THE IMPACT OF INDUSTRIAL ELECTRICITY PRICES ON EMPLOYMENT AND FIRMS ACROSS SECTORS

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Abstract

This paper examines the effects of industrial electricity prices on employment and number of active firms in the manufacturing, services and primary sectors. For identification, I exploit a wave of electricity market deregulation reforms enacted in 21 US states in 2000 and that counties have different shares of coal in their electricity mix. I use an Instrumental Variable (IV) identification strategy and find that a 1% increase in industrial electricity prices reduces manufacturing employment by 0.43% and the number of manufacturing firms by 0.44%, with positive but not statistically significant effects in the service and primary sectors. Assuming a Constant Elasticity of Substitution (CES) production function, electricity and labor are complements in the service sector. Conversely, I find that in the manufacturing sector, I cannot reject the hypothesis that the underlying production function is a Cobb-Douglas.

1 Introduction

Electricity is a critical input for firms in the modern economy. Globally, the industrial sector is the largest consumer of electricity, responsible for about 42% of total electricity consumption with an additional 21% consumed by the commercial and service sectors as of 2018[1]. This share is expected to increase due to the ongoing transition to industrial electrification worldwide (Sun et al., 2024; Toktarova et al., 2025). In the USA, a total of 2400 TWh was used by the industrial and commercial sectors in 2022, consisting of over 60% of the total US electricity production[2]. Similarly, in China, around 59% of total electricity

[1] Statista, "Electricity Consumption Share by Sector Worldwide 2022"
[2] US Energy Information Administration (EIA)

production in 2022 was used by the industrial sector and 8% by commercial sector[3]. In the EU, a third of total electricity consumption is from the industrial sector, representing the most significant input in manufacturing processes, according to the EU Commission[4].

However, electricity production is costly and electricity prices are an important driver of economic growth. **?** found that energy and electricity price shocks affect economic growth with different effects across sectors with different exposures and across countries with different policy reactions. Cox et al. (2014) find large effects of electricity prices on employment in german firms especially among high skilled workers. **?** find that higher electricity prices affect employment in the manufacturing sector and, especially, in financially constrained firms. These findings suggest that temporary and permanent increases of electricity prices can have significant effects on the economy and workers. Therefore, in a context where energy polices are oriented towards cleaner sources that usually increase electricity prices[5][6] (Yan, 2021; Hanoteau and Talbot, 2019; Zhang and Wei, 2010), understanding the impacts across different sectors of higher electricity prices on economic outcomes is of key importance for policy-makers.

In this paper, I estimate the elasticity of employment and active firms with respect to industrial electricity prices and the elasticity of substitution between electricity and labor in the United States (US). I estimate the elasticities separately for the manufacturing, service and primary sectors using an instrumental variable (IV) identification strategy. To construct the instrument, I exploit a reform that deregulated the electricity market and its heterogeneous effect on electricity prices across US counties that have different shares of coal in their electricity mix. I find that a 1% increase in electricity prices leads to a decline in manufacturing employment of 0.43% and in the number of manufacturing firms of 0.44%. In contrast, I find some positive but not statistically significant effects in the services and in the primary sector pointing towards some reallocation of workers in other sectors. I estimate the elasticity of substitution for the manufacturing and service sectors assuming a Constant Elasticity of Substitution (CES) production function of the economy. Combining estimates from this paper with parameters from the literature (Burke and Abayasekara, 2018; Bossler et al., 2023), I find that the elasticity of substitution between electricity and labor is 0.89 in the manufacturing sector and 0.63 in the service sector. Thus, labor and electricity are complements in the service sector while I can not reject the hypothesis that the underlying

[3]International Energy Agency (IEA),
[4]Eurostat Energy Statistics
[5]Ministry of Ecology and Environment of the People's Republic of China, press release, July 22, 2024
[6]International Carbon Action Partnership (ICAP), "Indian Carbon Credit Trading Scheme"

production function is a Cobb-Douglas in the manufacturing sector.

I estimate the elasticity of employment and number of firms with respect to electricity prices using an IV identification strategy due to endogeneity issues with using an Ordinary Least Squares (OLS) empirical strategy. I use an electricity market reform as my instrumental variable and I interact the reform with the share of coal in each county electricity mix in 1990 to account for its heterogeneous effects in areas with electricity production from different sources. I estimate a model with log employment and log number of firms as outcome variables and log electricity price as the main explanatory variable with time and county fixed effects. I use instrumental variables because estimating these elasticities through OLS regression may produce upward-biased estimates due to reverse causality. In particular, economic downturns can reduce electricity demand, which subsequently lowers electricity prices, potentially generating a reverse causality issue between electricity prices and labor market outcomes (Abeberese, 2017).

The instrumental variable exploits a wave of electricity market deregulation reforms adopted in 21 U.S. states. These reforms were approved by state legislatures between 1997 and 1999 and took effect in January 2000, following federal regulatory changes that allowed the creation of deregulated electricity markets. Although separately approved across different states, they entered into force at the same time and they shared the same policies and deregulation (Borenstein and Bushnell, 2000, 2015). Before deregulation, utilities generated electricity in their own plants purchasing only limited quantities from other generators at capped prices. Afterward, utilities were required to divest generation assets, buy most of the electricity needed from independent producers at market prices (Borenstein and Bushnell, 2000; MacKay and Mercadal, 2022). This shift increased producer markups and ultimately raised consumer prices (MacKay and Mercadal, 2022; Borenstein and Bushnell, 2015).

I exploit differences in the electricity mix across counties because I expect the effect of the reform on electricity prices to be smaller the higher the coal share Matthes et al. (2007). Therefore, I interact the reform with 1990 shares of coal-generated electricity that is supplying each county. Pre-deregulation generation assets shaped post-reform market competitiveness, as differences in fuel mix affected the degree of competition. More competitive markets tend to have lower electricity rates, since, for example, producers face less ability to raise prices during periods of high demand (Joskow, 2008; Borenstein et al., 2002; Borenstein and Bushnell, 2000). Accordingly, coal-dependent electricity markets may respond differently to deregulation than hydro- or nuclear-based markets, which face higher entry barriers and greater concentration among fewer producers.

My empirical strategy relies on the standard identification assumptions required for instrumental variables: relevance, exogeneity, and the exclusion restriction (Angrist and Imbens, 1995; Wooldridge, 2010; Angrist et al., 1996). The instruments I use are relevant. The reform unexpectedly increased prices in the years following its implementation by 17% in affected counties while an additional 1% in the coal share of a county reduces the effect of the reform by 0.3% with an F statistics of 19.5. The support for the assumption of exogeneity and non-anticipation of this reform stems from MacKay and Mercadal (2022) and Borenstein and Bushnell (2015), who justify this claim by using state legislature documents and anecdotal evidence from electricity market players. Moreover, prices of electricity do not show any sign of anticipation in the years before the reform. I interact the reform with the coal share in 1990 to capture its heterogeneous effects. This variable is predetermined and not influenced by the reform itself and reflects the electricity mix supplying each county well before the reform took place since it predates the first discussions in state legislatures by several years (Borenstein and Bushnell, 2000).

The exclusion restriction requires that the deregulation reform influenced labor outcomes only through its effect on electricity prices. I support this claim by estimating a specification following Card (1993) and with evidence from the literature on this reform. In this specification, I include the reform as an additional regressor in the second stage to test for direct policy effects on economic outcomes and I use the interaction between coal share in the county's electricity mix and the reform only in the first stage. This test provides suggestive evidence on whether the reform influences labor outcomes only through electricity prices. If so, the direct effect should not be significantly different from zero. I estimate that the direct effect of the reform is not statistically significant in the second stage, therefore, there is no evidence against the validity of my instrument. Moreover, to the best of my knowledge, the only effect caused by this reform, is the effect it had on electricity prices (Borenstein and Bushnell, 2000; Borenstein et al., 2002; Borenstein and Bushnell, 2015).

I develop an economic model of a sector producing a homogeneous good using electricity and labor as inputs, combined through a CES production function. I make two key assumptions: workers do not move across sectors and wages are determined within each local labor market. In the model, the effect of electricity prices on economic outcomes depends on two main factors: the electricity intensity of the sector and the degree of substitutability between electricity and labor in the production process. When electricity and labor are complements, an increase in electricity prices leads to a decline in labor and electricity demand, with the magnitude of this effect increasing in a sector's electricity intensity. On the other hand, when inputs are substitutes, higher electricity prices may increase employment. More electricity-intensive sectors experience larger changes in employment when electricity prices increase. I estimate the elasticity of substitution and its confidence intervals with estimates from the empirical results of this paper and from the related literature (Burke and Abayasekara, 2018; Bossler et al., 2023), using the equation from this model and the delta method.

I combine labor market and electricity data to construct a county-by-year panel with labor data and electricity prices between 1992 and 2008. Labor market information come from the Quarterly Census of Employment and Wages (QCEW) of the Bureau of Labor Statistics (BLS) and include annual employment and number of active firms by three-digit NAICS sectors. I aggregated the data into manufacturing, primary (construction, mining, and agriculture), and services. Industrial electricity prices are derived from Energy Information Administration (EIA) data, calculated as utilities' industrial revenues divided by electricity sales, and imputed to the county level using EIA service area maps that show which utilities are supplying each county. Moreover, from the utilities' operational data, I calculated and imputed to each available county variables describing their 1990 electricity mix.

I run several robustness checks to verify if the estimates from the main specification are consistent across different specification and data used. First, I implement a propensity score matching to create a new sample of county pairs between the control and treatment group on which I estimate the effect of electricity prices on economic outcomes. I define the treatment group as counties affected by the deregulation reform and the control group as those that were not. Second, I exclude small utility markets that could affect the estimation of the standard errors almost halving the number of clusters used. Third, I include post-reform years close to enactment of the reform from 2000 to 2003. Fourth, I exclude years between 2000 and 2003 to check whether the results are robust to exclude years when the reform was not yet fully implemented (MacKay and Mercadal, 2022). The estimates are similar and not statistically different from those in the main regression.

I contribute to the literature on the effects of electricity prices in three main ways. First, I estimate the elasticity of employment and active firms with respect to electricity prices in a novel empirical setting. Previous studies have typically relied on OLS regressions (Kahn and Mansur, 2013; Cox et al., 2014; Greenstone and Nath, 2020) or on Bartik-style instruments (Bartik, 1991; Autor et al., 2013; Jaeger et al., 2018), constructed from local fuel shares in the electricity mix combined with national commodity prices of electricity sources, to approximate production costs and generate exogenous variations in electricity prices (Kahn and Mansur, 2013; Abeberese, 2017; Marin and Vona, 2021). I exploit policy-induced variation in electricity prices from market deregulation. OLS estimates risk bias from reverse causality, while Bartik style instruments based on local fuel shares and national input prices may violate the exclusion restriction if those inputs such as coal or gas are directly used in production. In contrast, my reform-based instrument provides policy driven price variation that avoids the issue of Bartik-instruments since local market reforms do not affect global fuel prices and takes care of the endogeneity threats in OLS exploiting an exogenous change to electricity prices.

Second, I present additional estimates on the elasticity of employment to electricity prices in the manufacturing sector. Several papers estimate the effect of electricity prices on employment for the manufacturing sector. Abeberese (2017) finds that an increase in 1% electricity prices causes a decrease in employment by 0.2% in operating firms. Kahn and Mansur (2013) finds that sectors within the manufacturing industry have an elasticity of employment to electricity prices around $-0.3/-0.4$ on average, while non-manufacturing sectors show smaller elasticities around -0.1 using OLS estimates. Marin and Vona (2021) find that in the manufacturing sector in France the elasticity of labor to electricity prices is around -0.1 in active firms. Wolverton et al. (2022) find that a 1% increase in electricity prices leads to a reduction of 0.07% in employment for active firms. Cox et al. (2014) find that the elasticity of employment to electricity prices is between -0.1 and -0.7. My results are in line with the findings present in the literature.

Third, I estimate the effects of electricity prices on non-manufacturing employment, firm activity and the substitution between labor and electricity. Past works in this literature mainly focused on studying the effects of changes in electricity prices on manufacturing employment while I estimate its effects also on active firms and in non-manufacturing sectors (Abeberese, 2017; Kahn and Mansur, 2013; Marin and Vona, 2021). I find that a 1% increase in industrial electricity prices leads to a 0.4% decline in the number of active firms in the manufacturing sector. In contrast, the effect of higher electricity prices on firm activity and employment in other sectors is negligible. Then, I use both the empirical results of this paper and existing estimates from the literature to compute the elasticity of substitution between labor and electricity in the manufacturing and service sectors. Using the equations in the model presented in this paper, I find that the elasticity of substation in the is 0.89 in the manufacturing sector and 0.63 in the service sector.

The remainder of the paper is structured as follows. Section 2 outlines the institutional framework. Section 3 introduces a model of an economy using electricity and labor as inputs. Section 4 presents the dataset, while Section 5 details the empirical strategy and describes the IV regression used. Section 6 presents summary statistics, and Section 7 reports the empirical results for the electricity and labor markets. Finally, Section 8 concludes.

2 Institutional Framework

This section provides a brief description of the electricity market from production to final consumption. Afterwards, I present the outline of the reforms that restructured the market in several states at the end of the 1990s, that I use in my identification strategy.

2.1 The US Electricity Market

The electricity market in the United States is overseen by the Federal Energy Regulatory Commission (FERC). The FERC is responsible for regulating the transmission and wholesale sale of electricity in interstate commerce to prevent market failures. This regulatory authority also holds the power to oversee mergers and acquisitions within the energy sector. Together with the Department of Energy (DoE) and through legislative actions approved by Congress, FERC establishes the regulatory and legal framework that governs power generators, utilities, and retail energy providers.

The U.S. electricity market is primarily divided into four main processes: generation, transmission, distribution, and retail. Generation refers to the production of electricity from various sources such as fossil fuels, nuclear energy, and renewable resources like solar, wind, and hydropower. Transmission involves transporting high-voltage electricity over long distances. Distribution is the process of delivering this electricity to end consumers, including households, businesses, and industries. Finally, retail is the stage where electricity is sold directly to customers.

Electricity utilities are the main organizations ensuring that power is reliably produced and delivered to homes, businesses, and industries. They manage the systems that generate electricity, move it across long distances, and distribute it locally. In regulated markets, a single utility usually controls the entire process and is overseen by government agencies to keep prices fair and service reliable. In deregulated markets, electricity generation and sales are opened to competition, allowing consumers to choose from different providers. However, utilities still sell electricity to a large portion of consumers, especially those who do not switch providers. In both systems, utilities remain essential for maintaining the infrastructure and ensuring that electricity flows safely and consistently (Borenstein and Bushnell, 2000, 2015). For the rest of the paper, I define a group of counties served by the same utilities as a utility market.

2.2 Deregulation Reforms

In the late 1990s, many states began enacting regulations and laws to deregulate the electricity market for investor owned utilities. Historically, electric utilities in the U.S. were vertically integrated companies that handled generation, transmission, distribution, and retail sales. Electricity was viewed as a natural monopoly, with utilities serving local electricity markets, and prices were regulated to prevent monopoly pricing. Utilities were compensated based on their average generation costs plus a markup set by each U.S. state through public utility commissions (PUCs). However some states began initiating a process of deregulation within the electricity sector. This reform involved investor owned utilities that provided around 75% of generation and distribution of electricity in the USA as of 1994 (MacKay and Mercadal, 2022).

The deregulation of the electricity market initially focused on restructuring the electricity generation sector in the generation market. The objective of the reform was to make electricity producers compete on a free market to decrease prices and improve services. Prior to the reform, utilities across the whole country were vertically integrated, owning power plant that produced the electricity they needed, owning transmission infrastructures and relied on external electricity producers only to cover the demand they can not cover with utility owned generation power plants. Utilities were mandated to purchase this electricity at regulated prices. Following deregulation, utilities in deregulated states were required to gradually divest their ownership of power plants to existing and new independent power producers (IPP) and purchase most of the electricity from them in the market. Therefore, IPPs increased their share of electricity generation in deregulated markets after the reforms although almost all of the utilities were still allowed to keep some generation assets (Borenstein and Bushnell, 2000, 2015). After the reform, utilities were also allowed to purchase electricity from generators at market prices rather than being constrained to regulated rates.

The restructuring of the electricity market also had a significant impact on the downstream operations of utilities. Before the reform, utilities held a monopoly on the retail market, selling electricity directly to consumers. After deregulation, utilities in deregulated states were required to compete with retail electricity providers (REPs), who were allowed to purchase electricity from independent generators and sell it to consumers. However, this aspect of the reform has been largely limited in its implementation, with Texas being a notable exception. As a result, incumbent utilities still provide a significant portion of electricity to consumers. Utilities charge a price set by the PUCs to cover the cost plus a fixed mark-up (MacKay and Mercadal, 2022).

The deregulation reforms were approved in 21 states[7] in the late 90s. All the reforms were approved between late 1997 and 1999 but started to have effects from January 20000, following federal regulatory changes that allowed the establishment of deregulated electricity markets. The reforms were very similar in each state sharing the two main policies described above. Arizona, Arkansas, Nevada, and Montana approved this reform but abolished it after a few years. Moreover, the reform was not applied in Hawaii and Alaska due to their different electricity market in those states. Likewise, Tennessee and Nebraska could not implement the reform even if desired, as state laws prohibit investor-owned utilities with generation assets, making the reform inapplicable in their jurisdictions before changing previous regulations.

The deregulation of electricity markets in the late 1990s led to several important consequences, including higher electricity prices in many states, especially for business customers. There are many reasons why consumers, especially businesses and firms, were affected by higher electricity prices. First, utilities in deregulated states were no longer constrained to charge prices based on historical cost-of-service regulation. Therefore, prices became more responsive to market conditions and fluctuated more with commodity prices (Borenstein and Bushnell, 2015). Second, independent electricity generators expanded their market share, and utilities, which had previously generated much of their own electricity, increasingly relied on buying electricity from external suppliers. Buying electricity from generators had higher costs compared to electricity produced internally by utilities, which were then passed on to consumers. Third, in deregulated states, restrictions were lifted on the price at which utilities could buy electricity from independent generators. This allowed generators to increase their markups on electricity sold to utilities further increasing the price for the consumers (MacKay and Mercadal, 2022).

[7] States that deregulated includes Rhode Island, New York, California, New Hampshire, Massachusetts, Pennsylvania, New Jersey, Delaware, Maryland, Connecticut, Illinois, Maine, Ohio, Texas, Virginia, Oregon, Michigan, Arizona, Arkansas, Nevada, and Montana.

3 Model

I present a model of a sector of the economy using both labor and electricity as inputs following Autor and Dorn (2013). In both sectors, there are multiple firms with heterogeneous productivity (A) using electricity (E) and labor (L) as inputs. I assume workers can not move across sectors so workers that lose employment in manufacturing can be hired only in their sector or be unemployed. Inputs may be gross complement or gross substitutes. I consider three sectors separately: agriculture, manufacturing and services. The manufacturing sector is more electricity intensive than the others.

3.1 Firms

Firms produce an homogeneous output in each sector following a CES function and I define the firm production function as,

$$Y = A\left[\delta L^{\rho} + (1-\delta)E^{\rho}\right]^{\frac{v}{\rho}} \tag{1}$$

with $A > 0$ as the firm productivity parameter, ρ is the substitution parameter between inputs, the elasticity of substitution between labor and electricity is given by $\sigma = 1/(1-\rho)$. $v \in (0,1)$ is the degree of homogeneity of the production function with decreasing returns to scale. δ is the share parameter of the CES function and differs across firms in different sectors. Electricity intensity in the function is $1-\delta$.

Firms maximize their profits by choosing maximizing values of E and L. Firms set wages w according to their marginal productivity of labor while electricity price is exogenously determined. Firms take price of electricity p_E as given. Price of output is P is taken by firms in all sectors. There are fixed costs F. The profit function maximized by the firms in the two sectors is,

$$\Pi = P\left[A\left(\delta L^{\rho} + (1-\delta)E^{\rho}\right)^{\frac{v}{\rho}}\right] - wL - p_E E - F \tag{2}$$

Firms maximize the profit function firm with respect to labor and electricity inputs taking their derivatives of the profit function obtaining the First Order Conditions,

$$PAv\delta L^{\rho-1}\left(\delta L^{\rho} + (1-\delta)E^{\rho}\right)^{\frac{v}{\rho}-1} = w \tag{3}$$

$$PAv(1-\delta)E^{\rho-1}\left(\delta L^{\rho}+(1-\delta)E^{\rho}\right)^{\frac{v}{\rho}-1}=p_E$$

Then, I combine the FOCs to obtain an optimality condition relating L and E to get the optimality condition describing labor demand function of manufacturing firms,

$$L=E\left(\frac{w(1-\delta)}{p_E\delta}\right)^{\frac{1}{\rho-1}}$$

This is then log transformed to get a linear equation and derived with respect to $ln(p_E)$. This enables me to find the elasticity of employment L with respect to electricity prices p_E.

$$\ln L=\ln E+\frac{1}{\rho-1}\left(\ln w+\ln(1-\delta)-\ln p_E-\ln\delta\right)$$

Finally, I obtain an equation that relates the elasticity of employment to electricity prices with ρ and σ. Later, I will use the following equation to estimate ρ and σ in the empirical section.

$$\frac{d\ln L}{d\ln p_E}=\frac{d\ln E}{d\ln p_E}+\frac{1}{\rho-1}\frac{d\ln w}{d\ln p_E}+\frac{1}{1-\rho}$$

In this equation, $\frac{d\ln E}{d\ln p_E}$ represents the scale effect, when electricity prices increase there is a reduction in output and electricity use that decrease employment. On the other hand, $\frac{1}{1-\rho}$ represents the substitution effects and it is positive because the labor input becomes relatively cheaper compared to electricity. I can rewrite the previous equation in elasticity terms,

$$\epsilon_{L,p_E}=\epsilon_{E,p_E}+\frac{1}{\rho-1}\epsilon_{w,p_E}+\frac{1}{1-\rho} \tag{4}$$

In case there are heterogeneous firms in the economy, those with lower productivity exit from the market when electricity price increase due the presence of fixed costs F in the profit function (equation 2). For any value of the parameters ρ and δ it exists a value A^* such that $\Pi=0$ that represents the marginal firm. Moreover, when p_E increases, production output and profits decrease. For marginal firms, an increase in electricity prices causes negative profits and it makes them exit from the market by not being able to cover fixed costs F.

Increases in electricity prices lead to marginal firms to exit the market. Firms remaining on the market have larger values of productivity A compared to the exiting firms. The visual description of this mechanism is in figure 1.

In order to close the model, I compute the supply function for both sectors by finding the cost and marginal cost function using both sectors' firms optimality conditions. To find the cost function, I first rearrange (3) and substitute in (1) to get L and E as a function of Y.

$$E^* = \frac{Y^{\frac{1}{v}}}{A^{\frac{1}{v}}\left[\delta\left(\frac{w}{p_E}\right)^{\frac{\rho}{\rho-1}}\left(\frac{1-\delta}{\delta}\right)^{\frac{\rho}{\rho-1}}+1-\delta\right]^{\frac{1}{\rho}}} \tag{5}$$

$$L^* = \frac{Y^{\frac{1}{v}}}{A^{\frac{1}{v}}\left[(1-\delta)\left(\frac{p_E}{w}\right)^{\frac{\rho}{\rho-1}}\left(\frac{\delta}{1-\delta}\right)^{\frac{\rho}{\rho-1}}+\delta\right]^{\frac{1}{\rho}}} \tag{6}$$

Then, I combine the last two equations for L^* and E^* into the cost function $C(Y) = p_E E^* + wL^*$, I obtain the cost function for each firm in the manufacturing sector as

$$\begin{aligned} C(Y) = & \frac{Y^{\frac{1}{v}}p_E}{A^{\frac{1}{v}}\left[\delta\left(\frac{w}{p_E}\right)^{\frac{\rho}{\rho-1}}\left(\frac{1-\delta}{\delta}\right)^{\frac{\rho}{\rho-1}}+1-\delta\right]^{\frac{1}{\rho}}}+ \\ & + \frac{Y^{\frac{1}{v}}w}{A^{\frac{1}{v}}\left[(1-\delta)\left(\frac{p_E}{w}\right)^{\frac{\rho}{\rho-1}}\left(\frac{\delta}{1-\delta}\right)^{\frac{\rho}{\rho-1}}+\delta\right]^{\frac{1}{\rho}}} \end{aligned}$$

The supply functions is given by the marginal cost function by taking the derivatives of $C(Y)$ with respect to Y.

$$\begin{aligned} C'(Y) = & \frac{vY^{\frac{1}{v}-1}p_E}{A^{\frac{1}{v}}\left[\delta\left(\frac{w}{p_E}\right)^{\frac{\rho}{\rho-1}}\left(\frac{1-\delta}{\delta}\right)^{\frac{\rho}{\rho-1}}+(1-\delta)\right]^{\frac{1}{\rho}}} \\ & + \frac{vY^{\frac{1}{v}-1}w}{A^{\frac{1}{v}}\left[(1-\delta)\left(\frac{p_E}{w}\right)^{\frac{\rho}{\rho-1}}\left(\frac{\delta}{1-\delta}\right)^{\frac{\rho}{\rho-1}}+\delta\right]^{\frac{1}{\rho}}} \end{aligned} \tag{7}$$

The function describing the marginal cost for all firms, it exhibits decreasing returns to scale since $v \in (0, 1)$. The sector aggregated supply function shares this property, as all firms use the same production function as in equation 7.

3.2 Closing the Model

To get predictions on the effect of electricity prices p_E on employment L, I use the supply function and labor demand function of this economy. In this section, I want to analyze the effects of increase of electricity prices on manufacturing and service sectors that differ for electricity usage (Hardt et al., 2020; Miketa, 2001). Manufacturing is electricity intensive while services are not, therefore I assume that δ is higher in services than manufacturing. Moreover, I distinguish the case of gross complement or gross substitute inputs.

When electricity prices increase the marginal cost function (equation 7) increases the more the sector is electric intensive. When $1 - \delta \to 1$ and the sector is more electric intensive an increase of p_E has a larger larger effect on the marginal cost and output than a sector with lower electricity intensity. An increase in p_E raises the marginal costs and reduces the amount of output Y. Output decreases more for manufacturing than services and primary sector because the former has an higher electricity intensity than the other two sectors. This is valid in case of gross complement and gross substitute inputs. I will refer to this effect as output effect in the next paragraphs. I show in figure 2 comparative statics of the effect of the increase in electricity prices on output. Starting from a common equilibrium point, marginal costs increase more for the electricity intensive sector when electricity prices p_E raise.

An increase in electricity prices has different effects on employment depending if inputs are gross complements or gross substitutes. Higher electricity prices cause a positive substitution effect for labor since it becomes relatively more convenient than electricity. When inputs are perfect complement, $\rho \to -\infty$, an increase in electricity prices causes a decrease in employment. In this case, the output effect dominates the substitution effect and the overall effect on employment is negative. When inputs are perfect substitutes $\rho \to 1$ an increase in electricity prices has an increasing effect on employment. In this case the substitution effect is strong, it dominates the output effect and the overall effect on employment is positive. The effect on employment is smaller in sectors with lower electricity intensity, such as services, because the output response to changes in electricity prices is more limited, all else equal. For values of ρ closer to zero the effect is ambiguous depending on the magnitude of the substitution and the output effect. The effect of an increase in electricity price on employment, in this model, is given by equation 4. I show comparative statics in figure 3 on how employment changes when electricity price increases and inputs are substitutes or complements.

In the empirical analysis, I will estimate the effect of electricity prices on employment and number of firms across the manufacturing, services, and primary sectors. Using equation 4, I will estimate the parameter ρ and the corresponding elasticity of substitution, σ. Additionally, I will examine how increases in electricity prices affect the number of firms within each sector, testing whether higher energy costs lead to market exit.

4 Data

I construct my dataset using two primary data sources: electricity data from the U.S. Energy Information Administration (EIA) and county-level economic indicators from the Bureau of Labor Statistics (BLS). From the EIA data, I construct a time series of county-level electricity prices covering the period from 1992 to 2008. Using the same source, I also generate data on the composition of the electricity supply mix for each county in 1990. From the BLS, I obtain publicly available data on aggregated labor market outcomes at the county level. Specifically, I focus on employment levels and the number of firms as key economic variables. I merge these two sources to construct a panel dataset spanning the years 1992 to 2008, which includes both economic outcomes and electricity prices that I use in the empirical analysis.

4.1 Electricity Data

To collect data on electricity price I rely on two sources provided by the U.S. Energy Information Administration (EIA): balance sheets and operational data with generation assets of utilities. With those, I obtain detailed information on the electricity mix and the price of electricity across U.S. counties.

I construct county-level industrial electricity prices using data from summarized balance sheets of utilities. This provides utility-level information on electricity sales, revenues, number of customers, counties served and ownership type. I use data from 1992 to 2008 and I build a balanced panel of industrial electricity prices at the utility level. Industrial electricity prices are those charged to private sector companies. I use ownership information to identify investor-owned utilities (IOUs), which are the focus of my analysis, as they were the primary entities affected by the reform I use for identification and accounted for approximately 75% of electricity distribution in the United States as of 1990. Accordingly, I restrict the sample of utilities to IOU and counties served by at least one IOU. For each investor owned utility, I calculate the electricity price as the ratio of annual revenues to electricity sold. Then, using the price charged in each year and information on which utilities are serving each county, I create a panel dataset of county-by-year electricity prices. I impute county-level electricity prices as sales-weighted averages of the prices charged by utilities serving each county, using each utility's electricity sales as weights. Consequently, counties served by the same utilities share identical prices.

I use data on generation assets from utilities' operational records to construct variables capturing the electricity mix supplying each county. I use the operational reports of utilities to identify the number and types of generation assets owned. To calculate the fuel mix of each utility, I first sum the production capacity of all generators by each fuel type (hydro, wind, coal, oil and natural gas). I then express each fuel type's capacity as a share of the utility's total generating capacity. To impute the electricity mix to the counties in my dataset, I take a weighted average of the fuel mixes of all utilities serving each county, using total electricity sales of each utility as weights. This is a similar procedure to what I used to impute county-level electricity prices. Also in this case, counties served by the same utilities share the same electricity mix.

From this dataset, I exclude some states due to the specific characteristics of their electricity markets or due to the reversal of the deregulation reform. Hawaii and Alaska are omitted because their electricity systems are not connected to the mainland grid and operate under distinct market conditions. Arizona, Arkansas, Nevada, and Montana are excluded as well, since these states repealed the electricity market reform a few years after its implementation. These reasons make these states unsuitable for a valid analysis according to MacKay and Mercadal (2022). Lastly, I exclude the states of Tennessee and Nebraska because they lack investor-owned utilities; state laws in these states prohibit such ownership, making the reform inapplicable and the electricity market very different from other states.

4.2 Labor Data

I use county-level employment and firm data by industry from the BLS Quarterly Census of Employment and Wages (QCEW), covering years between 1992 and 2008. This dataset has information on labor market outcomes across all U.S. counties and across all 3-digits North American Industry Classification System (NAICS) sectors. It is compiled from reports submitted by employers to state unemployment insurance programs, covering more than 95% of U.S. jobs. Information are reported by employers on a quarterly basis and include nearly all establishments in both the private and public sectors. I use yearly data that aggregate quarterly reports on total employment and number of firms in each county. I use in the empirical analysis only those counties with a balanced panel between 1992 and 2008.

Industry classification in the QCEW dataset is based on the NAICS system with a consistent tracking of economic activity across sectors and years. I obtain employment and firm data at the 3-digit NAICS sector level. The classification system was updated periodically (e.g., in 1997, 2002, 2007), and the datasets available are harmonized to account for these changes to ensure consistent industry definitions over time.

Employment is measured as the average number of jobs reported by establishments in a given industry, county, and year. Employment figures represent the number of workers covered by unemployment insurance programs and reflect actual filled jobs, including both full- and part-time positions. I use data the yearly data that smooth out seasonal fluctuations and short-term volatility in the labor market.

Number of firms is measured as number of physical locations where business is conducted. Each establishment corresponds to a single physical location where economic activity takes place, such as a factory, retail store, or office, and is associated with a specific industry classification based on its primary activity.

I aggregate 3-digit NAICS sector employment and number of firms into three broad economic sectors within each county: primary, manufacturing, and services. The primary sector includes all industries classified by the North American Industry Classification System (NAICS) as agriculture, mining, and construction. The manufacturing sector consists of all industries categorized under manufacturing. The service sector encompasses all service-providing industries, including but not limited to trade, hospitality, transportation, financial activities, communications, education, and health services. I exclude county-by-3-digit NAICS sector observations with missing data between 1992 and 2008 and therefore aggregate, within each county, only the sectors that have complete data for the entire period of interest.

5 Empirical Strategy

I present in this section the estimation strategy based on an IV regression and discuss the identification conditions for its validity. First, I show the structural equation of my IV regression to estimate the elasticity of employment and active firms to electricity prices. Then, I present the first stage regression. To conclude, in the second part of this section, I discuss the identification conditions according to the econometric theory. I also present a test to support the exclusion restriction from Card (1993).

5.1 Regression Equations

I employ an IV identification strategy to estimate the effects of electricity prices on employment and number firms to address endogeneity issues in and Ordinary Least Squares (OLS) regression. This is necessary because estimating the elasticity of employment and other economic outcomes with respect to electricity prices using OLS can lead to biased and incorrect estimates due to reverse causality issues between the two variables.

I regress labor outcomes on electricity prices to estimate the elasticity of employment and active firms to electricity prices. The outcome variables Y_{ct} are log employment and log active firms, where t is the year and c is the county considered. Moreover, I also estimate the regression equation using these variables separately for: primary sector, manufacturing sector and services. The naïve OLS regression equation is:

$$Y_{ct} = \beta_0 + \beta_1 P_{ct} + \lambda_c + \delta_t + pop_{ct} + \epsilon_{ict} \tag{8}$$

P_{ct} is log industrial electricity price from the first-stage regression. The term pop_{ct} controls for the total population in county c at time t. λ_c are county fixed effects and δ_t are year fixed effects. I estimate, using the second stage regression, the causal impact of electricity prices on local economic performance, using a 2SLS model. I use robust standard errors clustered at the utility market level, following MacKay and Mercadal (2022) and Kahn and Mansur (2013). Utility markets are groups of counties served by the same electric utilities. I cluster standard errors at this level because the effects of the reform are heterogeneous across utility markets due to the different fuel mix used and for the fact that electricity prices vary at the utility market level. With this clustering, I can also account for correlation in labor market outcomes within local labor markets. In my dataset, I have a total of 213 different utility markets across the states I include in my dataset.

I use an IV identification strategy to address reverse causality in the relationship between electricity prices P_{ct} and labor outcomes Y_{ct}. A key source of endogeneity arises because fuel prices, such as those for natural gas or coal, are often counter-cyclical: they tend to decrease during economic downturns and increase during periods of economic growth. This pattern implies that electricity prices may be lower in periods of weak economic activity and higher during booms, creating a spurious positive correlation with outcomes such as employment or output. By using 2SLS and instrumental variables based on exogenous variation in electricity prices from electricity market deregulation, I aim to isolate the causal impact of electricity price changes on employment and the number of firms.

In the first stage regression I use the reform and its interaction with coal share in each county in 1990 to instrument for electricity prices. The first stage equation estimates instrumented values of P_{ct} that are used to estimate equation 8 and to correctly identify the effect of electricity prices on Y_{ct}[8]. The first stage regression is,

$$P_{ct} = \theta_0 + \theta_1 R_{ct} + \theta_2 R_{ct} * C_c + \lambda_c + \delta_t + pop_{ct} + \epsilon_{ct} \tag{9}$$

where P_{ct} is the log industrial electricity price in county c and year t. The variable R_{ct} is an indicator equal to 1 if county c is in a state that has implemented the deregulation reform by year t, and 0 otherwise. C_c represent the county-level share of coal in the electricity mix in year 1990, this variable is 0 if the electricity mix of the county has 0% coal while it is 1 if 100% of the electricity is produced by coal. The interaction term $R_{ct} * C_c$ allows the reform's impact on electricity prices to vary depending on the local energy mix. The variable pop_{ct} is county population while county fixed effects λ_c is and year fixed effects δ_t.

I use a wave of reforms adopted in 21 U.S. states that deregulated the electricity market to define the instrumental variable R_{ct}. The reforms were approved between 1997 and 1999 by state legislatures of the affected states and came into effect in January 2000. I use those reforms as an instrument following MacKay and Mercadal (2022) because it increased

[8]To estimate equation 8 with an IV identification strategy, I use the built-in command in STATA ivreghdfe that estimates IV models with a large number of fixed effects

market power in the electricity generation market, which raised costs for utilities purchasing electricity from power generators and, in turn, led to higher electricity prices for consumers.

I interact the reform variable with the 1990 share of coal in the electricity supply of each county C_c. I do so because the effects of the deregulation reform may differ across counties with varying electricity mixes. Different types of electricity generation can shape the market structure in distinct ways, leading to heterogeneous impacts of deregulation. For instance, coal-dependent markets may exhibit greater competition compared to those dominated by nuclear or hydro generation where there are higher barriers to entry and market concentration among few producers (Matthes et al., 2007). Consequently, after deregulation, electricity generators in more competitive markets face greater constraints on charging high markups to utilities, ultimately resulting in lower electricity rates for final consumers compared to less competitive markets (Joskow, 2008; Borenstein et al., 2002; Borenstein and Bushnell, 2000).

5.2 Identification

Instrumental variables shall satisfy three conditions to be valid: exogeneity, relevance and the exclusion restriction (Angrist and Imbens, 1995; Wooldridge, 2010; Angrist et al., 1996). The state-level reforms (see section 2) I use as my main instrument mandated the privatization of utility-owned generation assets and deregulated the electricity market in states that approved these reforms. I interact the reform variable with the 1990 share of coal in the electricity supply of each county to capture potential heterogeneous effects of the reform on electricity prices across areas with different electricity mixes.

I consider the reform exogenous and unanticipated following the literature studying this reform following Borenstein and Bushnell (2000, 2015); MacKay and Mercadal (2022). The reforms approved across many U.S. states were unexpected in the years preceding the legislative process. Market participants did not fully understand how a deregulated market would operate until the reforms were passed and implemented. The reforms were approved in a short time period during 1998 and 1999, this was not expected by market players in the previous years therefore they did not have a possibility to anticipate the policy change. As an example in California, a huge electricity crisis was linked to the deregulation of the market since many market operators did not fully understand the new market mechanisms (Clark and Lund, 2001). Another evidence of lack of anticipation is the behavior of electricity prices before 2000. In states that were deregulated or not, prices remained flat during the 90s with no differences in pre-reform trends and no anticipation (figure 4). Moreover, I do not observe differences in employment trends in the years leading to the reform implementation between states affected or not by the deregulation reforms, even between counties with high or low share of coal in their electricity mix (see figures 8, 9, A2, A3, A4 and A5).

The state-level deregulation reforms implemented in various U.S. states during the 1990s and early 2000s represented the main legislative changes in the electricity market at that time. These reforms can serve as a valid instrumental variable for studying the effects of deregulation on electricity prices, provided that no other contemporaneous reforms occurred in the same states that could influence electricity prices. Few acts other than the deregulation reforms were implemented around that time. Federal reforms, such as the FERC regulation in 1996 opening electricity transmission networks to independent power producers, applied uniformly to all states and therefore cannot bias the instrument. Similarly, the Energy Policy Act of 1992, which focused primarily on energy efficiency and the promotion of clean energy sources, was enacted well before the wave of state deregulation and did not produce observable changes in electricity prices in the years immediately following its approval. Because these federal measures affected all states equally rather than only those that later deregulated, they do not compromise the validity of the state-level instrument. To the best of my knowledge, no other contemporaneous state-level reforms overlapped with the timing of deregulation in the treated states.

I interact the reform with the 1990 share of coal in each county's electricity supply mix, using it as a plausibly exogenous proxy for the post-reform electricity supply mix. The electricity mix is a variable stable over time especially in the 1990 in USA[9]. Moreover, the reforms started to be discussed in the late 90s making the electricity mix in 1990 not affected by the implementation of reforms in the future (Abeberese, 2017; Kahn and Mansur, 2013). Other papers employ similar strategies, treating pre-policy conditions as exogenous to subsequent reforms or unanticipated shocks (Jaeger et al., 2018). Finally, I find no evidence of differing pre-reform trends in employment or industrial electricity prices across counties with high or low 1990 coal shares in their electricity supply mix, further supporting the validity of using this variable as a proxy for the electricity supply mix after the reform (see figures 5, 6, 8, 9, A2, A3, A4 and A5).

My first stage regression shows that my instruments are relevant as I show in the empirical analysis section in the following sections. The reform increases electricity prices over the

[9]EIA historical data, `https://www.eia.gov/electricity/data/state/`

years following its implementation by 16%, this is due to high market power of electricity producers in a competitive and deregulated market. In markets with higher shares of coal in the electricity production mix the effect of the deregulation is smaller due to lower market power of producers in these markets. An additional 1% of coal in the fuel mix decreases prices by 0.3% in counties affected by the reform. The F statistic is around 19 meaning that my instruments are strong according to the usual rule of thumb requiring an F statistic of minimum 10.

I provide suggestive evidence on why the exclusion restriction holds. My instrumental variables shall affect the outcome variable in the main regression only through their effect on electricity prices. First, to the best of my knowledge based on the literature studying this reform (Borenstein and Bushnell, 2000; Borenstein et al., 2002; Borenstein and Bushnell, 2015; MacKay and Mercadal, 2022), the only effect it had has been on electricity prices with no effect on prices of commodities used in electricity or consumption.

Second, I estimate a similar specification to Card (1993) to check for possible violation of the exclusion restriction. I include R_{ct} directly in the regression equation. With this test, I provide suggestive evidence on whether there is a direct effect of the reform on employment or active firms. If this would be the case, the exclusion restriction would be violated. On the other hand, if the effect of the reform on employment and firms comes only through its effect on electricity prices, then the direct effect of the reform on economic outcomes should be statistically not significant. This would provide suggestive evidence to support the assumption that the reform is a valid instrumental variable and that the exclusion restriction holds. It is important to notice that this exercise provides only suggestive evidence regarding the exclusion restriction due to possible factors such as measurement errors, multicollinearity between regressors or low power. The regression is formulated as,

$$Y_{ct} = \beta_0 + \beta_1 \hat{P}_{ct} + \beta_2 R_{ct} + \lambda_c + \delta_t + pop_{ct} + \nu_{ict} \tag{10}$$

I use equation 9 as the first stage of this specification and I find that the direct effect β_2 is not significant in any of the regressions I run. Therefore, I exclude direct effects of the reform on employment or firms other than its effect through electricity prices. My estimates provide no evidence against the assumption that the reforms deregulating the electricity market are exogenous to economic outcomes. I show these results in detail in section 7.2 and in table 6.

6 Summary Statistics

In this section, I present summary statistics for U.S. counties from my dataset, focusing on electricity generation and economic indicators in the early 1990s. In table 1, I show descriptive statistics for the energy mix for counties in the USA in 1990. The energy variables capture the share of electricity generation capacity by fuel type—coal, natural gas, nuclear, oil, and hydropower. These capacity shares range from 0 to 1, representing the fraction of a county's total electricity generation capacity sourced from each fuel. In 1990, coal was the dominant source of electricity, followed by nuclear, hydropower, natural gas, and oil. In figure A1 in the appendix, I show the distribution of coal capacity serving single each county in 1990.

In figure 4, I show the average industrial electricity price between 1992 and 2008 for utilities affected by the reform and those that were not. Prices are normalized to be equal in 1999. Prior to 2000, industrial electricity prices in the two groups followed parallel trends. From 2000, the year the reforms began to be implemented in the states that approved the deregulation of electricity markets, industrial prices of electricity of utilities in deregulated markets started to rise. By around 2008, this price gap reached approximately 15$.

In figures 5 and 6, I present the average industrial electricity price for utilities with low and high coal shares in their electricity mix. I divide the sample into utilities above and below the first quartile of the coal share distribution in 1990. figure 6 shows the electricity price for utilities with a coal share below the first quartile, which were highly affected by the reform, while figure 7 shows the electricity price for utilities with a coal share above the first quartile, where the price increase for utilities impacted by the reform is smaller. These figures illustrate the first-stage regression, indicating that the reform increased electricity prices, with the effect being larger and more concentrated among utilities with low coal shares in their electricity mix. Prices are normalized to be equal in 1999 between utilities affected and unaffected by the reform, the year before the reform began to take effect, following MacKay and Mercadal (2022). Furthermore, figure 7 shows how electricity prices vary across U.S. counties in 1992, the first year included in my dataset.

I present figures showing manufacturing employment in counties affected and unaffected by the reform to graphically illustrate the reduced-form effect of the reform on manufacturing log employment for counties with electricity produced from a low- or high-coal mix. Log employment is normalized to be equal in 1999 across counties affected and unaffected by the reform. I define high-coal counties as those above the first quartile in the county distribution of coal share in 1990 and low-coal counties as those below the first quartile. In figure 8, I observe no change in manufacturing employment in counties affected by the deregulation reform with a high coal share in their utility market's electricity mix. In contrast, there is a decline in manufacturing employment for counties in low-coal utility markets, where electricity prices increased the most, as shown in figure 9. Therefore, the effect of the reform on manufacturing employment is concentrated in counties served by utilities with a low coal share in their electricity mix, mirroring the findings on electricity prices. I show in the appendix that I do not find changes in employment after the reforms were enacted for the other sectors (figure A2 to A5).

In table 2, I present summary statistics for the two main types of utilities in 1990: investor-owned utilities (IOUs) and publicly owned utilities such as cooperatives and municipals. The electricity market reform used in my identification strategy primarily targeted IOUs. As of 1990, IOUs accounted for over 75% of total electricity sales, despite numbering only 197, compared to more than 2000 publicly owned utilities. IOUs typically served larger geographic areas and, prior to the reform, held the majority of generation assets. In contrast, many publicly owned utilities operated in a limited number of counties, often in areas not served by IOUs. IOUs were, and continue to be, the primary providers of electricity in terms of market share and number of costumers, and in states that did not restructure their electricity market, they also remained the major owners of generation assets. This shows the relevance of studying this reformed that focused on restructuring the market of IOUs.

7 Empirical Analysis

In this section, I present the regression results from equation 8, focusing on the effect of electricity prices on employment and number of firms. In my main specification, I estimate the effect of electricity prices on county employment and firms, then I conduct heterogeneity analysis by studying the effect of electricity prices on employment and firms on each of the sectors I defined earlier: manufacturing, services and primary sector. I find that an increase in electricity price by 1% reduces manufacturing employment and active firms in the sector by around 0.4%. The elasticities estimated can be defined as the medium term elasticity of firm and employment to electricity prices since I use data up to eight years after the deregulation reform. Therefore, the effect of electricity prices on employment include a price effect and a scale effect caused by reduction in production.

I perform a series of robustness checks to support the results estimated in the main specification. First, I use a 1-to-1 propensity score matching approach to pair counties with similar characteristics. Second, I exclude counties served by small utility markets to focus only on major utilities and verify that the results are not driven by particularly small markets. Additionally, I estimate the specification proposed by Card (1993) to test the validity of the exclusion restriction and confirm the robustness of the results. Then, I exclude the first two years after the reforms were approved to account for potential delays in implementation. To conclude, I restrict the sample to years up to 2004 to examine whether the results are robust in the short-term after the reform. In the appendix, I present results with standard errors clustered at the state level and the OLS regression estimates of equation 8.

7.1 Regression Results

I present the estimation results from Equation 8 in Panel 1 of table 3, using employment as the outcome variable. I estimate the regression using the IV regression model described in Section 5. In the first column of table 3, the outcome variable is the log of county employment in a given year. In column 2, I present the results when the outcome variable is the log of manufacturing employment, while in columns 3 and 4, the outcome variables are the log of service employment and the log of primary sector employment, respectively. In each column I report the results for log employment and firms. In the second panel, I report the results of the first stage of the IV model.

In panel 1 of table 3, I find that an increase in electricity prices does not have a significant effect on employment and firms in the for services and primary sector while there is a significant decrease in the manufacturing sector. I find that an increase in 1% in industrial electricity prices does not affect overall employment in a county and there is positive but no significant effect neither on services nor primary sectors. On the other hand, employment and number of firms decrease significantly in the manufacturing sector. An increase in industrial electricity prices of 1% decreases employment by 0.43% and number of firms by 0.44%. The effect on employment reflects both workers laid off from existing firms and those who lose their jobs when firms close. This finding is reasonable since manufacturing is by far the most energy intensive sector (Miketa, 2001). The results are also coherent with what the model in section 3 predicts and, although the point estimate are not significant for the agricultural and service sector, they suggest some reallocation of workers from manufacturing to other sectors.

In Panel 2 of table 3, I present the first-stage results for each regression. The results are consistent across specifications, as the same counties are included with only a few observations excluded due to missing data. I find that the reform has a positive effect on county industrial electricity prices (P_{ct}), but this effect decreases as a county's electricity supply relies more heavily on coal. Specifically, the reform increases electricity prices by 16.7%, while the coefficient on the interaction between the reform and the county's coal share in 1990 (C_c) is -0.303. This implies that for a county affected by the reform with a 10% coal share in its 1990 electricity mix, the total effect of the reform on electricity prices is 13.67%. The F-statistic confirms that the first stage is strong, as $F > 10$.

7.2 Validity of Instrument

I present in this section the results from equation 10 to test whether the reform I use as instrumental variable has direct effects on economic outcomes, thereby violating the exclusion restriction. The second stage equation of this instrumental variable regression includes the reform effect along with other regressors as population, year fixed effects and county fixed effects. The exclusion restriction would be violated if the direct effect of the reform on the outcome variable would be significantly different from zero while if this would be the case, this exercise would provide suggestive evidence in support of the validity of my instrumental variable.

In table 4, I present the estimates and I show that the direct effect of the reform is not significant therefore not violating the exclusion restriction. In this specification, the estimated elasticities of employment and active firms with respect to electricity prices are similar to the estimates in main specifications while the direct effect of the reform is not significantly different from zero. The estimated elasticities are similar in magnitude and significant to the ones in the main regression with the manufacturing sector being the only one significantly negatively affected by an increase in electricity prices. Using this specification, I find that an increase in industrial electricity prices of 1% decreases manufacturing employment and active firms by 0.43%. These estimates provide no evidence against the assumption that this reform is an exogenous determinant of electricity prices and a valid instrument.

7.3 Robustness Checks

In the first robustness check, I use propensity score matching as an alternative to the main specification by constructing a sample of comparable counties affected and unaffected by the reform. I begin by estimating propensity scores with a logistic regression, using the reform as the treatment variable. I define the treatment group as counties affected by the deregulation reform, and the control group as those that were not. The scores are based on geographic characteristics, population, manufacturing share, and average income in 1992. I then apply a nearest-neighbor matching algorithm, ensuring that matches are restricted to counties whose propensity scores differ by no more than 0.2, thereby creating a sample of similar county pairs from the treatment and control groups.

I use the matched sample to estimate the regression in equation 8 and I find that an increase in electricity prices decreases manufacturing employment with no effects on other sectors. These findings are similar to those in the main specification presented in table 3. In table 5, I show the results of the regression on the matched sample for the whole economy, manufacturing sector, services and primary sector. I find that 1% increase in industrial electricity prices reduces employment by 0.32% and number of firms around 0.3%. The first stage is similarly strong and relevant to the first stage regressions showed in table 3 as well.

In the second robustness check, I exclude utility markets that serve four or fewer counties finding comparable results to the estimates of the main specification and to the analysis on the matched sample. These markets are typically areas where multiple utilities operate, creating highly localized and atypical market conditions that differ from the usual structure, in which a single utility generally serves more than ten counties. Excluding these small markets helps limit the influence of these particular cases on the results. It also reduces the number of clusters in the regression, since clustering is performed at the utility market level, which increases the standard errors. Consequently, if the results remain significant under this specification, it provides stronger evidence of their robustness. I have a total of 108 utility clusters in this specification. I present the results in table 6 and I show that an increase in 1% in industrial electricity prices decrease manufacturing employment by 0.41% and number of firms by 0.37%. I find no effects on the overall county employment and firms. Moreover, I find no effect of an increase in electricity prices on services and primary sector employment and firms.

In table 7, I exclude from the sample years between 2000 and 2003 because the application of the reform was relatively gradual (Borenstein and Bushnell, 2000, 2015; MacKay and Mercadal, 2022). Utilities, during the first years after 2000, gradually divested a large part of their generation facilities to independent power producers. I want to check whether my results are robust to the exclusion of the immediate years after the policy has been approved when the market was transitioning from a regulated market before the reform to the deregulated market that was implemented by the reforms approved across the different states. I find similar results to the ones previously shown with the effect of electricity prices mainly affecting the manufacturing sector. I find that a 1% increase in industrial electricity prices decrease manufacturing employment and firms by 0.4%.

To conclude, I exclude from the analysis years after 2004 from the analysis to estimate shorter term effects of electricity prices on employment and firms. I expect short term effects of electricity prices on economic outcomes to be somewhat larger because in the long period firms can adjust their production structure and reduce the impact of electricity prices. I find that the effect on the whole economy, primary sector and services of electricity prices on employment and firms is negligible while an increase in 1% of electricity prices decreases manufacturing employment and firms by 0.6%. I report these findings in table 8.

In Appendix tables A1 and A2, I present the results of the main specification with standard errors clustered at the state level and the results of the OLS specification. Clustering by state increases the standard errors, but the effect of electricity prices on manufacturing employment and firms remains statistically significant while the F-statistic on the first stage is strong across the different specifications expect one in which the F-statistic is around 9. Clustering at the state level reduces the number of clusters from around 200 to less than 40. On the other hand, the OLS estimates are all insignificant, and the manufacturing coefficients are positive rather than significantly negative as found in the IV regression, likely reflecting reverse causality bias in the OLS regressions.

7.4 Estimates of Elasticity of Substitution

In this section, I use my empirical results to estimate the elasticity of substitution (σ) and the substitution parameter (ρ) between electricity and labor in a CES production function. To do so, I use equation 4 derived in the model section that I again report below,

$$\epsilon_{L,p_E} = \epsilon_{E,p_E} + \frac{1}{\rho - 1}\epsilon_{w,p_E} + \frac{1}{1-\rho}$$

In this equation, the elasticity of labor with respect to electricity prices ϵ_{L,p_E} is a function of the elasticity between electricity consumption and electricity prices ϵ_{E,p_E}, the elasticity between wages ϵ_{w,p_E} and electricity prices and the substitution parameter ρ.

I combine my own estimations with parameters already estimated in other papers. First, I estimate in the empirical section of this paper the elasticity of labor with respect to electricity prices. Second, I calibrate the remaining parameters using values from the literature. Then, I back out the value of ρ and σ and I use the delta method to estimate the confidence intervals at the 95% level. I focus on the manufacturing and service sectors since previous literature lacks of reliable estimates of the elasticities in the primary sector. I am estimating a medium term elasticity of substitution since both the parameters retrieved from the literature and those found in this paper are estimated on a time horizon of around ten years.

The estimates from the literature I use are:

- I use the estimates for ϵ_{E,p_E} in the manufacturing sector from (Burke and Abayasekara, 2018), it estimates the elasticity to be -1.34 with standard errors of 0.33. Similar results have been found in other similar works (Abeberese, 2017; Kim et al., 2019; Csereklyei, 2020). I use Burke and Abayasekara (2018) results because they estimate the elasticity in the US with similar data and for a similar period to mine.

- I use the estimates for ϵ_{E,p_E} in the service sector again from (Burke and Abayasekara, 2018), it estimates the elasticity to be -0.56 with standard errors of 0.17. Compared to the estimates in the manufacturing sectors I did not find other estimates for the service sector.

- I use estimates for ϵ_{w,p_E} for the manufacturing sector from Bossler et al. (2023), it estimates the elasticity to be equal to -0.018 with a standard error of 0.007. Almost the same elasticity is estimated in Marin and Vona (2021).

- I did not find any estimate in the literature for ϵ_{w,P_E} regarding the service sector, although Cox et al. (2014) suggest that the effect is null, therefore, I consider this elasticity to be zero.

The estimates indicate complementarity between labor and electricity although I can not reject the hypothesis that inputs follow a Cobb-Douglas production function. In the results, I assume that the covariance between ϵ_{L,p_E} and ϵ_{E,p_E} is zero. The estimated values of ρ and σ are -0.59 and 0.63, respectively, for the service sector. In contrast, for the manufacturing sector, the estimated values are $\rho = -0.12$ and $\sigma = 0.89$. However, when I assume no covariance between the elasticities of electricity and employment like in this case, I cannot reject the hypothesis that labor and electricity follow a Cobb-Douglas production function ($\sigma = 1$) using a two sided t-test with a p-value of 0.05. The results and the 95% level confidence intervals computed with the delta method are shown in panel B of table 9

When I assume covariance between ϵ_{L,p_E} and ϵ_{E,p_E} I can accept the hypothesis that inputs are complements in the service sector. The elasticities of labor, output and electricity consumption with respect to electricity prices are positively correlated (Abeberese, 2017). Therefore, I assume $\text{cov}(\epsilon_{L,p_E}; \epsilon_{E,p_E})$ to be above zero in the results in panel C of table 3.9. When I include the covariance term the point estimates do not change but standard errors and confidence intervals do. I still can not reject the possibility that labor and electricity follow a Cobb-Douglas production function ($\sigma = 1$) in the manufacturing sector but the I can reject this hypothesis for the service sector according to the same t-test used in the previous paragraph. This interpretation does not change for every value of $\text{cov}(\epsilon_{L,p_E}; \epsilon_{E,p_E})$ above 0.05. To summarize, it is safe to conclude that labor and electricity are complements in the service sector. On the other hand, for any value of $\text{cov}(\epsilon_{L,p_E}; \epsilon_{E,p_E})$ between 0 and 1, I can not reject the hypothesis that these inputs follow a Cobb-Douglas production function in the manufacturing sector.

8 Conclusion

In this paper, I examined how electricity prices affect employment and number of firms in the U.S. across three different sectors: manufacturing, services and primary sector. To identify causal effects, I used a major reform enacted in the late 1990s in 21 U.S. states as an exogenous shock to electricity prices. This reform wanted to deregulate the electricity market by pushing existing utilities to sell their own facilities used to produce electricity. The intended objective was to foster competition among generators and thereby lower electricity generation prices. However, the reform produced the opposite outcome: due to limited entry and a small number of independent generators, market power remained concentrated. As a result, these generators were able to charge high markups, leading to an increase rather than a decrease in electricity prices (MacKay and Mercadal, 2022).

I find that electricity prices negatively affect employment and firms in the manufacturing sector. I find that an increase of 1% in industrial electricity prices decreases manufacturing employment and number of firms between 0.4% and 0.5% while I find no significant effect on services and primary sector. The effect are larger for manufacturing due to its energy intensity in production compared to the other sectors. These estimates are coherent with the model I presented in section 3, where I analytically show that following an increase of electricity prices has a larger effect on employment and number of active firms the more a firm or a sector is electric-intensive.

I computed the substitution parameter ρ and the elasticity of substitution σ of a CES production function with labor and electricity as inputs using the delta method. I use the coefficients estimated in my regressions with other parameters from other papers to calculate ρ, σ and their distribution using the delta method. I estimate an elasticity of substitution between the two inputs of 0.63 in the service sector and of 0.89 in the manufacturing sector. Analyzing their confidence intervals computed using the delta method, I find that electricity and labor are gross complements in the service sector but I can not statistically rule out the possibility that, in the manufacturing sector, these inputs behave following a Cobb-Douglas production function.

My estimates of the elasticity of employment with respect to electricity prices are in line with those in the existing literature. Kahn and Mansur (2013) estimates that 1% increase in electricity prices affects manufacturing employment between 0.2% and −0.8% in the USA. Marin and Vona (2021) finds that in active firms employment decreases by 0.08% after a 1% increase in electricity prices in French manufacturing firms, this is in line with my findings since I also include employment losses due to exiting firms. Cox et al. (2014) estimate an unconditional elasticity of labor with respect to electricity prices in the German manufacturing sector between −0.1 and −0.7 across workers in different skill groups.

The effect of higher electricity prices on employment is relevant and has important implications for energy policies worldwide. Recently adopted carbon pricing policies in many countries increase electricity prices and may lead to losses in manufacturing employment and firms before the energy mix shifts toward lower-carbon sources. To ensure a just transition, welfare policies should target groups that are particularly vulnerable to electricity price increases, such as workers in manufacturing sectors.

Recent simulations from the U.S. Energy Information Administration indicate that a $15 carbon tax would increase electricity prices by about 8%, leading to a significant reduction in economic activity. Based on the estimates in this paper, such an increase in electricity prices would reduce manufacturing employment and the number of manufacturing firms by roughly 3%, with larger effects expected as the carbon tax rises. Therefore, the effect of a potential carbon tax on the manufacturing sector and its workers could be large in electricity markets where the use of polluting electricity sources like oil, coal and gas is still large.

To mitigate the economic harm that policies affecting electricity prices may cause to specific population groups, targeted measures should be implemented. For example, carbon taxes usually increase electricity prices in the short and medium term. Therefore, governments could use part of the carbon tax revenues to provide income support for manufacturing workers who lose their jobs or to fund training programs that help them transitioning to new occupations. Since wage effects are almost null (Bossler et al., 2023; Marin and Vona, 2021) and the impact is concentrated on manufacturing employment, broader transfer policies that rebate carbon taxes to large parts of the population may be inefficient (Ohlendorf et al., 2021; Carattini et al., 2018), as the economic burden of higher electricity prices falls primarily on manufacturing workers. For instance, when a carbon tax is implemented, a worker in manufacturing faces both higher household electricity costs and an increased risk of job loss, whereas for someone employed in services, the latter risk is much smaller.

I contribute to the literature on the economic impacts of electricity prices by providing novel estimates of the effect of electricity prices on labor market outcomes and by using a new quasi-experimental setting to identify the effect. I estimate the effect of electricity prices on employment and firms using a policy change, in contrast to previous studies that primarily rely on OLS or Bartik-type instruments, methods that have some limitations regarding identification in this context. Furthermore, I extend the existing literature on this topic by providing new estimates of the effects of electricity prices on labor outcomes for the manufacturing sector. Moreover, I estimate this effect also on service and primary sectors separately. To conclude, using the empirical estimates in this paper and parameters already estimated in the literature, I present estimates on the elasticity of substitution between electricity and labor in the manufacturing and in the service sector using a CES production function.

There are some limitations to this study and opportunities for future research on this topic. The main limitation is the use of imputed county electricity prices based on utility-level data, rather than firm-specific prices. A key improvement would be to construct a dataset that combines firm personnel records with firm-level balance sheet data containing information on electricity prices. This would allow the estimation of the elasticity of employment or wages to electricity prices, not only across sectors but also across different occupations within the same sector. Another interesting research direction using firm-level data could be to examine the impact of electricity prices on fixed capital, especially in manufacturing firms. Since fixed capital typically relies on electricity to operate, reductions in machinery utilization or delays in replacement can serve as a channel through which higher electricity prices adversely affect workers, particularly when capital and labor are complementary.

In sum, I provide sector-specific estimates on the effects of electricity prices on employment, number of firms and on the elasticity of substitution between electricity and labor. I exploit a quasi-experimental setting to estimate the elasticities of interest using a market deregulation reform for identification. The results presented in this paper indicate that increases in electricity prices disproportionately impact manufacturing firms and employment while the effects are negligible for the service sector and for the primary sector. Therefore, carefully designed policies are essential to protect vulnerable workers while advancing measures that increase electricity prices as a side effect. Such protections are also critical to sustaining the political feasibility of the energy transition policies (Bocquillon, 2024; Pahle et al., 2022).

Tables

Table 1: Summary Statistics

	Mean	**SD**	**Min**	**Max**
Capacity Share - Coal	0.5473	0.3082	0	1
Capacity Share - Natural Gas	0.1605	0.2541	0	1
Capacity Share - Nuclear	0.1068	0.1271	0	0.5177
Capacity Share - Oil	0.1087	0.1573	0	1
Capacity Share - Hydropower	0.0721	0.1549	0	1
Observations	2352			

Note: Values reported are from the earlier period I have the data for both electricity variables on fuel shares and for labor variables. Electricity fuel shares are from 1990. Data are from the data repository of the Electricity Information Administration (EIA)

Table 2: Utility Statistics in 1990

Ownership	**Sales Electricity (TWh)**	**Number of Utilities**	**Customers**
Investor Owned	1964.41	197	80,301,590
Public Owned	618.46	2179	29,284,541

Note: Statistics are from the U.S. Energy Information Administration (EIA), covering all utilities in the United States. Investor-owned utilities are for-profit entities, while publicly owned utilities are operated by local governments. Data are based on surveys collecting balance sheet information. Sales refers to the total electricity sold (in TWh) by each utility type in 1990. Number of Utilities represents the count of utilities by ownership type in 1990. Customers indicates the total number of customers served by each type in 1990.

Table 3: Effect of Electricity Prices on Employment and Firms

	All Sectors		Manufacturing		Services		Primary Sector	
	Log Employment	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**
Panel A: Results								
P_{ct}	0.107	0.098	-0.433**	-0.438***	0.063	0.100	0.100	-0.179
	(0.296)	(0.307)	(0.020)	(0.001)	(0.484)	(0.358)	(0.496)	(0.143)
N	22970	22970	15301	15301	22813	22813	21990	21990
Panel B: First Stage Regression								
R_{ct}	0.167**	0.167**	0.167**	0.167**	0.174**	0.174**	0.174**	0.174**
	(0.053)	(0.053)	(0.053)	(0.053)	(0.052)	(0.052)	(0.052)	(0.052)
$R_{ct} \times C_c$	-0.306***	-0.306***	-0.306***	-0.306***	-0.316***	-0.316***	-0.316***	-0.316***
	($<$ 0.001)	($<$ 0.001)	($<$ 0.001)	($<$ 0.001)	($<$ 0.001)	($<$ 0.001)	($<$ 0.001)	($<$ 0.001)
N	22970	22970	15301	15301	22813	22813	21990	21990
F-statistic	19.57	19.57	19.57	19.57	22.44	22.44	22.92	22.92

Note: p-values in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. In panel A, estimates are from equation 8 using IV regression. Standard errors are clustered at the utility market level. County by Industry level data from the Bureau of Labor Statistics (BLS). In "All Sectors" I use county employment and number of firms as outcome variable. In "Manufacturing" I use aggregate manufacturing employment and number of firms according to NAICS classification. In "Services", I aggregate service employment and number of firms according to NAICS classification. In "Primary Sector", I include agriculture, mining and construction sub-sectors according to NAICS classification. In panel B, I show the first stage regression presented in equation 9 with the F-statistic.

Table 4: Effect of Electricity Prices on Employment and Firms - Exogeneity Check from Card (1993)

	All Sectors		**Manufacturing**		**Services**		**Primary Sector**	
	Log Employment	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**
Panel A: Second Stage Results								
P_{ct}	0.103	0.093	-0.430**	-0.431***	0.061	0.099	0.103	-0.162
	(0.334)	(0.335)	(0.019)	(0.001)	(0.531)	(0.376)	(0.488)	(0.134)
R_{ct}	0.019	0.002	-0.012	-0.017	0.014	0.012	-0.005	-0.005
	(0.232)	(0.871)	(0.758)	(0.358)	(0.415)	(0.361)	(0.743)	(0.704)
N	22970	22970	15301	15301	22813	22813	21990	21990
Panel B: First Stage Regression								
R_{ct}	0.167***	0.167***	0.167***	0.167***	0.174***	0.174***	0.174***	0.174***
	(0.005)	(0.005)	(0.002)	(0.002)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
$R_{ct} \times C_c$	-0.306***	-0.306***	-0.306***	-0.306***	-0.316***	-0.316***	-0.316***	-0.316***
	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
N	22970	22970	15301	15301	22813	22813	21990	21990
F-statistic	21.11	21.11	26.05	26.05	29.86	29.86	30.22	30.22

Note: p-values in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Estimates are from equation 8 using IV regression. Standard errors are clustered at the utility market level. County by Industry level data from the Bureau of Labor Statistics (BLS). In "All Sectors" I use county employment and number of firms as outcome variable. In "Manufacturing" I use aggregate manufacturing employment and number of firms according to NAICS classification. In "Services", I aggregate service employment and number of firms according to NAICS classification. In "Primary Sector", I include agriculture, mining and construction sub-sectors according to NAICS classification. In panel B, I show the first stage regression presented in equation 9 with the F-statistic. In this regression, I run the same specification as (Card, 1993) to check whether R_{ct} is a valid instrumental variable by not having a direct effect on economic outcomes excluding thought its effect on prices.

Table 5: Effect of Electricity Prices on Employment and Firms using Matching

	All Sectors		Manufacturing		Services		Primary Sector	
	Log Employment	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**
Panel A: Results								
P_{ct}	-0.00336	0.0155	-0.320*	-0.309***	-0.0808	-0.0493	0.0430	-0.0783
	(0.950)	(0.831)	(0.058)	(0.005)	(0.204)	(0.486)	(0.755)	(0.481)
N	11584	11584	11537	11537	11584	11584	11546	11546
Panel B: First Stage Regression								
R_{ct}	0.195***	0.195***	0.192***	0.192***	0.191***	0.191***	0.192***	0.192***
	(0.077)	(0.077)	(0.064)	(0.064)	(0.065)	(0.065)	(0.065)	(0.065)
$R_{ct} \times C_c$	-0.343***	-0.343***	-0.345***	-0.345***	-0.344***	-0.344***	-0.347***	-0.347***
	(0.091)	(0.091)	(0.075)	(0.075)	(0.075)	(0.075)	(0.074)	(0.074)
N	11584	11584	11537	11537	11584	11584	11546	11546
F-statistic	12.03	12.03	17.83	17.83	17.94	17.94	18.56	18.56

Note: p-values in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. In panel A, estimates are from equation 8 using IV regression. Standard errors are clustered at the utility market level. County by Industry level data from the Bureau of Labor Statistics (BLS). In "All Sectors" I use county employment and number of firms as outcome variable. In "Manufacturing" I use aggregate manufacturing employment and number of firms according to NAICS classification. In "Services", I aggregate service employment and number of firms according to NAICS classification. In "Primary Sector", I include agriculture, mining and construction sub-sectors according to NAICS classification. In panel B, I show the first stage regression presented in equation 9 with the F-statistic. I match county pairs with nearest neighbor matching based on geographic characteristics, personal income in 1992, share of manufacturing employment in 1992 and population in 1992 using propensity scores estimated with logit regression.

Table 6: Effect of Electricity Prices on Employment and Firms - Excluding Small Utility Markets

	All Sectors		Manufacturing		Services		Primary Sector	
	Log Employment	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**
Panel A: Results								
P_{ct}	0.037	-0.006	-0.412*	-0.369**	0.054	0.051	0.036	-0.202
	(0.691)	(0.957)	(0.066)	(0.012)	(0.592)	(0.684)	(0.835)	(0.168)
N	20490	20490	13221	13221	20333	20333	19514	19514
Panel B: First Stage Regression								
R_{ct}	0.184***	0.184***	0.177***	0.177***	0.184***	0.184***	0.184***	0.184***
	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)
$R_{ct} \times C_c$	-0.330***	-0.330***	-0.313***	-0.313***	-0.329***	-0.329***	-0.329***	-0.329***
	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)
N	20490	20490	13221	13221	20333	20333	19514	19514
F-statistic	16.48	16.48	13.01	13.01	16.49	16.49	16.68	16.68

Note: p-values in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. In panel A, estimates are from equation 8 using IV regression. Standard errors are clustered at the utility market level. County by Industry level data from the Bureau of Labor Statistics (BLS). In "All Sectors" I use county employment and number of firms as outcome variable. In "Manufacturing" I use aggregate manufacturing employment and number of firms according to NAICS classification. In "Services", I aggregate service employment and number of firms according to NAICS classification. In "Primary Sector", I include agriculture, mining and construction sub-sectors according to NAICS classification. In panel B, I show the first stage regression presented in equation 9 with the F-statistic. I exclude utility markets with four or less counties.

Table 7: Effect of Electricity Prices on Employment and Firms - Exclude Years between 2000 and 2003

	All Sectors		Manufacturing		Services		Primary Sector	
	Log Employment	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**
Panel A: Second Stage Results								
P_{ct}	0.0681	0.0483	-0.406**	-0.421***	0.0926	0.115	0.0946	-0.158
	(0.439)	(0.637)	(0.024)	(0.001)	(0.338)	(0.301)	(0.504)	(0.195)
N	20100	20100	13379	13379	19964	19964	19243	19243
Panel B: First Stage Regression								
R_{ct}	0.1969***	0.1969***	0.1963***	0.1963***	0.1969***	0.1969***	0.1979***	0.1979***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
$R_{ct} \times C_c$	-0.3523***	-0.3523***	-0.3489***	-0.3489***	-0.3520***	-0.3520***	-0.3524***	-0.3524***
	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)
N	20100	20100	13379	13379	19964	19964	19243	19243
F-statistic	20.27	20.27	16.93	16.93	20.30	20.30	20.72	20.72

Note: p-values in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Estimates are from equation 8 using IV regression. Standard errors are clustered at the utility market level. County by Industry level data from the Bureau of Labor Statistics (BLS). In "All Sectors" I use county employment and number of firms as outcome variable. In "Manufacturing" I use aggregate manufacturing employment and number of firms according to NAICS classification. In "Services", I aggregate service employment and number of firms according to NAICS classification. In "Primary Sector", I include agriculture, mining and construction sub-sectors according to NAICS classification. In panel B, I show the first stage regression presented in equation 9 with the F-statistic. In this regression, I exclude years between 2000 and 2003 in this regression excluding a transitory period during which the reform was gradually applied.

Table 8: Effect of Electricity Prices on Employment and Firms - Exclude Years After 2004

	All Sectors		Manufacturing		Services		Primary Sector	
	Log Employment	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**
Panel A: Second Stage Results								
P_{ct}	0.00715	-0.00830	-0.580**	-0.507***	0.0162	0.0751	0.109	-0.293**
	(0.931)	(0.945)	(0.024)	(0.005)	(0.849)	(0.539)	(0.560)	(0.039)
N	17235	17235	11521	11521	17115	17115	16541	16541
Panel B: First Stage Regression								
R_{ct}	0.1359***	0.1359***	0.1191**	0.1191**	0.1358***	0.1358***	0.1364***	0.1364***
	(0.003)	(0.003)	(0.009)	(0.009)	(0.003)	(0.003)	(0.003)	(0.003)
$R_{ct} \times C_c$	-0.2440***	-0.2440***	-0.2223***	-0.2223***	-0.2439***	-0.2439***	-0.2436***	-0.2436***
	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)	(< 0.001)
N	17235	17235	11521	11521	17115	17115	16541	16541
F-statistic	13.63	13.63	10.88	10.88	13.64	13.64	13.53	13.53

Note: p-values in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Estimates are from equation 8 using IV regression. Standard errors are clustered at the utility market level. County by Industry level data from the Bureau of Labor Statistics (BLS). In "All Sectors" I use county employment and number of firms as outcome variable. In "Manufacturing" I use aggregate manufacturing employment and number of firms according to NAICS classification. In "Services", I aggregate service employment and number of firms according to NAICS classification. In "Primary Sector", I include agriculture, mining and construction sub-sectors according to NAICS classification. In panel B, I show the first stage regression presented in equation 9 with the F-statistic. In this regression, I exclude years after 2004.

Table 9: Elasticity Inputs and Simulation Results

	Service	**Manufacturing**
Panel A: Input Elasticities		
ϵ_{L,P_E}	0.067 (0.090)	-0.433 (0.180)
ϵ_{E,P_E}	-0.560 (0.170)	-1.340 (0.330)
ϵ_{w,P_E}	0 (0)	-0.018 (0.007)
Panel B: Results (cov(ϵ_{L,p_E}; ϵ_{E,p_E})=0)		
ρ	-0.59 (-1.55, 0.36)	-0.12 (-1.03, 0.79)
σ	0.63 (0.24, 1.01)	0.89 (0.17, 1.61)
Panel C: Results (cov(ϵ_{L,p_E}; ϵ_{E,p_E})=0.8)		
ρ	-0.59 (-1.15, -0.04)	-0.12 (-0.64, 0.40)
σ	0.63 (0.40, 0.85)	0.89 (0.47, 1.31)

Note: Estimates of ρ and σ using elasticity of employment to electricity prices estimated in the empirical analysis of this paper. Elasticity of electricity consumption and wages to electricity prices is obtained from the literature and I report their mean and standard errors. I estimate ρ and σ using the delta method Oehlert (1992); Bera and Koley (2023). I show the mean value over and the confidence intervals at the 95% level in the results. I use different values of cov(ϵ_{L,p_E}; ϵ_{E,p_E})=0.8) because the two values are likely to be positively correlated. In panel A, point estimates and standard errors of parameters used are reported. In panel B and C, point estimates and 95% confidence intervals are reported.

Figures

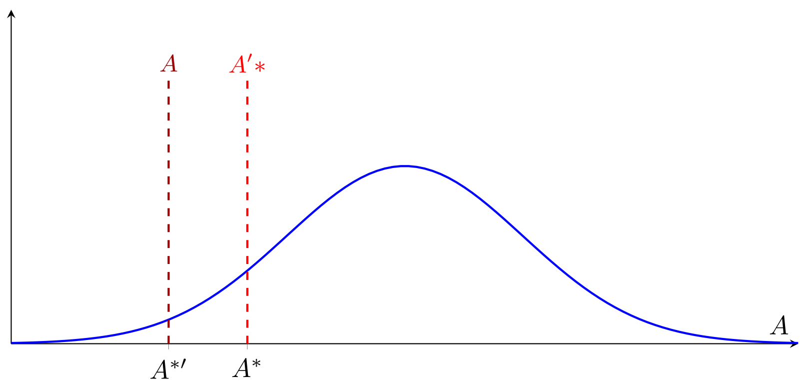

Figure 1: Distribution of A and shift in threshold A^* due to increased electricity prices

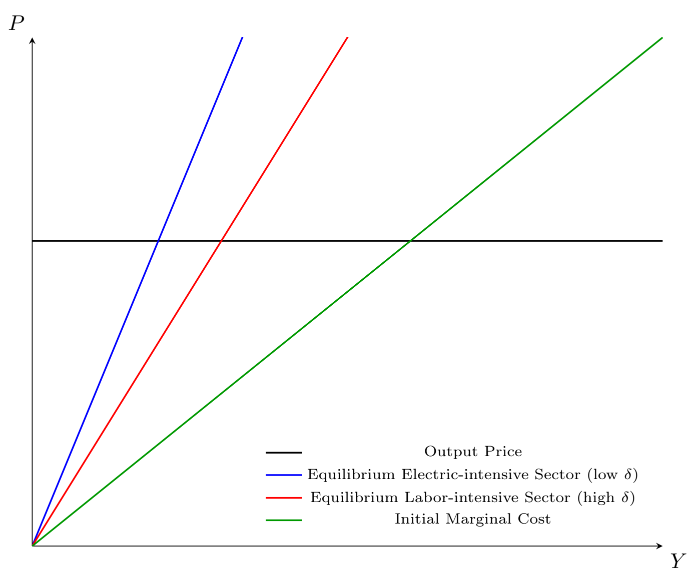

Figure 2: Effect of electricity price on output under different sector intensities δ

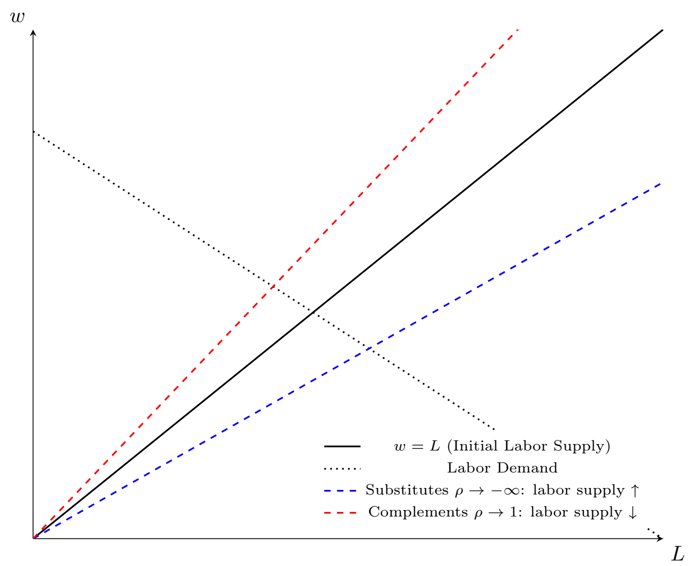

Figure 3: Labor Supply Adjustment to Electricity Price Changes

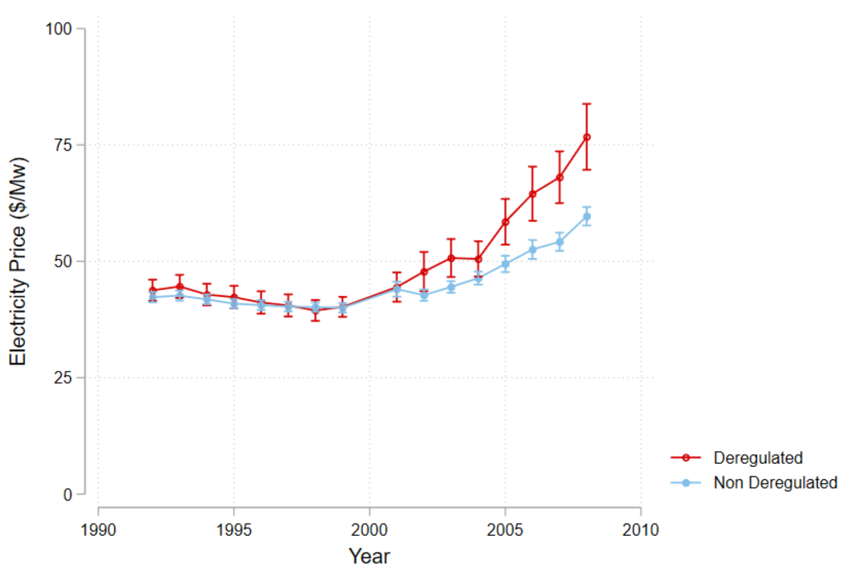

Figure 4: Average Industrial Electricity Price in Deregulated and non Deregulated States

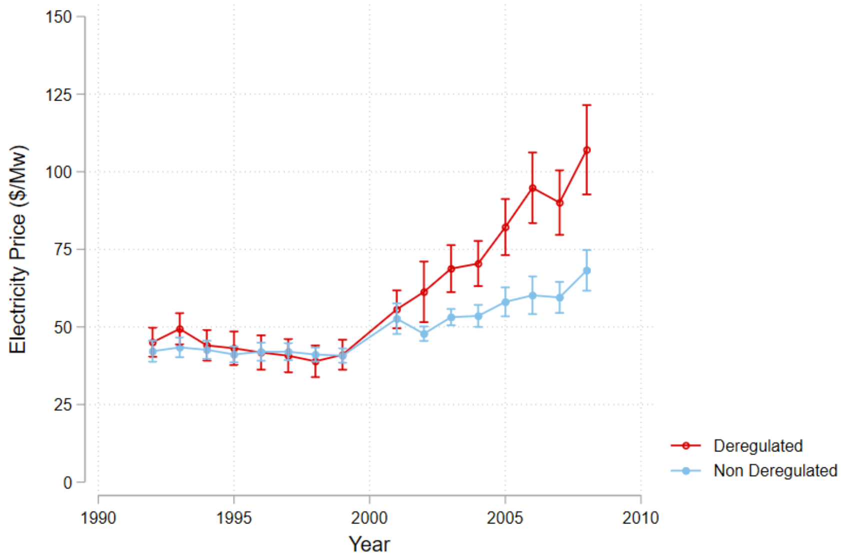

Figure 5: Average Industrial Electricity Price in Deregulated and non Deregulated States for Low Coal Counties

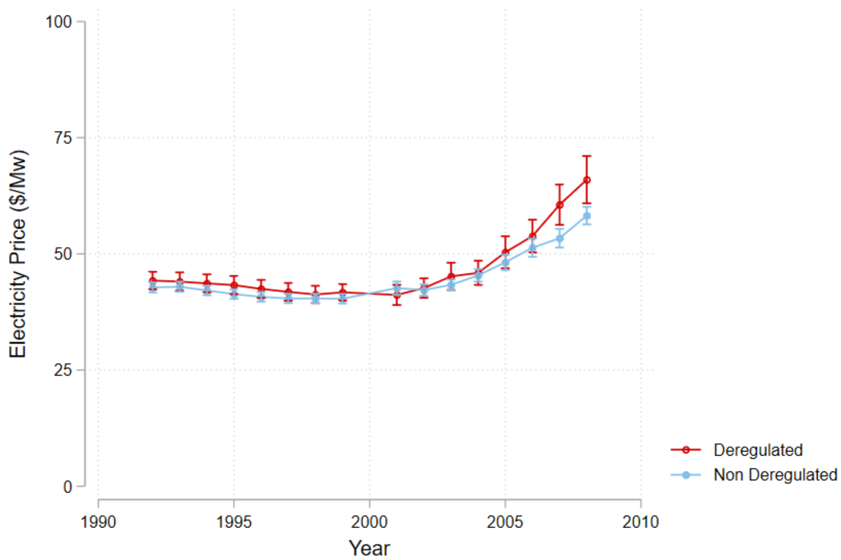

Figure 6: Average Industrial Electricity Price in Deregulated and non Deregulated States for High Coal Counties

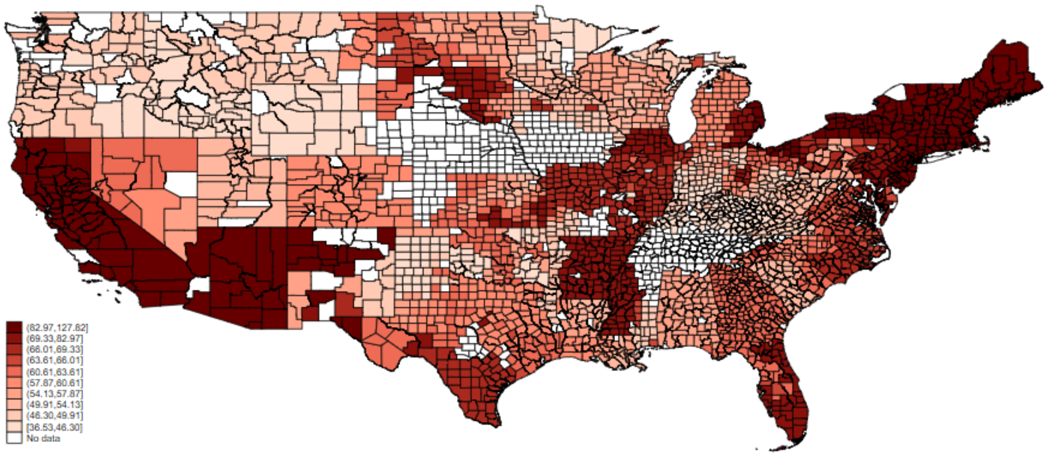

Figure 7: Electricity Price by County in 1992

Figure 8: Manufacturing Employment in High Coal Counties

Figure 9: Manufacturing Employment in Low Coal Counties

Appendix

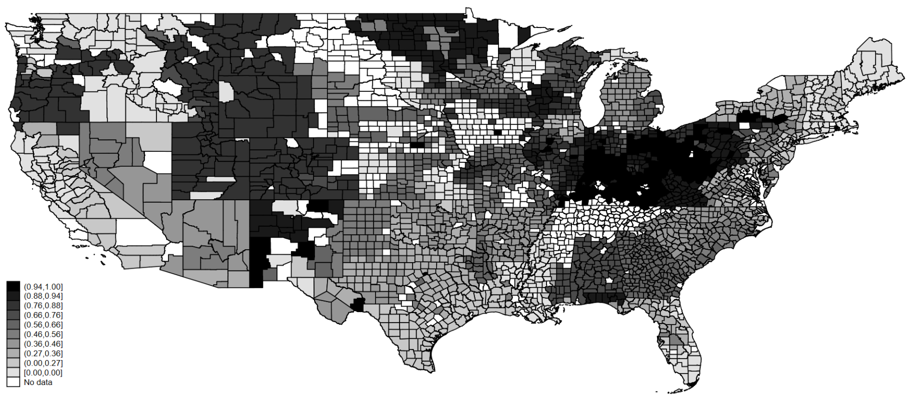

Figure A1: Coal Share by County in 1990

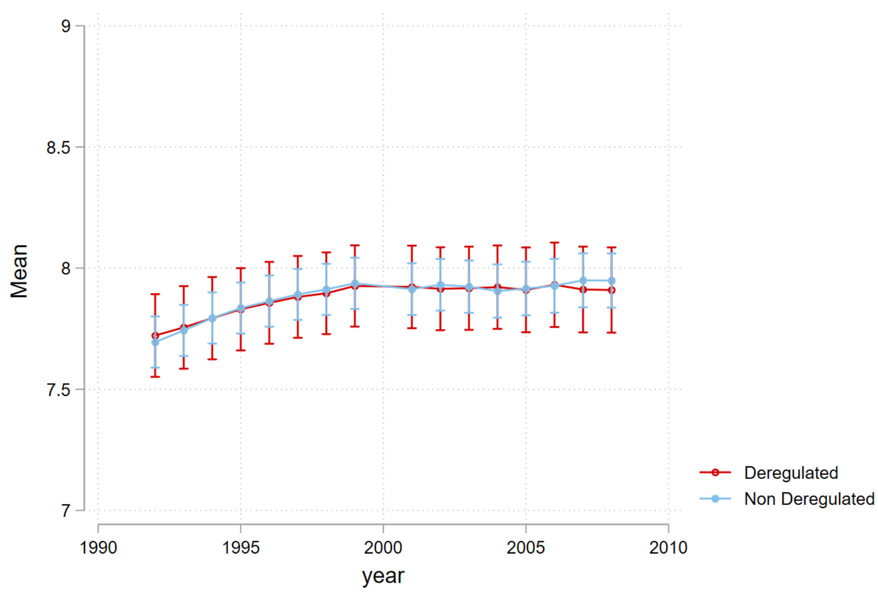

Figure A2: Service Employment in High Coal Counties

Figure A3: Service Employment in Low Coal Counties

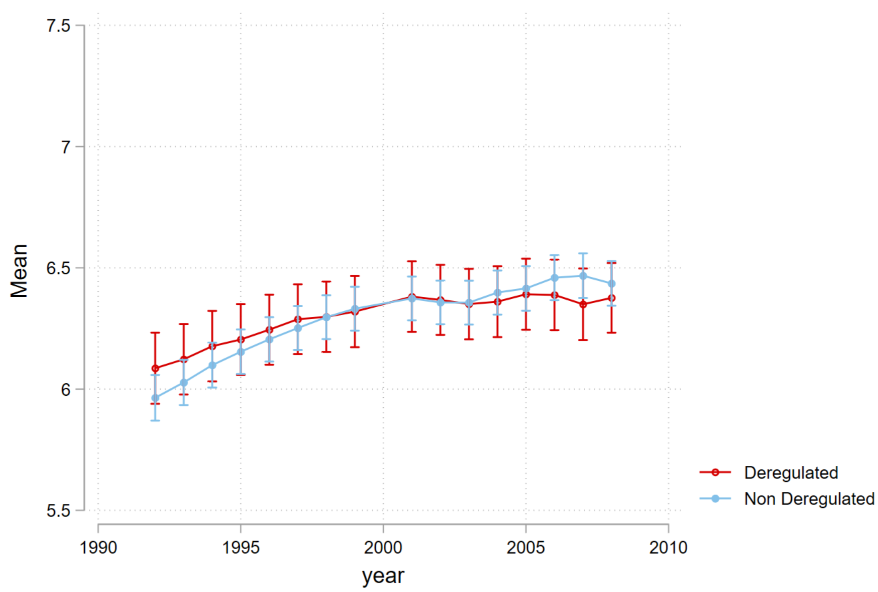

Figure A4: Primary Sector Employment in High Coal Counties

Figure A5: Primary Employment in Low Coal Counties

Table A1: Effect of Electricity Prices on Employment and Firms - OLS Regression

	All Sectors		**Manufacturing**		**Services**		**Primary Sector**	
	Log Employment	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**
P_{ct}	0.0166	0.0297	0.00912	-0.0235	0.00794	0.0413	-0.0129	0.00338
	(0.352)	(0.112)	(0.907)	(0.477)	(0.748)	(0.140)	(0.673)	(0.943)
N	22970	22970	15301	15301	22813	22813	21990	21990

Note: p-values in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Estimates are from ordinary least squares (OLS) regression. Standard errors are clustered at the utility market level. County by Industry level data from the Bureau of Labor Statistics (BLS). In "All Sectors" I use county employment and number of firms as outcome variables. In "Manufacturing" I use aggregate manufacturing employment and number of firms according to NAICS classification. In "Services", I aggregate service employment and number of firms according to NAICS classification. In "Primary Sector", I include agriculture, mining and construction sub-sectors according to NAICS classification.

Table A2: Effect of Electricity Prices on Employment and Firms - IV Regression with State Clustering

	All Sectors		Manufacturing		Services		Primary Sector	
	Log Employment	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**	**Log Employment**	**Log Firms**
Panel A: Results								
P_{ct}	0.103	0.0925	-0.433*	-0.438**	0.0631	0.1000	0.100	-0.179
	(0.294)	(0.412)	(0.084)	(0.032)	(0.692)	(0.502)	(0.610)	(0.380)
N	22970	22970	15301	15301	22813	22813	21990	21990
Panel B: First Stage Regression								
R_{ct}	0.167*	0.167*	0.167*	0.167*	0.174**	0.174**	0.174**	0.174**
	(0.090)	(0.090)	(0.061)	(0.061)	(0.038)	(0.038)	(0.038)	(0.038)
$R_{ct} \times C_c$	-0.306**	-0.306**	-0.306**	-0.306**	-0.316**	-0.316**	-0.316**	-0.316**
	(0.011)	(0.011)	(0.004)	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)
N	22970	22970	15301	15301	22813	22813	21990	21990
F-statistic	8.85	8.85	10.74	10.74	10.32	10.32	9.41	9.41

Note: p-values in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. In panel A, estimates are from equation 8 using IV regression. Standard errors are clustered at the state level. County by Industry level data from the Bureau of Labor Statistics (BLS). In "All Sectors" I use county employment and number of firms as outcome variable. In "Manufacturing" I use aggregate manufacturing employment and number of firms according to NAICS classification. In "Services", I aggregate service employment and number of firms according to NAICS classification. In "Primary Sector", I include agriculture, mining and construction sub-sectors according to NAICS classification. In panel B, I show the first stage regression presented in equation 9 with the F-statistic.

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