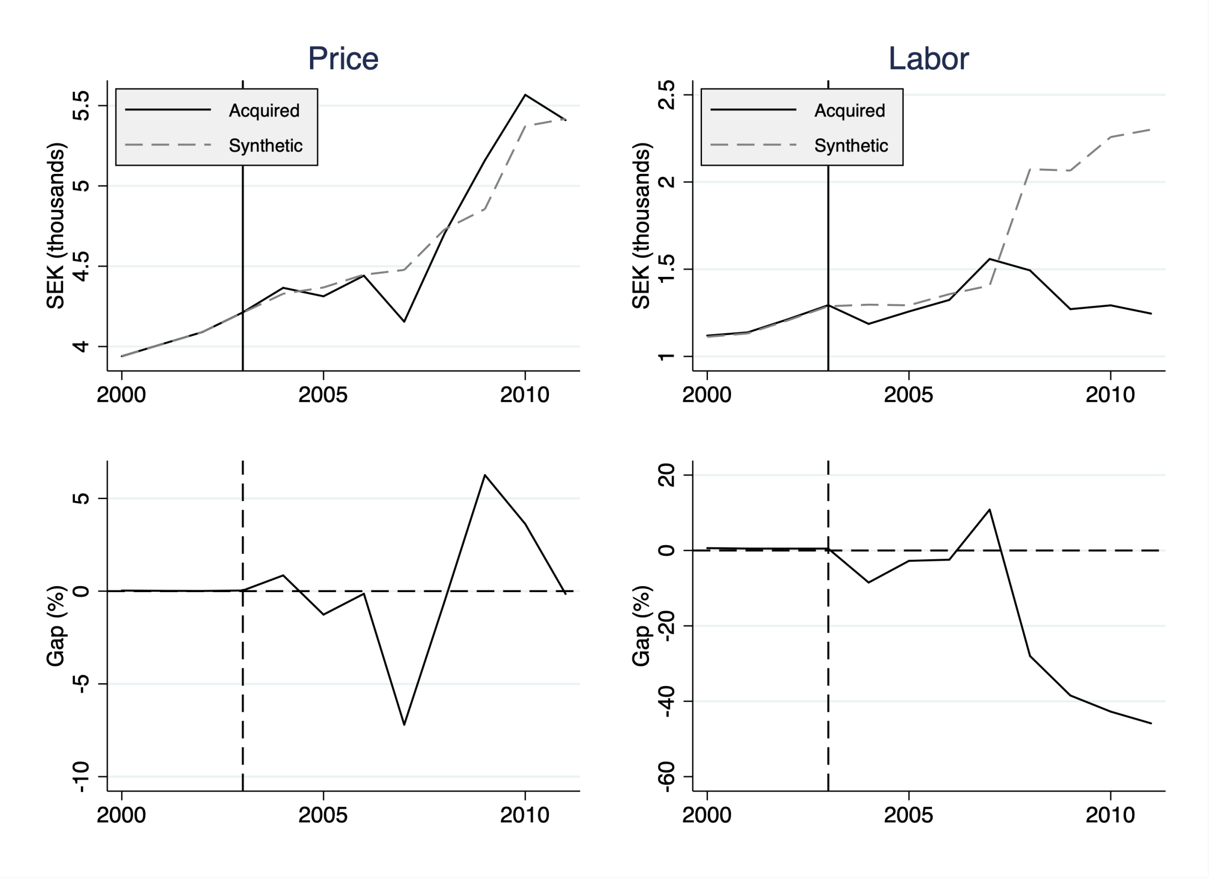
Note: Results using the synthetic control method. Effects are expressed in SEK/customer, with the corresponding figure in percent to the right. The $r$-values are computed as the fraction of placebo estimates where the post/pre-acquisition MSPE ratio exceeded the estimated effect for the acquired network.

a ratio as large as for the acquired networks is $69/145 \simeq 0.48$.

One interpretation of the zero effect on the price is that the regulation has been effective, as the acquirers have not been able to push up the price even though it would lead to higher profits.

The upper right diagram in Figure 5 compares the trajectory of the labor cost in the acquired network to its synthetic analogue. In contrast to the price, the trajectories differ substantially, and the average acquisition effect is -18 percent (-427 SEK) per customer. The effect is mainly driven by a sharp increase in the labor cost of the synthetic network. The gap is depicted in the bottom right diagram of Figure 5, where it is clear that the effect has increased over time. This is expected, since it takes time to restructure the labor force, due to e.g. labor regulations. Compared to their pre-privatization levels, labor costs in the acquired networks were about 40 percent lower than the corresponding figure for the synthetic network in 2011. The trajectory of the placebo effects are depicted in Figure B4. Four of the 145 placebo networks had an MSPE ratio higher than the estimated effect.

Figure 5: Effect of acquisitions on price and labor cost



Note: First row: Trajectories of outcome variables for the acquired and the synthetic networks in SEK/customer. Second row: Outcome gaps in percentages.

Table 4: Network specific effects

| | Price (SEK) | % | Labor (SEK) | % |
|---|---|---|---|---|
| E.ON (1) | -23 | 1.8 | 107* | -10.3 |
| Fortum (1) | 69 | 1.8 | -433** | -21.9 |
| Fortum (2) | 292 | 5.0 | -942*** | -34.5 |
| Fortum (3) | -186 | -4.5 | -210** | -15.5 |
| Fortum (4) | -140 | -2.4 | -981*** | -37.3 |
| **Mean across networks** | 28 | 0.3 | -560 | -23.9 |

* $r < .10$, ** $r < 0.05$, *** $r < 0.01$

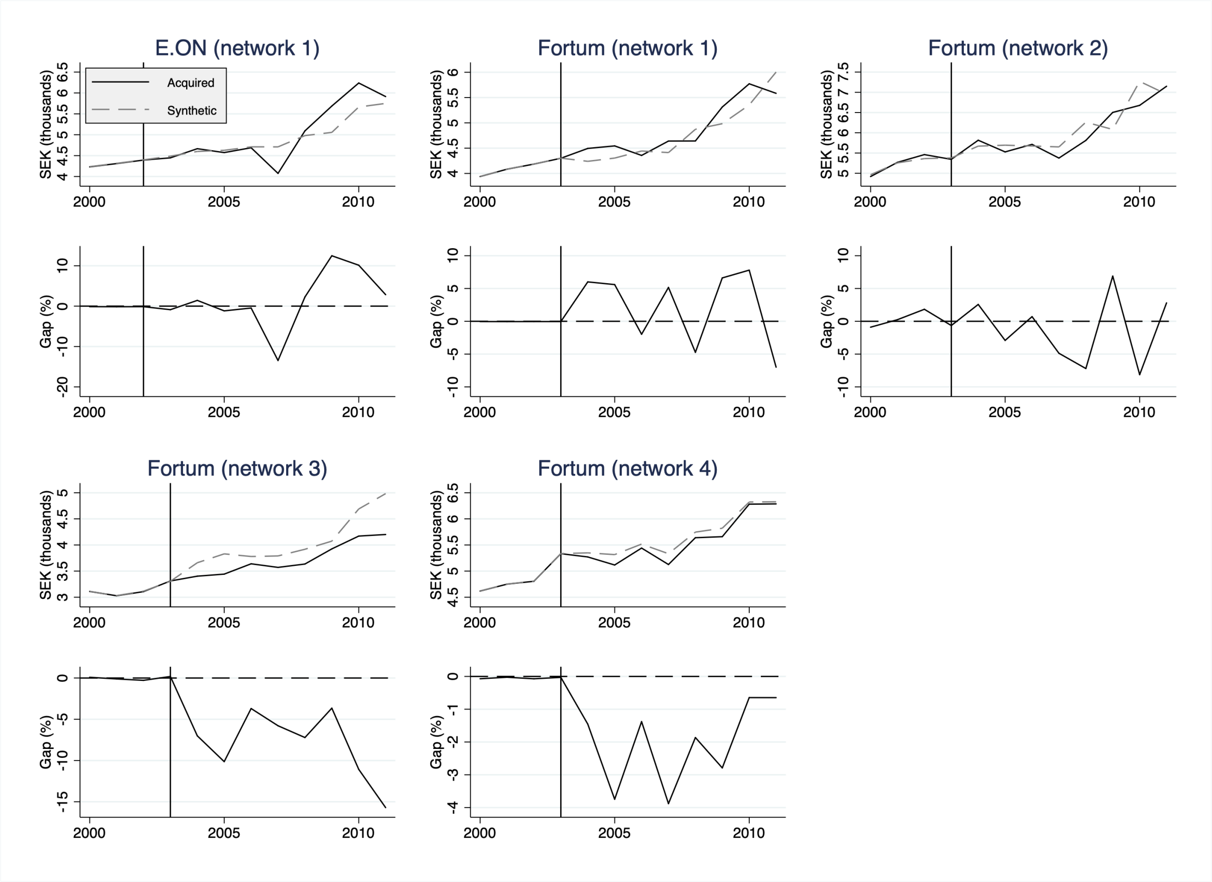
Note: Results for each specific network using the synthetic control method. Effects are expressed in SEK/customer, with the corresponding figure in percent to the right. The $r$-values are computed as the fraction of placebo estimates where the post/pre-acquisition MSPE ratio exceeded the estimated effect for the acquired networks.

Hence, the probability of obtaining a ratio as large as for the acquired networks is 5/145 $\simeq 0.034$, meaning that the effect is also statistically significant.

The network specific effects are presented in Table 4, and trajectories of the outcome variables are depicted in Figures 6 and 7. Results are broadly in line with the results from the representative network. The effect on price is small in each of the networks: The average effect is 0.3 percent, corresponding to 28 SEK per customer and year. Also, there is no systematic difference between E.ON's and Fortum's networks, and the effect is not statistically significant in any of the networks. The effect on labor cost is negative for all networks, although the effect in the networks acquired by Fortum are relatively more pronounced, ranging between -22 and -37 percent. For E.ON's network, the effect is more modest at 10 percent. In this light, it appears plausible that the storm Per in 2007 inflated the labor cost of E.ON, as the observed labor cost in 2007 is larger than for any other year. All of the effects are statistically significant, although the effect in E.ON's network is only significant at the 10 percent level. The mean effect on labor across networks is -24 percent, which is larger than for the representative network. However, since E.ON's network has the largest number of customers, the volume weighted average is lower, at 19 percent, which corresponds very well to the estimated effect of the representative network.

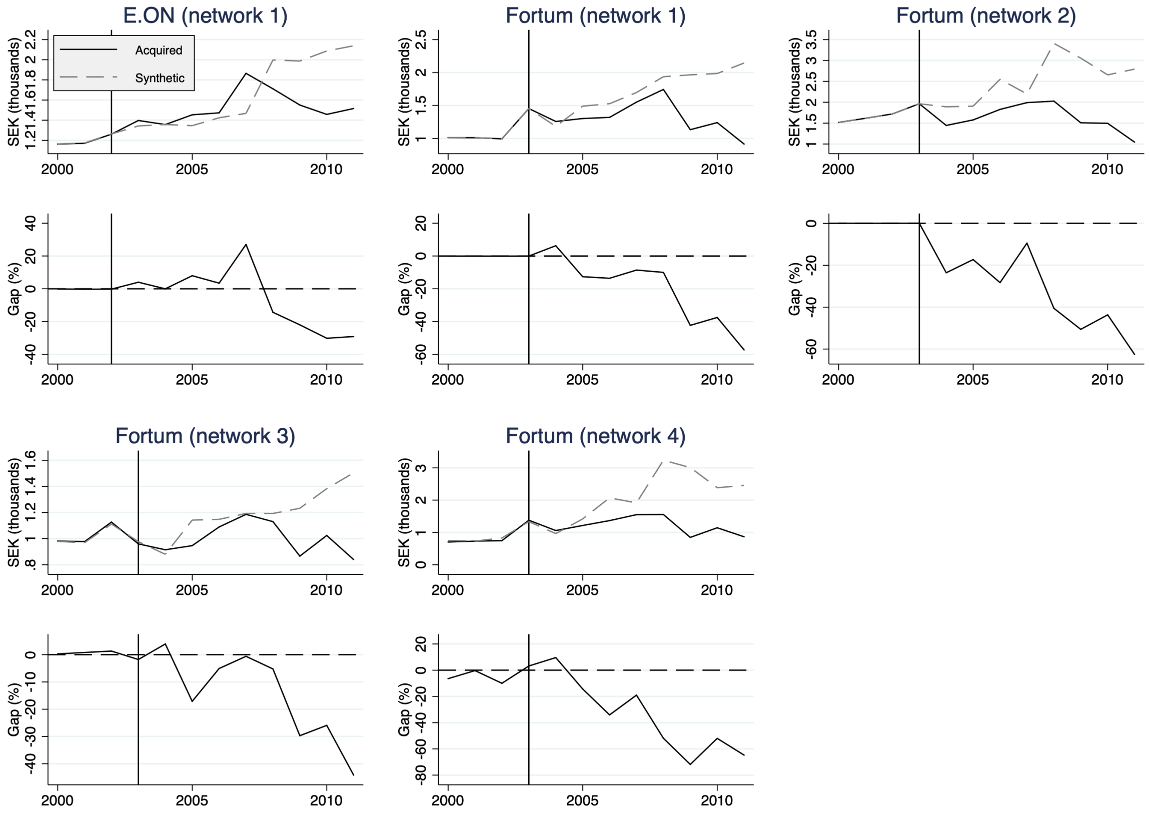
Results from the alternative specifications are presented in rows 2-4 in Table 3, and Figures B5, B6, and B7 depicts the trajectories of the outcome variables. Overall, these results confirm the zero effect on price, but suggest that savings on labor cost are smaller and somewhat less statistically significant relative to the main specification. When restricting labor costs to only in-house labor, the effect is -9 percent, i.e. only about half of the original estimated effect. When the control group is restricted to firms that only engage in electricity distribution, the effect is also less pronounced, at -8 percent. In both specifications, the effect is also less statistically significant relative to the main specification, although the probability of estimating an equally large effect on a network chosen at random is still less than 10 percent. When the control group is restricted to those firms that have an approximately equal share of in-house/total labor cost as the representative network, the effect is somewhat more pronounced, at -14 percent.

Figure 6: Network specific effects on price



Note: Trajectory of the price in the acquired networks and the corresponding synthetic networks in SEK/customer.

Figure 7: Network specific effects on labor cost



Note: Trajectory of the labor cost in the acquired networks and the corresponding synthetic networks in SEK/customer.

## 5.2 DiD results

Results from the DiD estimation are presented in Table 5. The magnitudes of the estimated effects on price are in line with the results using the synthetic control method. The effect is not statistically significant in any of the specifications, and the estimated magnitude ranges between -70 to -62 SEK/customer and year depending on specification. However, since the standard errors are very large in every specification, this indicates that there is significant noise in the data, and that estimates are still consistent with a wide range of price changes. The sign of the estimated effect on labor cost is identical to the results using the synthetic control method for all specifications. However, the effect is generally less pronounced, or comparable to, the results using the synthetic control method. In the main specification in column (2), the effect is -238 SEK, which is only slightly more than half of the corresponding effect using the synthetic control method at -427 SEK. The explanation for this difference is that the weighting algorithm in the synthetic control method assigns a higher weight to networks that experienced a relatively sharp increase in the labor cost during the pre-acquisition period. Since the labor cost in these networks increased relative to the other control networks also during the post-acquisition period, the estimated effect using the synthetic control method is large relative to the DiD estimate. The precision of the DiD estimate is also comparatively low, with a standard error of 128 SEK. In column (3), when estimating the effect on in-house labor only, the effect is instead somewhat larger, at -67 SEK compared to -50 SEK for the synthetic control method. Column (5) presents the results when the control group is restricted to firms that only engage in electricity distribution. The estimated effect is now comparable to the synthetic control estimates, at -116 SEK compared to -107 SEK. In column (7), when restricting the control group to firms that have a similar share of in-house/total labor cost as the acquired networks, the effect is instead less pronounced, at -169 SEK compared to -225 SEK.

In sum, depending on specification, the estimated efficiency gains under the DiD method are either less pronounced, or comparable to, the results using the synthetic control method. Further, the precision of the estimates are comparatively low under both methods for several of the specifications. Therefore, results should be interpreted with care, and the estimated efficiency gain using the synthetic control method under the main specification should be regarded as an upper bound of the true effect.

When interpreting the coefficients on the control variables, it is important to recall that the only identifying source of variation comes from changes within each concession area across time. Therefore, the variation in most of the control variables is likely to be small, and largely explained by residents gradually relocating from rural to urban areas. Looking at row 2 in Table 5 reveals that customer density has a negative and statistically significant effect on price in all of the specifications, which is expected. However, although the effect of customer density on labor cost is also negative in all specifications, it is imprecisely measured. A likely reason is that it is difficult to adjust labor costs as a direct response when residents relocate, resulting in a lag. Adjustments to the physical network may also incur an initial labor cost in itself, even when the network is contracted. Looking at row 3, the effect of underground line length per customer on price is positive in all specifications, which is expected. Except for column (4), where the control group is restricted to firms that only engage in electricity distribution, the effect is also statistically significant. Analogous to the customer density variable, the effect of underground line length on labor cost is insignificant in all specifications. The effect of the overhead line variable is instead negative in most specifications, although the effect on labor cost is positive and statistically significant in the main specification. Although the negative sign of the effect is unexpected, a likely reason is due to the large number of fixed effects, and the correlation with the other density measures. The effect of the number of transformer stations per customers is positive for both price and labor in all specifications but one, but is generally imprecisely measured.

Moving on to the non-technical variables, the effect of SAIDI on price is negative and significant in all specifications. As discussed in the data section, this is expected, since the price variable is measured after adjusting for repayments to customers due to service disruptions. Conversely, the effect on labor cost is positive in all specifications, and statistically significant in all specifications but one. This is expected, as service disruptions increase the need for costly maintenance. Notably, when restricting labor cost to in-house labor in column (3), the effect is much less pronounced than in the other specifications. This indicates that a large share of the maintenance work due to failures is outsourced. The wind speed variable is insignificant in all specifications, which is expected given that SAIDI is included in the estimation.

# 6 Conclusion

Using a synthetic control method, I examine the effects of privatization in the Swedish electricity distribution sector. Specifically, I examine the effects of private acquisitions of municipally owned distribution networks that were conducted around the turn of the century. In comparison to their synthetic counterparts, I find that the acquired networks increased labor efficiency by on average 9-18 percent during the nine years following privatization, and that the effect increased over time. By contrast, no effect is found on price. Thus, the evidence suggests that efficiency gains are economically meaningful, but that these are not fed through to consumer prices. The finding that privatization was not followed by lower prices is not unexpected, since the regulatory mechanism primarily determined prices based on exogenous characteristics of each network. Results using a DiD estimator largely confirms the results from the synthetic control method, although the estimated efficiency gains are generally both less pronounced and less precisely estimated. Since the standard error of the price effect is large, it should be noted that results are still consistent with a wide range of price changes.

In terms of magnitudes, the current study points to potentially larger efficiency gains than previous Swedish studies. Kumbhakar and Hjalmarsson (1998) find labor efficiency to be 12-17 percent higher in private relative to municipally owned firms depending on model specification. Although this figure is comparable to the average post-acquisition effect estimated in the present study, labor costs in the acquired networks were about 40 percent lower compared to the synthetic network nine years after privatization. Comparisons to Kumbhakar and Hjalmarsson should however be interpreted with care, since their

Table 5: Results from the difference-in-differences estimates

| | Full sample | | | Contr. group only distr. | | Contr. group sim. | |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Acquisition effect ($\hat{\delta}$) | −61.9 | −237.7* | −66.7* | −67.0 | −115.6** | −70.3 | −169.4* |
| | (67.9) | (128.4) | (38.3) | (95.9) | (82.1) | (59.1) | (89.3) |
| Customer density | −0.0097** | −0.0062 | −0.0035* | −0.013*** | −0.0081 | −0.013** | −0.0062 |
| | (0.004) | (0.005) | (0.002) | (0.005) | (0.006) | (0.006) | (0.004) |
| Underground line | 4.63** | −4.39 | 1.08 | 5.64 | 0.44 | 4.88** | 0.39 |
| | (2.1) | (3.2) | (1.0) | (4.3) | (2.8) | (2.2) | (1.8) |
| Overhead line | −8.86*** | 5.33* | 0.50 | −7.57* | −0.39 | −6.69*** | −0.37 |
| | (3.0) | (3.2) | (0.9) | (4.2) | (2.7) | (1.9) | (1.6) |
| Transformer stations | 51.3** | 91.3 | 5.13 | 15.7 | −2.94 | 18.0 | 30.5** |
| | (24.1) | (60.1) | (7.1) | (42.7) | (12.5) | (13.8) | (14.1) |
| Transformer capacity | 0.012** | 0.0080 | −0.0022 | 10.8 | −4.81 | 12.1 | −3.88 |
| | (0.005) | (0.007) | (0.003) | (27.2) | (9.8) | (17.7) | (14.1) |
| SAIDI | −0.11* | 0.15 | 0.023* | −0.17*** | 0.31*** | −0.14*** | 0.35*** |
| | (0.06) | (0.1) | (0.01) | (0.06) | (0.08) | (0.04) | (0.05) |
| Days above 15 m/s | −16.9 | −2.12 | 2.50 | −46.9 | 10.2 | −25.5 | −10.4 |
| | (16.7) | (14.3) | (6.7) | (46.4) | (24.4) | (28.4) | (18.6) |
| Dependent variable | Price | Labor | In-house labor | Price | Labor | Price | Labor |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Area FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs | 1820 | 1820 | 1820 | 491 | 491 | 923 | 923 |

* $p < .10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Note: Results from the difference-in-differences specifications. All specifications include year and concession area fixed effects. In columns (1)-(3), the full set of control networks are included. In columns (4)-(5), the control group is restricted to firms that engage in electricity distribution only. In columns (6)-(7), only firms that have a similar share of in-house labor/total labor cost are included. Standard errors are clustered by concession area.

identification relies on cross-sectional variation. The only current study using a sample period that overlaps with the current study is Söderberg (2011), who estimates that private firms are only about five percent more efficient than their municipal counterparts. However, since Söderberg's cost measure also includes capital costs, this figure should not be directly compared to the current results. By international standards, the estimated efficiency gains are not unusually large. For example, Domah and Pollitt (2001) estimate that labor productivity in England and Wales nearly doubled after the first eight years following privatization. Similar to the present study, they find that the efficiency gains did not materialize until several years after privatization, and consumers started to gain only about a decade after the privatizations. Further, in the study of Latin American distribution firms by Estache and Rossi (2005), private firms operating under a price cap regulation are found to use about 60 percent less labor than public firms for a given output.

A topic for future studies could be to disentangle the mechanisms driving the efficiency gains. For example, the regulatory structure does not take into consideration economies of scope between various stages in the supply chain. This should provide E.ON and Fortum with a cost advantage compared to municipally owned networks that generally do not engage in generation or regional transmission. Except for returns to scope, returns to scale is likely to be a contributing explanation, since several of the acquisitions involved bordering networks that were previously operated by each respective municipality. As discussed in the introduction, it is also likely that some publicly owned firms prefer to offer higher wages relative to private firms, in which case it would be valuable to examine if the number of hours worked were reduced to the same extent as the labor cost. Further, it would be of interest to study in greater detail whether private firms attach less weight to quality of service than public firms. In Sweden, customers are only entitled to repayments when service disruptions are 12 hours or longer, with stepwise increases in repayments at subsequent daily thresholds. Therefore, firms attaching less weight to quality could be less willing to incur extra costs to repair the network swiftly, which could result in bunching of service disruption lengths just below the thresholds.

It should also be of interest to look into dimensions of strategic behavior that considers the synergy aspects of controlling both generation and distribution within the same area, as opposed to examining firm behavior in each market separately.

# References

**Abadie, Alberto, Alexis Diamond, and Jens Hainmueller**, "Synthetic Control Methods for Comparative Case Studies: Estimating the Effect of California Tobacco Control Program," *Journal of the American Statistical Association*, 2010, *105* (490), 493–505.

**_ , _ , and _** , "SYNTH: Stata module to implement Synthetic Control Methods for Comparative Case Studies," Statistical Software Components, Boston College Department of Economics October 2011.

**Averch, Harvey and Leland L. Johnson**, "Behavior of the Firm Under Regulatory Constraint," *The American Economic Review*, 1962, *52* (5), 1052–1069.

**Berg, Sanford, Chen Lin, and Valeriy Tsaplin**, "Regulation of State-Owned and Privatized Utilities: Ukraine Electricity Distribution Company Performance*," *Journal of Regulatory Economics*, 2005, *28* (3), 259–287.

**Borghi, Elisa, Chiara Del Bo, and Massimo Florio**, "Institutions and Firms' Productivity: Evidence from Electricity Distribution in the EU," *Oxford Bulletin of Economics and Statistics*, 2016, *78* (2), 170–196.

**Dalarna's newspaper**, "Municipalities wants to buy back the electricity network," http://www.dt.se/dalarna/mora/mora-beredd-kopa-tillbaka-salda-elnatet (accessed March 20, 2017), 2014.

**Domah, Preetum and Michael G. Pollitt**, "The restructuring and privatisation of the electricity distribution and supply businesses in England," *Fiscal Studies*, March 2001, *22* (1), 107–146.

**Energy Markets Inspectorate**, "Ägarstrukturen på elmarknaden," Report EI R2012:21, Energy Market Inspectorate 2006.

**_** , "Utvecklingen av elnätsavgifter 2009-2010," Report PM 2010:03, Energy Market Inspectorate 2011.

**_** , "Bedömning av elnätsföretagens nätavgifter nätavgifter 2011," Report Ei R2012:13, Energy Market Inspectorate 2012.

**Estache, Antonio and Martín A. Rossi**, "Do regulation and ownership drive the efficiency of electricity distribution? Evidence from Latin America," *Economics Letters*, 2005, *86* (2), 253 – 257.

**Heden, H**, *Energimarkandsinspektionen - en sekellång historia*, Energimarkandsinspektionen, ISBN 978-91-977417-1-2, 2012.

**Jamasb, Tooraj and Magnus Söderberg**, "The Effects of Average Norm Model Regulation: The Case of Electricity Distribution in Sweden," *Review of Industrial Organization*, May 2010, *36* (3), 249–269.

_ **and Michael Pollitt**, "Reference models and incentive regulation of electricity distribution networks: An evaluation of Sweden's Network Performance Assessment Model (NPAM)," *Energy Policy*, May 2008, *36* (5), 1788–1801.

**Karahan, Hatice and Mehmet Toptas**, "The effect of power distribution privatization on electricity prices in Turkey: Has liberalization served the purpose?," *Energy Policy*, 2013, *63* (C), 614–621.

**Kumbhakar, Subal C. and Lennart Hjalmarsson**, "Relative performance of public and private ownership under yardstick competition: electricity retail distribution," *European Economic Review*, January 1998, *42* (1), 97–122.

**Kwoka, John E.**, "The Comparative Advantage of Public Ownership: Evidence from U.S. Electric Utilities," *The Canadian Journal of Economics / Revue canadienne d'Economique*, 2005, *38* (2), 622–640.

**Laffont, Jean-Jacques and Jean Tirole**, *A Theory of Incentives in Procurement and Regulation*, 1 ed., Vol. 1, The MIT Press, 1993.

**Meyer, Roland**, "Vertical Economies and the Costs of Separating Electricity Supply: A Review of Theoretical and Empirical Literature," Bremen Energy Working Papers 0006, Bremen Energy Research April 2011.

**Niskanen, William A.**, "The Peculiar Economics of Bureaucracy," *The American Economic Review*, 1968, *58* (2), 293–305.

**NordReg**, "Economic regulation of electricity grids in Nordic countries," Nordic Energy Regulators, report nr.7, 2011 2011.

**OECD**, "Germany - Regulatory Reform in Electricity, Gas, and Pharmacies," Country Studies 2004.

**SABO**, "Large price increases in networks owned by E.ON, Fortum and Vattenfall," `http://www.sabo.se/aktuellt/nyheter_s/2011/mar/Sidor/St%C3%B6rst-pris%C3%B6kningar-i-eln%C3%A4t-%C3%A4gda-av-EON-Fortum-och-Vattenfall.aspx` (accessed March 20, 2017), 2011.

**Shleifer, Andrei**, "A Theory of Yardstick Competition," *RAND Journal of Economics*, Autumn 1985, *16* (3), 319–327.

**Söderberg, M.**, "The Role of Model Specification in Finding The Influence of Ownership and Regulatory Regime on Utility Cost: The Case of Swedish Electricity Distribution," *Contemporary Economic Policy*, 2011, *29* (2), 178–190.

**SvD**, "Fortum säljer sitt svenska elnät," `http://www.svd.se/fortum-saljer-sitt-svenska-elnat` (accessed March 20, 2017), 2015.

**Swedish Competition Authority**, "Consultation response to the NPAM framework," `http://www.konkurrensverket.se/Beslut/03-0538.htm` (accessed March 20, 2017), 2003.

# Appendix A

### The Network Performance Assessment Model

The implementation of the NPAM can roughly be summarized by the following steps (the description has largely been adapted from Jamasb and Pollitt, 2008).

1. **Data collection.** Information about the geographical coordinates of customers and their consumption usage are collected, together with the coordinates of the network's connection points to neighboring and overlying regional networks.

2. **Computation of reference network.** The NPAM algorithm constructs a hypothetical reference network, including meters of line per exit point; a density measure to every meter of line; the capacity for every transformer station, and a density measure for every transformer.

3. **Computation of reference network costs.** The investment cost for each network is computed using the standard costs of equipment found in the Swedish Electricity Building Rationalization (EBR) catalogue. The costs of building and operating the network today are derived using cost functions for capital costs, return on capital, operation and maintenance, network administration, and network losses. The costs are also adjusted for quality of service in terms of supply interruptions.

4. **Computation of charge rate and regulatory scrutiny.** The revenue of the actual network is divided by the computed costs of the hypothetical reference network, obtaining the network's "charge rate". The charge rate is computed each year *ex-post*, and the comparison is made only with respect to the previous year's revenue. A charge rate lower than unity indicates that the firm is more efficient than its reference network. If the charge rate is above a certain threshold, the concession holder is subject to a detailed investigation. The trigger charge rate is determined ex-post by the regulator. In 2003 it was 1.3, in 2004-2005 it was 1.2, and from 2006 and onwards it was 1.1. If the detailed investigation shows that the charges are justified, the case is closed. Otherwise, the concession holder is required to retrospectively lower prices and pay back customers.

Under the NPAM model, *all* firms could in theory be subject to regulatory scrutiny, since the relative performance of the firms should not matter. However, the trigger charge rate is set *ex-post* depending on the choice of the regulator. Thus, it is likely that the trigger charge rate is set such that a "reasonable" share of the firms are exempted from regulatory scrutiny, adding an element of yardstick regulation also to the NPAM model. Further, the use of the EBR catalogue as a determinant of the investment cost of each network adds another element of yardstick regulation to the model, since the costs in the EBR catalogue are determined by actual costs reported by all firms in the industry. It should be noted that the EBR catalogue not only serves as a reference for the cost of physical equipment, but also contains estimates of the number of hours needed to install different types of equipment[3]. Jamasb and Söderberg (2010) examine how network owners have

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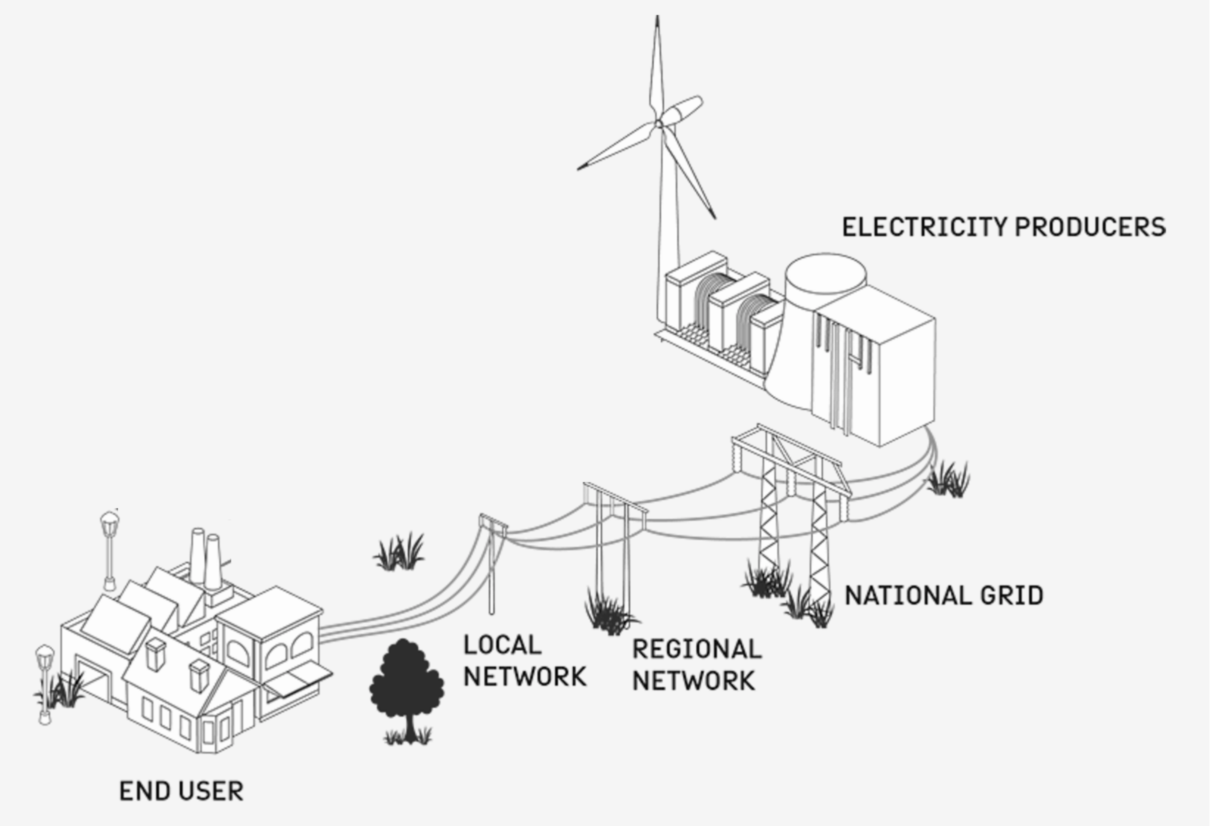
[3] The risks of coordination on manipulation of costs in the EBR catalogue are impending, and has

responded to the incentives given by the NPAM regulation, finding that owners respond by inflating (reducing) their costs when they have low (high) charge rates.

During 2009-2011, there was a slight change in the NPAM regulation to facilitate the transition to the new regulation. During these years, the reference cost was computed based on the actual technical characteristics of the physical network, and there was a higher emphasis on price trends, as opposed to the static relationship between costs and price in each separate year (Energy Markets Inspectorate, 2012).

## Appendix B

Figure B1: Schematic diagram of the physical supply chain



Note: This figure depicts a schematic diagram of the physical route of electricity. The "local network" is equivalent to the distribution network. Source: Svenska Kraftnät.

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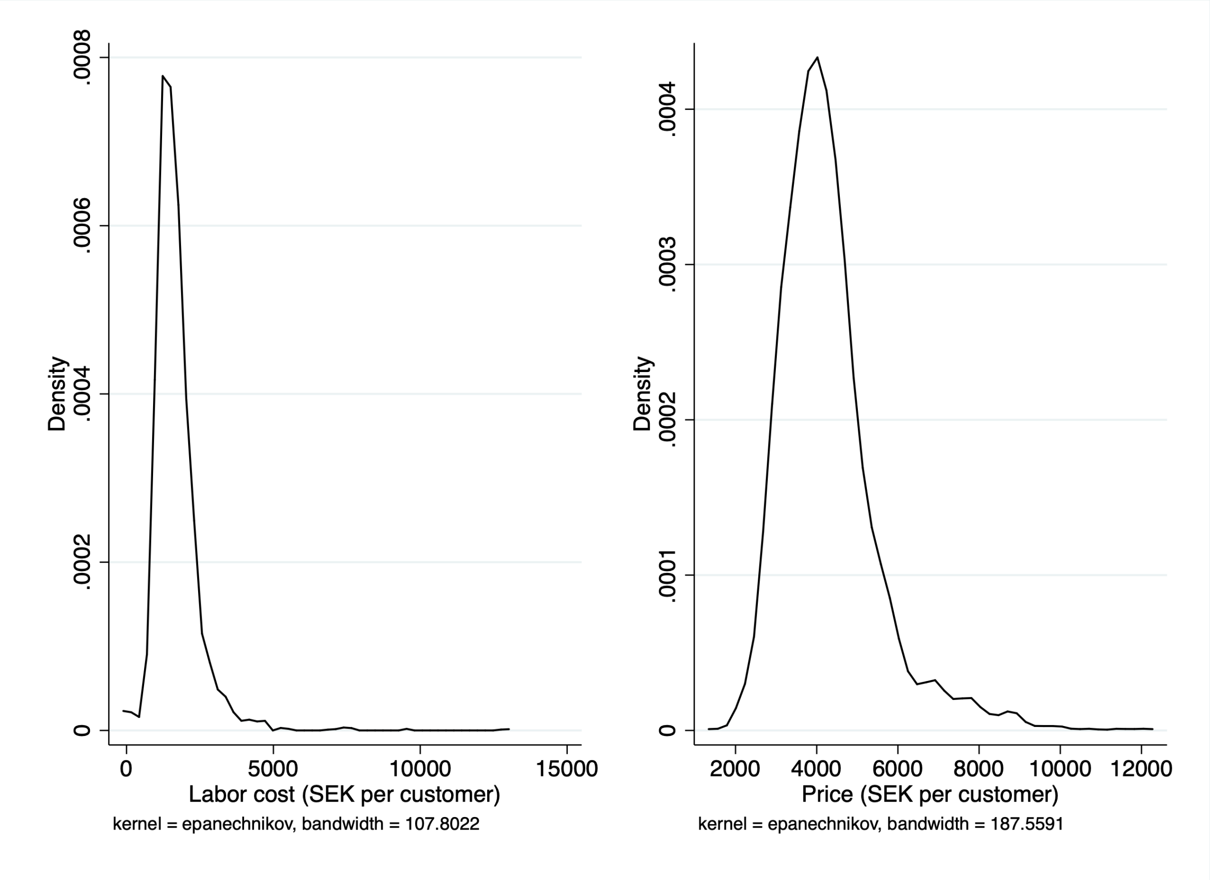
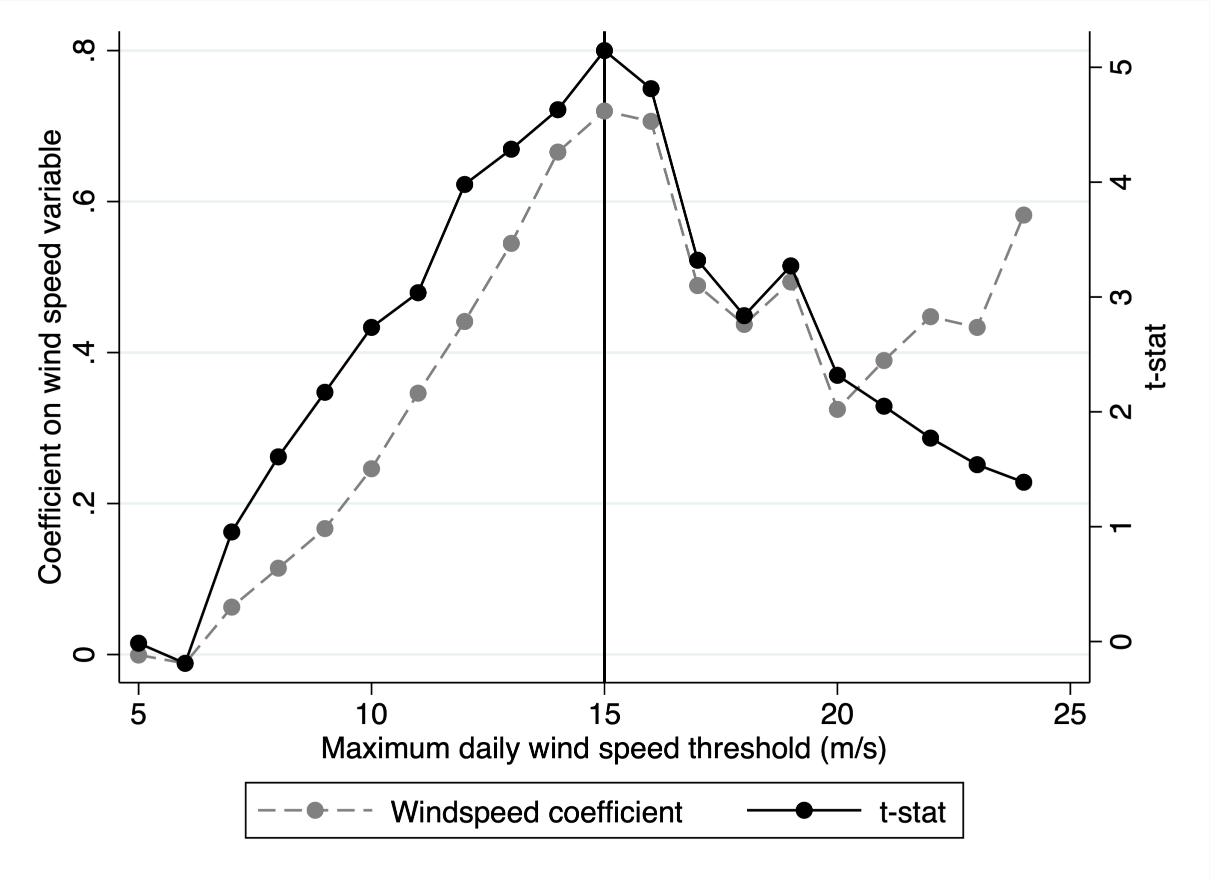
been noted by the Swedish Competition Authority (2003) and Jamasb and Pollitt (2008).

Figure B2: Density functions of the outcome variables



Note: This figure depicts density functions of the outcome variables during the whole sample period for all networks.

Figure B3: The effect of wind speed on SAIDI

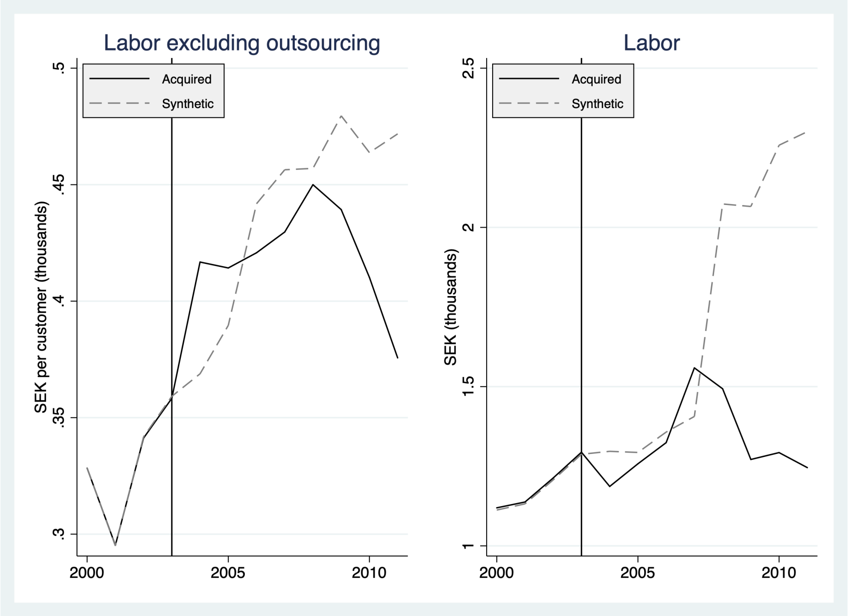


Note: This figure depicts coefficients and t-statistics from regressing SAIDI on a variable measuring the percentage of days when the maximum daily wind speed was at least above the threshold. Network fixed effects are included in all regressions. Variables have been log transformed.

Figure B4: Trajectory of placebo effects

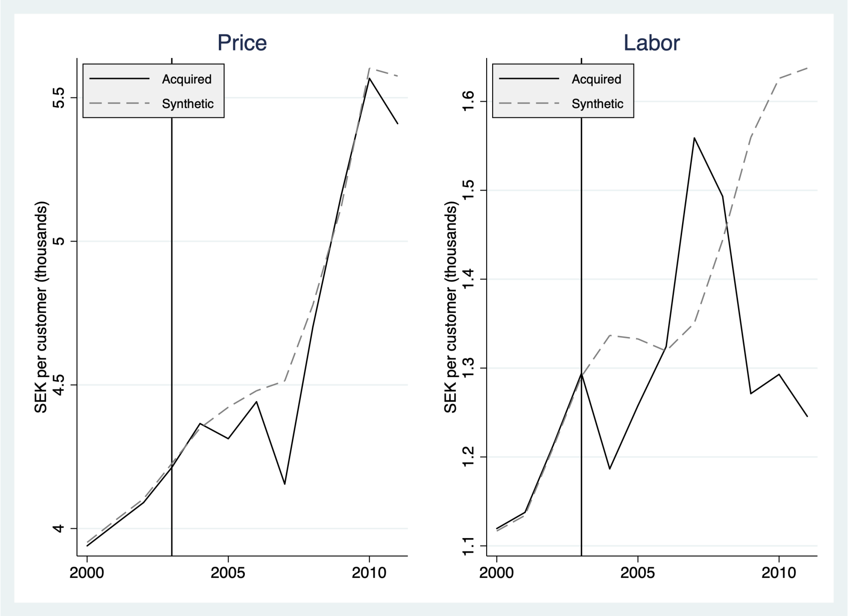
Note: Trajectory of outcome gaps between real and synthetic networks for each network in the sample. Networks with a mean squared prediction error more than twice as large as the acquired network are excluded.

## Figure B5: Effect on in-house labor



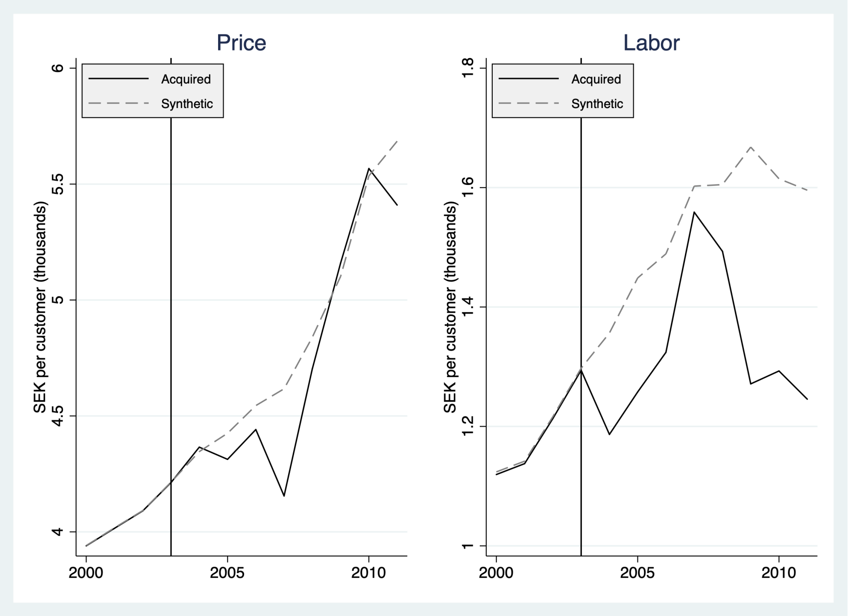
Note: Trajectory of the labor cost in the real acquired networks and the corresponding synthetic networks in SEK/customer.

## Figure B6: Control firms restricted to electricity distribution



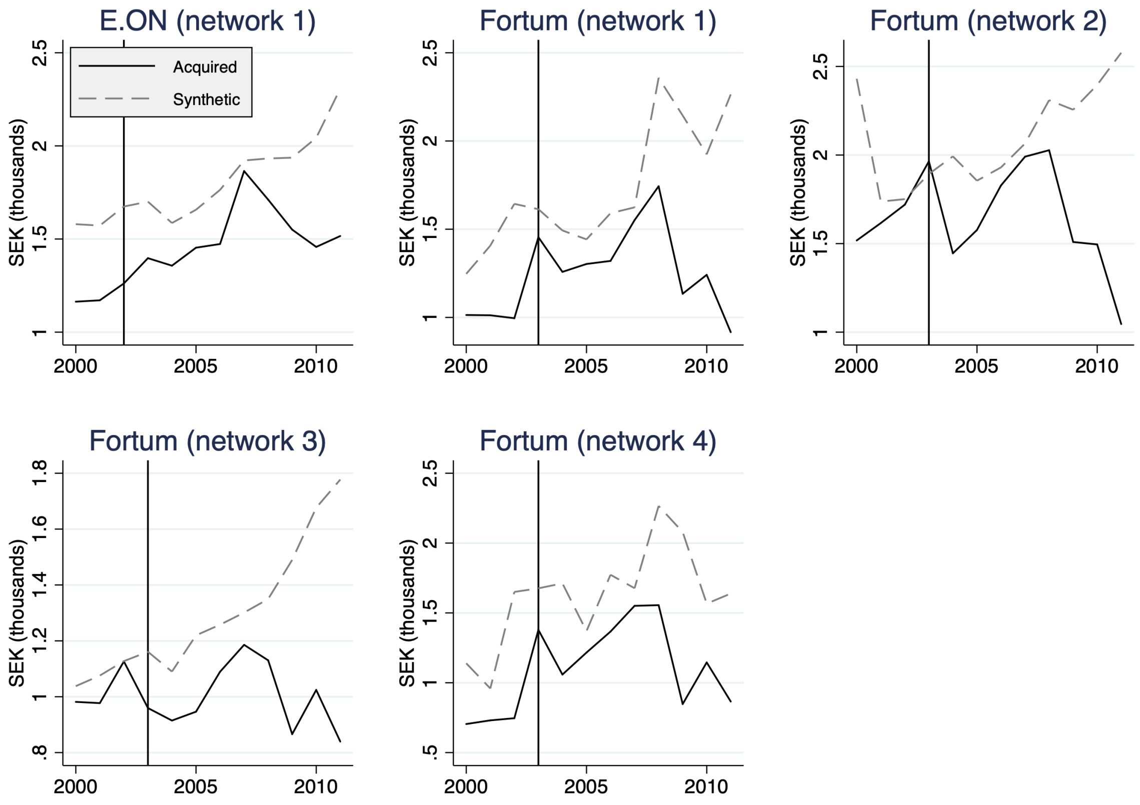
Note: Trajectory of the outcome variables when the control networks are restricted to firms that only engage in electricity distribution.

Figure B7: Control firms restricted to similar share of in-house labor



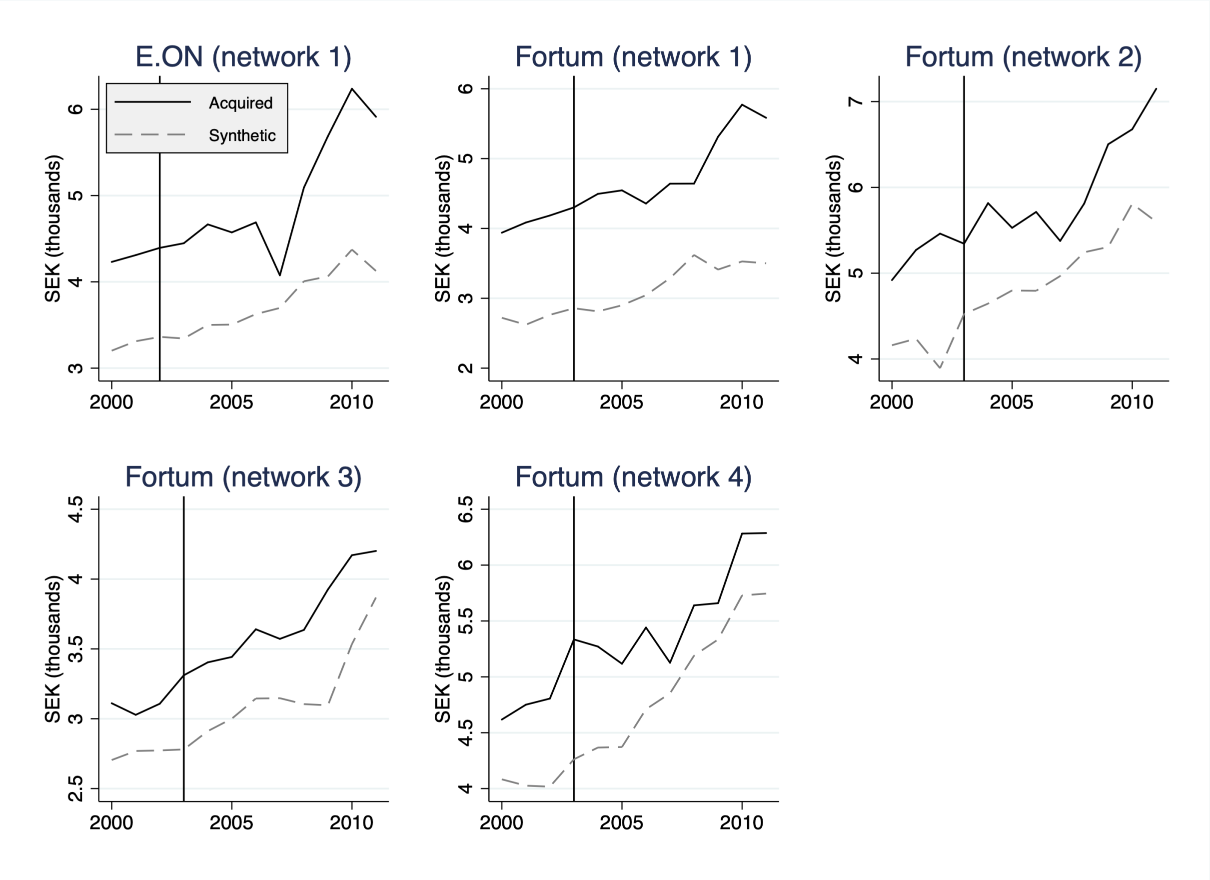
Note: Trajectory of the outcome variables when the control networks are restricted to firms that only engage in electricity distribution.

Figure B8: Labor cost trajectories of comparable control networks



Note: This graph depicts the trajectory of the labor cost in the real and synthetic networks when the synthetic networks have been constructed from control variables only.

Figure B9: Price trajectories of comparable control networks



Note: This graph depicts the trajectory of the price in the real and synthetic networks when the synthetic networks have been constructed from control variables only.