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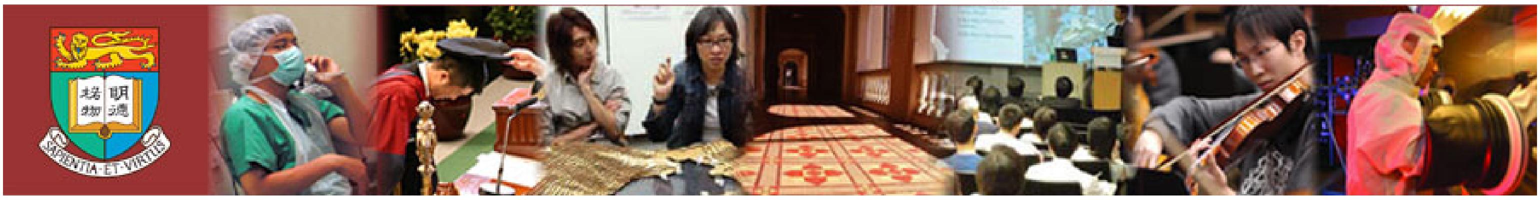

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Production Flexibility, Product Markets, and Capital Structure Decisions[☆]

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Abstract

We examine how production flexibility affects financial leverage. A worldwide sample of energy utilities allows us to apply direct measures for production flexibility based on their power plants. We find that production flexibility increases financial leverage. For identification, we exploit privatizations and deregulations of electricity markets, geographical variations in natural resources, the technological evolution of gas-fired power plants, and differences in electricity prices and recapitalization cost across regions. Production flexibility affects financial leverage via the channels of reduced expected cost of financial distress and higher present value of tax shields. The relative importance of these channels depends on firms' profitability. (*JEL* G30, G32)

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This paper analyzes the relationship between production flexibility and financial leverage. We focus on one particular aspect of production flexibility: the ability to easily adjust production volume. A related concept is operating leverage. In fact, production flexibility can be interpreted as a form of operating flexibility on the asset level that influences operating leverage. We overcome the challenge of measuring production flexibility by focusing on energy utilities. Detailed data on more than 30,000 current and past power plants allow us to construct two direct measures of production flexibility: average run-up time and ramp-up cost. These are based on production technologies of the firms' different power plants. For example, gas-fired power plants have higher production flexibility than nuclear or coal power plants. Flexible firms are able to adjust the production volume quickly and at low cost, enabling them to avoid operating losses by stopping production whenever price falls below marginal cost.

Theoretically, production flexibility may increase the tax benefits of debt financing and reduce the expected cost of financial distress by lowering default risk. This idea was formalized in the models of Mauer and Triantis (1994) and Aivazian and Berkowitz (1998). In the context of operating leverage, the related idea of a trade-off between financial and operating leverage goes back to Van Horne (1977). Similar to higher production flexibility, lower operating leverage reduces firms' expected cost of financial distress.

The literature mainly supports the hypothesis of a substitution effect between operating and financial leverage (e.g., Ferri and Jones 1979; Mandelker and Rhee 1984; Kahl et al. 2014). The empirical measurement, however, varies between different studies. Whereas Novy-Marx (2011) defines operating leverage as operating costs divided by assets, Mandelker and Rhee (1984) approximate the degree of operating leverage as the "percentage change in X [EBIT] that is associated with a given percentage change in the units produced and sold" (49). MacKay (2003) analyzes volume flexibility, which he defines as "the elasticity of cash flow to output level" (1,140) and finds a negative relationship between production flexibility and leverage.[1] The proxies that have been applied in the literature are mainly indirect and/or based on (past) realizations of demand, profits, or cost. This, however, leads to several problems, and the challenge of measuring operating flexibility is not yet finally resolved.[2]

We provide a novel direct measure for production flexibility, which is based on asset-level characteristics instead of on past realizations. This measure has several advantages. First, it captures not only realizations of flexibility but also the possibility of reacting to changing market conditions. For financing decisions, realizations may be less important as they are backward looking. Rather, the future flexibility should be most important when firms decide about their financing structure. Second, our proxy needs no time-series history for estimation and thus avoids the assumption of constant effects over the estimation period. Third, our measure changes over time due to plant openings and closures. This creates observable time-series variation and allows us to apply firm fixed effects. Fourth, the direct interpretation and detailed data about firms' production assets make it easier to address endogeneity concerns. Fifth, our proxy is—at least in the short run—neither directly influenced by accounting practices (e.g, depreciation) nor by managerial decisions (e.g., hedging) or economic conditions (e.g., shifts in demand). This makes our measure comparable across different countries and over time, which is more difficult for proxies that are indirect and/or based on past realizations. We exploit this advantage by analyzing how characteristics of different power markets affect the impact of production flexibility on leverage.

To empirically investigate the relationship between financial leverage and pro-

[1] MacKay (2003) argues that the negative impact of asset substitution and risk shifting outweighs increased debt capacity. However, the former aspects are unlikely to be highly relevant in our setting because neither risk shifting nor asset substitution is easily possible in the context of power plants (as their construction and mothballing takes time, is easily observable, and can be regulated in debt contracts). This may explain why we find a positive impact of production flexibility on leverage.

[2] O'Brian and Vanderheiden (1987), for instance, criticize traditional measures as "certain popular proxy measures for DOL may not be theoretically sound" (50). Dugan et al. (1994) state that "an inconsistency appears to exist between the underlying assumptions of the time-series regression estimation techniques and the theoretical implications of the 'tradeoff' hypothesis" (333). Chen et al. (2011) argue that "measures are backward looking, but the concept of operating leverage in its nature is forward looking" (30).

duction flexibility, we start by performing pooled OLS and firm fixed effects regressions. All models point at a positive relationship. For identification, we first exploit the deregulation of electricity markets and the wave of privatizations in the 1990s as exogenous shocks. Financing was unlikely to influence production assets before deregulation and privatization because (1) public ownership enabled utilities to access capital via the state and/or (2) the absence of competition allowed them to finance even large-scale projects without significant risk in a cost-plus pricing regime. These days, production assets have been heavily influenced by political preferences (Peltzman and Winston 2000). For example, the high prevalence of nuclear power plants in France goes back to the plan of the former French Prime Minister Pierre Messmer to give priority to nuclear electricity ("Messmer plan"). Thus, production assets of energy utilities before privatization and deregulation can be regarded as being independent of financing decisions. Using pre-deregulation and pre-privatization production flexibility as instruments confirms the prior results.

As a second identification strategy, we apply natural reserves of coal, gas, and oil in U.S. states as instruments. For example, higher gas reserves are expected to lead to the construction of more flexible gas-fired power plants. At the same time, natural resource reserves are plausibly exogenous as they are unlikely to influence firms' capital structures directly. Rather, they represent a given physical feature of a region. Both IV approaches confirm a positive impact of production flexibility on leverage. To further reduce concerns about omitted variables, we present additional tests, which focus on asset salability, regional diversification, technology concentration, asset age, and asset lifetime. We also exploit the technological evolution of gas-fired power plants during the 2000s. This evolution led to higher plant flexibility and thus a higher impact of gas-fired power plants over time.

As a final identification approach, we examine the impact of electricity price characteristics and recapitalization cost. If their impact is in line with theoretical predictions, alternative explanations or omitted variables are unlikely to drive our results. We first analyze electricity price volatility. Intuitively, production flexibility would have no value if price volatility would be zero because production volume would never be adjusted to price changes. Hourly electricity prices for power markets in 23 countries allow us to test this prediction empirically. In line with expectations, the positive impact of production flexibility is amplified by more volatile electricity prices. Second, we expect a higher impact of production flexibility if the variable production costs of a firm are similar to the electricity price. If the price is much higher or lower than the variable costs, production volume is rarely adjusted and flexibility has little value. Indeed, we find that the effect of production flexibility is highest if the variable costs of a firm are similar to the price of electricity in this region. Third, in line with the predictions of Mauer and Triantis (1994), we find that the impact of production flexibility is less pronounced if recapitalization costs are low. Intuitively, production flexibility is less important if firms can issue new equity more quickly.

After analyzing the relationship between production flexibility and financial leverage in general, we shed light on the channels via which production flexibility may affect leverage. Both theoretical models discuss a higher value of (future) tax shields and lower distress risk in this context. Exploiting staggered deregulation across U.S. states yields evidence that the impact of production flexibility on leverage increases with default risk. Analysis of competitive markets around the globe also shows that this impact is more pronounced if competition is severe, volatility of equity returns is high, and price hedging is difficult. Splitting firms into subsamples based on their profitability reveals that this channel is mainly relevant for less profitable firms. Analyzing differences in corporate taxes across countries/states and time, we find evidence that the impact of production flexibility increases with taxes. This effect, however, is mainly relevant for more profitable firms. Overall, our results indicate that production flexibility affects financial leverage via tax shields and distress risk. However, the importance of these channels differs across firms. For more profitable firms, the tax channel is of first-order importance. For less profitable firms, the distress risk channel matters most.

This focus on energy utilities has several advantages besides the direct measurement of production flexibility. First, they produce and sell mainly one product, that is electricity. Thus, their flexibility with regard to power generation is a reliable measure of their overall level of production flexibility. Second, technologies for electricity generation are highly standardized and limited in number, allowing us to assign a technology-specific value for run-up time and ramp-up cost. Third, the high entry barriers in the energy utilities industry reduce concerns that our results are affected by new firms, which may, for example, focus on more flexible and less expensive production assets.

Single industry studies come, however, also at a cost. Although we are not the first to use a sample based on energy utilities (e.g., Perez-Gonzalez and Yun 2013), regulation may be a concern. As with many other industries, these firms are regulated to some extent. However, the majority of this regulation nowadays focuses on factors that do not directly impact financing decisions (e.g., access to the grid). Nevertheless, we follow several strategies to alleviate concerns that the results are biased by peculiarities of energy utilities. First, country-year and firm fixed effects control for any country-year-specific or time-invariant impact of regulation. Second, we restrict our analysis to firms located in regions with liquid wholesale markets for electricity. Their introduction is often regarded as the last step in the liberalization process. Third, we control for public ownership, supplier concentration, and restrict the sample to rather homogenous European power markets. We also challenge our proxy for production flexibility along several dimensions. Among others, we consecutively remove single technologies to ensure that our results are not driven by one particular power plant type (e.g., nuclear), apply cost and cash flow-based measures for operating flexibility, and adjust the flexibility for the age of the power plants. All these robustness tests confirm our prior results. We also show that production flexibility is economically relevant for energy utilities.

This paper makes three main contributions. First, we apply a novel, asset-based flexibility measure and show that production flexibility increases financial leverage. We also present identification strategies to mitigate endogeneity concerns. Our findings reveal that operating characteristics are of pronounced importance for firms' financial decision making. This adds to the literature on operating flexibility and financial leverage (e.g., Mandelker and Rhee 1984; MacKay 2003; Kahl et al. 2014), employment flexibility (e.g., Hanka 1998; Chen et al. 2011; Kuzmina 2013), and operating leverage in general (e.g, Petersen 1994; Novy-Marx 2011). Second, we present novel evidence on how market characteristics affect the impact of operating flexibility on leverage. We find strong evidence that this impact depends on product market characteristics, such as price volatility. In this regard, we also contribute to the literature on product markets and firm behavior (e.g., Kovenock and Phillips 1997; Hoberg and Phillips 2010; Matsa 2011). Third, our findings contribute to the literature on leverage and expected cost of financial distress as we shed light on the impact of production (in)flexibility as a source of distress risk (e.g., Bradley et al. 1984; Titman and Wessels 1988).

1. Production Flexibility and Financial Leverage

Production flexibility has many dimensions. For example, the ability to easily switch between different products or adjust features of products can be regarded as production flexibility. We focus on one particular aspect: the ability to adjust production volume. Firms react to price changes by increasing or decreasing production volume. Flexible firms are able to do this quickly and at low cost, for example, by shutting down and restarting production facilities. A related concept is operating leverage, which can be defined as the "use of fixed costs in the firm's production scheme" (Ferri and Jones 1979, 632). Similarly, Aivazian and Berkowitz (1998) define operating leverage as a "commitment to ex-ante production" (2). By contrast, production flexibility in their model is the ability to adjust output ex post. This shows that there is a link between production flexibility and operating leverage. Production flexibility can be seen as a form of operating flexibility (besides, e.g., labor flexibility) on the asset level that influences operating leverage.[3]

With regard to financial leverage, we hypothesize that production flexibility may affect financial leverage via two possible channels: lower distress risk and higher present values of (future) tax shields. Under the strict Modigliani-Miller assumptions, capital structure decisions are irrelevant and production flexibility should play no role. However, firms trade off the benefits and cost of leverage if, for example, tax benefits of debt financing and cost of financial distress exist. In this context, production flexibility can have two effects: it may increase the tax benefits of debt financing and reduce expected cost of financial distress by lowering default risk. Intuitively, firms with high production flexibility are able to avoid operating losses by stopping production whenever price falls below marginal cost. By contrast, less flexible firms can suffer from operating losses because they cannot stop production immediately.

For Figure 1, we assume a random electricity price P (which cannot be predicted by firms), constant marginal cost MC, and two otherwise identical firms with either a high or low flexibility.[4] Whenever P>MC (P<MC), the firm rationally decides to start (stop) production. For the high flexibility firm, we assume no lag between the production decision and actual production adjustment. This lag is three hours for the low flexibility firm. In this example, the high flexibility firm never experiences operating losses (Figure 1A), in contrast to the low flexibility firm (B).

— Figure 1 about here —

Thus, higher production flexibility allows firms to avoid operating losses, thereby

[3]Production flexibility is related to cost structures as they are likely different for flexible and inflexible plants. This was already described by Stigler (1939), who argues that "flexibility will not be a 'free good': A plant certain to operate at X units of output per week will surely have lower costs at that output than will a plant designed to be passably efficient from X/2 to 2X units per week" (311). In a robustness test, we explicitly consider cost structures to analyze how they affect our findings for production flexibility (cf. Section 3.4.3).

[4]For this simple example, we assume that firms differ in start/stop time but have no start/stop cost. Furthermore, the assumption of constant variable production cost, but stochastic electricity prices over short periods is related to the fact that energy utilities often fix part of their production cost, for example, via long-term supply contracts. Furthermore, short-term fluctuations of electricity prices are heavily driven by demand shocks, for example, due to unexpected weather.

reducing distress risk and expected cost of financial distress.[5] This idea is formalized in the models of Mauer and Triantis (1994) and Aivazian and Berkowitz (1998). In the former model, a firm produces a commodity with a stochastic price. The firm has the option to start and stop production for a certain cost. It can also adjust its capital structure by issuing debt and equity, and this causes recapitalization cost. The authors find "that higher production flexibility (due to lower costs of shutting down and reopening a production facility) enhances the firm's debt capacity [...]" (1,253). Aivazian and Berkowitz (1998) draw similar conclusions. Production flexibility also enhances firms' present value of tax shields in these models. Thus, firms with higher production flexibility may choose higher financial leverage due to their lower default risk and/or higher present value of tax shields.

Several market/country characteristics may affect the impact of production flexibility on leverage. In particular, the volatility of the product price plays a crucial role in the model of Mauer and Triantis (1994). Intuitively, production flexibility would have no value if volatility was zero as firms would never change their production decision. When volatility increases, the impact of production flexibility becomes more important (see C and D). Again, the high flexibility firm avoids operating losses. The low flexibility firm, however, generates only losses due to the lag between the production decision and actual start/stop. The impact of production flexibility may also be more pronounced if electricity prices are close to a firm's marginal production cost. In such a situation, production is frequently started and stopped (see E and F). Lastly, recapitalization cost also play an important role in the Mauer and Triantis (1994) model.[6] They predict a substitution effect between production flexibility and low recapitalization cost. In particular, they state that "when the costs to dynamically manage capital structure are small, the hedging benefit of production

[5] In a similar vein, Petersen (1994) argues based on MacKie-Mason (1990) that "[f]irms with more variable cash flows will find that the tax shields are less valuable and the expected costs of financial distress are higher. Accordingly, these firms have less debt in their capital structure" (364).

[6] Mauer and Triantis (1994) denote firms with low recapitalization cost as being financially flexible. We will not use the term "financial flexibility" in this context as recent literature (e.g., Denis and McKeon 2012) often denotes firms that preserve (parts of) their debt capacity for future borrowing as being financially flexible.

flexibility has less of an impact [...]." (1272). Thus, production flexibility should be less important if firms can easily issue equity in response to negative shocks.

2. Data

2.1. Sample construction

The sample covers energy stock-market-listed utilities from all over the world. For its compilation, we start by combining lists of active and inactive utility companies from OneBanker and Datastream, both products of Thomson Reuters. The sample is organized as unbalanced panel and covers the years 2002 to 2009, the period for which we can obtain the necessary data on firms' production assets.[7] This final sample, for which we require data on leverage and production assets, covers 2,449 firm-year observations from 460 firms, located in more than fifty countries.

2.2. Production flexibility

Before explaining the calculation of the measures for production flexibility, we introduce the World Electric Power Plants (WEPP) database and provide details on the matching process.

2.2.1. The WEPP database. All information on firms' production assets is based on the WEPP database, which is published annually by Platts. This comprehensive database contains power plants of all sizes and technologies around the globe. Practitioners, such as analysts of energy utilities and management consultants, regularly use this database. It includes information on single power plant units, such as their production technologies, capacities, geographic locations, start dates of commercial operation, and their owners/operators.[8]

[7] Several steps are conducted to ensure the adequacy of this sample for our purposes. First, we eliminate all firms without a primary security classified as equity (5 firms). Second, all companies that were never active between 2002 and 2009 are excluded (138 firms). Third, and to ensure that our sample only covers companies that focus on the generation of electricity, we check the industry classification of all utilities. For this, we mainly rely on their SIC and ICB codes. In total, we eliminate 426 firms that do not fulfill our criteria of an energy utility. These removed firms are, among others, utilities specialized in water supply or gas transmission.

[8] A detailed description of the database is provided by Platts' Data Base Description and Research Methodology (www.platts.com/IM.Platts.Content/downloads/udi/wepp/descmeth.pdf). Concern-

We rely on this database because information on production assets reported by energy utilities on their Web sites or annual reports has several drawbacks. First, relevant data are often not available because there are no disclosure requirements. Second, there is no standardized disclosure. Hence, firms may engage in selective reporting. Third, even if firms report details on their production assets, the level of detail differs substantially. Consequently, we rely exclusively on the WEPP database to obtain detailed and unbiased data on firms' production assets.

The problem, however, with this database is that all data are unconsolidated and reported for single power plant units. Hence, it is necessary to match the single power plants to our sample firms. We conduct this by manually matching the WEPP database item *Company* to the names of our sample companies.[9] It is important to note that we use the edition of the WEPP database that corresponds to the respective sample year. Hence, we use eight different editions of this database. Relying only on the most recent version could cause bias because the most recent owner reported in the database might not necessarily have been the past owner. For example, the ownership of a power plant can change due to defaults and subsequent asset sales, mergers, or asset deals.

Table 1 provides an overview on the data included in the WEPP database. In total, 114,664 power plants are included in 2009. They account for an overall capacity of 4,732 GW. This figure is consistent with the International Energy Agency (IEA 2011), which reports an installed capacity of 4,957 GW for 2009. We are able

ing the coverage of the database, Platts states that "[t]he WEPP Data Base covers electric power plants in every country in the world and includes operating, projected, deactivated, retired, and canceled facilities. Global coverage is comprehensive for medium- and large-sized power plants of all types. Coverage for wind turbines, diesel and gas engines, photovoltaic (PV) solar systems, fuel cells, and mini- and micro-hydroelectric units is considered representative, but is not exhaustive in many countries. Nonetheless, about a quarter of the data base consists of units of less than 1 MW capacity. Generating units of less than 1 kW are not included" (5). Thus, we consider the database to be representative for our analysis. With regard to the owner/operator of the power plants, Platts states that "[a]s a general matter, the listed COMPANY is both the operator and sole or majority owner" (10).

[9]Since the WEPP database item *Company* does not necessarily equal a company name in our sample, but might be a subsidiary of such a company, we also use a subsidiaries list for our sample firms in the matching process. If a subsidiary is owned by more than one company in the sample, we assume that all owners hold equal parts of this subsidiary.

to match more than 50% of the installed capacity, that is about 2,500 GW, and approximately 30% of all power plants to the energy utilities in our sample. This outcome does not seem implausible because our sample only covers listed companies.

— Table 1 about here —

2.2.2. Production flexibility measures. Based on the information about single power plants, we construct two main measures of production flexibility: run-up time and ramp-up cost. These capture the start/stop time and cost of specific technologies. Higher *Run-up time* is expected to decrease a firm's production flexibility. The values used for the calculation, their sources, and the fraction of each production technology are shown in Table 2. We define the average run-up time of company i as follows:

$$\textit{Run-up time}_i = \frac{\sum_{k=1}^{M} \text{Capacity}_k \cdot \text{Run-up time}_k}{\sum_{k=1}^{M} \text{Capacity}_{k,}} \tag{1}$$

where k denotes a production technology and M the number of different technologies of an energy utility. As a second measure, we use *Ramp-up costs*. These are the cost for a hot start of a power plant. More expensive shutdowns and restarts are expected to decrease production flexibility. Thus, higher values of ramp-up cost go along with lower production flexibility. This definition is very similar to the one used by Mauer and Triantis (1994), who argue that "costs of shutting down and reopening a production facility" (1,253) determines production flexibility. We define average ramp-up costs of company i as follows:

$$\textit{Ramp-up costs}_i = \frac{\sum_{k=1}^{M} \text{Capacity}_k \cdot \text{Ramp-up costs}_k}{\sum_{k=1}^{M} \text{Capacity}_{k.}} \tag{2}$$

Detailed definitions of all variables can be found in Table A1. In Appendix A, we illustrate the calculation of the production variables with an example.

— Table 2 about here —

2.3. Financial variables

Our main *Leverage* measure is total debt divided by the sum of total debt and the book value of equity. Alternative leverage definitions are applied in a robustness test. The variables for which we control in all regressions are size, profitability, tangibility, and growth opportunities (Frank and Goyal 2009). Our results are similar if we also include alternative control variables like earnings volatility, cash flow volatility, or a dividend payer dummy. Variable definitions can be found in Table A1. To account for country- and year-specific effects, for example, taxes or regulation, we include country and year or country-year fixed effects. Firm-years with obvious data errors are not considered, that is, we demand that the leverage is between zero and one, that *Profitability* is higher than minus one, and that *Market-to-book* is higher than zero. To restrict the impact of outliers, all financial variables are winsorized at the 1% and 99% levels.

2.4. Descriptive statistics

Table 3 shows descriptive statistics for several variables, averaged from 2002 to 2009. Average run-up time is 2.77 hours and varies between 0.08 hours for the 25% percentile and three hours for the 75% percentile. The mean ramp-up cost are 28.05 € per MW. Furthermore, average fixed cost are about 61% of total cost. Slightly more than 20% of all energy utilities operate plants in more than one country and most own plants with different generation technologies. The mean lifetime of plants is about 37 years, and they are on average about 20 years old. For the median firm, there are about five other companies operating plants with the same technology in a region and year as potential buyers. With regard to the hourly electricity prices, we observe an average volatility of 24% and a mean price of 48.35 USD/MWh, which is slightly above average variable production cost. The average book leverage in our sample is 43%.

— Table 3 about here —

3. Empirical Results

3.1. Methodology

The main estimation methodologies in this section are pooled OLS and firm fixed effects regressions. The pooled OLS model includes year and country fixed effects. To control for country-year-specific effects like electricity demand, we also use country-year fixed effects (Gormley and Matsa 2014). Alternatively, we apply a firm-fixed effects regression, which includes a firm-specific fixed effect α_i and year fixed effects. To ensure that all regressors are in the information set of the dependent variable, they are lagged by one year. Due to the panel structure of our data, we apply cluster-robust Huber/White standard errors (White 1980), which are adjusted for clustering within firms (Petersen 2009). If country or power market variables, such as electricity price volatility, are included in a regression, standard errors are adjusted for clustering within countries or markets.

3.2. First results

First results for the relationship between production flexibility and capital structure are reported in Table 4. Flexibility is measured by run-up time in model 1. We control for country and year fixed effects in model 1a. As there might be factors that vary over time within countries, we include country-year fixed effects in model 1b. Thus, this model controls for any demand side effects, such as industry structure in a country and year. Model 1c includes firm-fixed effects; thus, it controls for all time-invariant firm characteristics. All specifications indicate a negative relationship between run-up time and leverage. Because higher values for run-up time go along with lower production flexibility, this provides evidence for positive relationship between leverage and production flexibility.

The impact of run-up time on leverage is economically important. Based on the firm-fixed effects estimates, a hypothetical firm with only gas-fired power plants would have a leverage that is about 5% (in absolute terms) higher than an otherwise identical utility with only lignite-fired power plants. As another example, there would be a nearly a 10% difference between two hypothetical energy utilities, with one having only oil and the other one only waste-fired power plants. A one-standard-deviation increase in run-up time leads to about a 4% decrease in leverage. The corresponding figures for tangibility and profitability are, for comparison, below 3%. Results for the ramp-up cost in model 2 are of similar statistical and economic significance. Control variables are discussed in Section 3.3.1. Overall, these findings indicate a strong link between production flexibility and leverage.

— Table 4 about here —

These results so far do not allow us to draw conclusions on causality. Identification strategies are presented in Section 4. Before that, we challenge the robustness of these first results along three dimensions: generalizability, measurement of production flexibility, and miscellaneous.

3.3. Generalizability

Unlike the majority of empirical studies in corporate finance, our sample only includes energy utilities. We are, however, not the first to focus on this industry. Fabrizio et al. (2007), for instance, analyze if markets reduce costs based on energy utilities. Becher et al. (2012) investigate corporate mergers, and Perez-Gonzalez and Yun (2013) use energy utilities to disentangle the value contribution of risk management with derivatives. Furthermore, the mechanism of how production flexibility affects leverage is not specific to the energy utility industry. Rather, adjusting production volume to price fluctuations is common in most manufacturing industries. For example, steel producers may react to a price decline by reducing production of their factories. Thus, similar patterns are likely to exist in other manufacturing industries as well. Nevertheless, we provide several additional tests for the generalizability of our results.

3.3.1. Determinants of leverage. We first investigate whether the factors determining leverage are systematically different for this industry. As shown in Table 4, size and tangibility have a positive impact on leverage. For profitability, we find a negative influence. These findings are in line with prior empirical studies based on multi-industry samples. For market-to-book, we detect a positive impact.[10] Overall, this indicates that financial leverage in the utility industry is determined by similar factors as in other (nonfinancial) industries.

3.3.2. Regulation. Regulation may be a concern with the energy utility industry. However, the energy utility industry is largely deregulated in most countries nowadays (Dewenter and Malatesta 1997).[11] It is also important to note that we only focus on stock-market-listed energy utilities. However, some aspects not directly related to financing can still be influenced by regulation. For example, grid access fees are often determined by federal entities (cf. Section 4.1 for a more comprehensive discussion of regulation). However, a certain degree of regulation exists in most industries. Among others, in the United States the drug admission process is regulated by the FDA, the chemical industry has to fulfill the Toxic Substances Control Act, and firms have to comply with rules set by the FTC.

To control for any country-level regulation, we apply firm fixed effects and pooled OLS regressions with country, year, and country-year fixed effects, which capture unobserved heterogeneity across countries and time (Gormley and Matsa 2014). Thus, we control for country-specific factors like electricity grid in all models. The firm fixed effects regression controls for all time-invariant firm-specific factors. As all models indicate a positive relationship between production flexibility and leverage, omitted variables related to regulation are unlikely to bias our results.

Although there is a high degree of deregulation in most countries, we additionally

[10] At first glance, this is surprising as prior literature mainly supports a negative relationship. However, as also indicated by Frank and Goyal (2009), this effect is not reliable for book leverage, but only for market leverage. For the latter, we also find a negative impact in OLS models. Furthermore, this finding may simply reflect that growth opportunities of energy utilities are mostly limited. Chen and Zhao (2006) show that the impact of market-to-book on book leverage is positive for most firms and that a negative effect is driven by a small number of firms with very high market-to-book ratios.

[11] In the United States, deregulation initiatives started in the late 1980s (e.g., Ovtchinnikov 2010). However, the deregulation process is still ongoing in many U.S. states. A more detail discussion of deregulation in the United States is provided in Section 5.2.

construct a subsample of firms operating in markets for which we find clear evidence that the deregulation process is far advanced. As it is impossible to identify a particular year in which an electricity market was deregulated, because this is a step-wise process, we focus on the introduction of a competitive wholesale market for electricity. This is commonly regarded as the last step in the liberalization process. As no nation-wide electricity markets exist in the United States, Canada, and Australia, we focus on single states in these countries. We use a press and Web search to obtain the necessary information. If we find no convincing evidence for the existence of a competitive wholesale market, we conservatively assume that there is no such market. Figure 2 shows whether there was a competitive wholesale market in at least one year during our sample period for all sample countries/states.

— Figure 2 about here —

To test the impact of regulation, we now only include observations if a competitive wholesale market for electricity existed in the particular region and year. Results can be found in Table 5, model 1. Alternatively, we only include firms located in regions in which such a market exists since 2002 in model 2. The firm fixed effects regressions confirm our prior findings of a positive link between production flexibility and leverage. Compared to the full sample, the economic impact of our measures for production flexibility is even higher in this setting. This provides further evidence that our results are not driven by regulation.

— Table 5 about here —

3.3.3. Market structure and public ownership. There may be significant heterogeneity between different power markets, even in deregulated markets. As it is impossible to control for all potentially relevant factors, we follow a different approach to mitigate concerns that this biases our findings. In particular, we focus exclusively on deregulated markets in the European Union (plus Norway and Switzerland). These markets underwent a rather homogenous deregulation process based on the E.U. directive 96/92/EC.[12] The aim of this directive was to establish "common rules for the generation, transmission and distribution of electricity." Thus, power markets that were formed on the basis of this directive are likely rather similar. Results are presented in model 3. They show that the outcome for this subsample is very similar to our main findings.

Next, we analyze the impact of public ownership. For historical reasons, in most countries public ownership is still more common for energy utilities than for firms from other industries. Information on firms' owners comes from the Thomson Reuters Global Ownership database. This allows us to construct a dummy variable *Public ownership*, which equals one if the state or any public entity is among the three largest shareholders. This is the case in about 10% of all firm-years. In model 4, we include this indicator variable for public ownership as an additional control variable. Its impact is, however, insignificant and the effect of production flexibility remains unchanged. We thus conclude that public ownership does not bias the prior results.

Finally, we analyze whether supplier concentration affects our findings. It could be argued that firms with a very high market share (e.g., monopoly suppliers) cannot use their production flexibility as they have to ensure sufficient power supply and grid stability. To test this, we construct a subsample of firms that account for less than 10% of total installed production capacity in a country/state and year (model 5). Again, we find similar and even stronger results. Thus, we conclude that supplier concentration does not bias our findings.

3.4. Measurement of Production Flexibility

Next, we analyze whether the results are biased by measurement errors of production flexibility. For example, it may be that the impact of a specific technology on leverage is not related to production flexibility, but to other (omitted) characteristics

[12] In 1995, electricity markets in the European Union were largely regulated. In 1996, the E.U. directive 96/92/EC demanding that all member states deregulate their electricity markets was issued. In the early 2000s, the majority of all E.U. markets were deregulated.

of this technology. Furthermore, nuclear may be special along several dimensions, for example, environmental risk. Thus, we start by consecutively excluding firms owning at least one plant with the following technologies: coal, gas, nuclear, and oil. Models 1 to 4 in Table 6 show that the magnitude and statistical significance of the coefficient for run-up time remains rather unchanged when the technologies are excluded. The results for ramp-up cost in Table A2 are similar. We conclude that the impact of production flexibility on leverage represents a general effect that does not depend on any specific technology.

— Table 6 about here —

3.4.1. Active dispatching. Another possible concern is that some power plants are not actively switched on and off. In particular, wind and solar plants produce electricity whenever there is wind or sun. There is no active dispatching of such power plants. To a smaller extent, this concern also applies to hydro power plants. To analyze whether this biases our results, we exclude all firm-years of utilities operating any of these three technologies. Results in model 5, Table 6 again confirm the prior findings. The coefficient for run-up time is even higher as in our base specification. Thus, not actively managed power plants do not bias our findings.

3.4.2. Power plant age. Our proxies for production flexibility may be imprecise because we assign the same flexibility values to all power plants within one technology class, independent of the age of the power plants. In reality, however, newer plants tend to be more efficient and also more flexible (cf. Section 4.4 for a discussion of technological changes). Thus, we adjust the production flexibility to the age of the specific power plant in this robustness test.[13] The empirical results, which are shown in Table 7, model 1, are very similar as those in our main specifications.

— Table 7 about here —

[13]The adjustment factors come from Ellersdorfer (2009) and are based on the construction time of the power plant (i.e., before 1975, 1975 to 1985, 1986 to 1995, and after 1995).

3.4.3. Cost-based measures. Most traditional measures for operating leverage focus on cost structures. In this test, we analyze whether our results change if we control for such measures. For this purpose, we first construct a measure for *Operating cost*, which is based on accounting data. It is defined as the cost of goods sold (COGS), plus selling, general, and administrative expenses divided by total assets (Novy-Marx 2011). The second measure we use is *Fixed cost*, which is based on plant-level data. It considers the average fixed and variable costs of the production technologies of a firm's power plants and is calculated as fixed cost divided by the sum of fixed and variable costs. Fixed costs include capital cost, and variable costs include costs for fuel.[14] Results are reported in Table 7, model 2. Even after controlling for cost structures, we find a strong positive impact of production flexibility on leverage. This is in line with the view that traditional proxies fail to capture the full effect of production flexibility as they are indirect, backward looking, and unable to measure unrealized flexibility.

3.4.4. Cash flow-based measures. Our measures for production flexibility are based on firms' production assets. Alternatively, cash-flow-based measures can be used to approximate operating flexibility. For example, MacKay (2003) uses the elasticity of cash flow to output as empirical proxy for volume flexibility. As argued in the introduction, our measure has several advantages, for example, because it is forward looking. Nevertheless, we compare our proxies with a cash-flow-based measure and follow the idea of MacKay (2003) to estimate the elasticity of cash flow to output with the help of firm-level regressions.[15] The empirical results in Table 7, model 3, show that the cash-flow-based measure is insignificant in all specifications. Our proxies, however, are of high statistical significance and confirm the previous

[14] Data come from the U.S. Energy Information Administration (EIA) and refers to U.S. power plants. As prices for fuel vary between countries, our measure may not be perfectly representative for all markets. However, we argue that it is a reasonable approximation. Values for fixed cost are summarized in Table 2.

[15] In particular, we estimate the following model for each firm with more than two observations: $ln(cashflow)_t = \alpha + \epsilon\, ln(output)_t + u_t$. Following MacKay (2003), the firm-specific proxy for volume flexibility is then calculated as $abs[ln(\epsilon)]$.

findings. This indicates that our findings are related to using a forward-looking proxy for production flexibility.

3.4.5. Economic relevance. The economic relevance of ramp-up cost is underlined by the following example. We assume two otherwise identical energy utilities, with one having a ramp-up cost of 15 €/MW (25% percentile) and the other 40 €/MW (75% percentile). We further assume a capacity of 1,000 MW for both firms. Thus, a start of their production assets costs on average 15,000 € for the flexible firm and 40,000 € for the less flexible firm. Assuming an electricity price of 30 €/MWh and variable cost of 25 €/MWh, both firms generate hourly profits of 5,000 €. Thus, the power plants of the flexible firms have to run three hours at full-load until start-up cost are covered; the corresponding number for the less flexible firm is eight hours. This example illustrates that ramp-up costs are economically relevant for utilities. The existence of negative power prices also provides an idea of how important flexibility is for utilities. In this context, the Web site of the European Power Exchange states that "[n]egative prices are not a theoretical concept. Buyers are actually getting money and electricity from sellers. However, you need to keep in mind that if a producer is willing to accept negative prices, this means it is less expensive for him to keep their power plants online than to shut them down and restart them later." Overall, production flexibility offers real benefits for firms as they can stop production as soon as prices fall below variable cost. This leads to frequent starts and stops of flexible power plants in practice, dependent on the current electricity price.[16]

3.5. Miscellaneous

To further challenge the results' robustness, we apply system-GMM estimation with lagged leverage as independent variable. This allows us to capture the dynamic

[16]Unreported results also show that higher production flexibility is associated with a lower number of hours in which a specific technology was connected to the electricity transmission system (based on data from the NERC). This provides further indication that energy utilities consider production flexibility in their production decisions.

nature of the firm's debt-equity choice (e.g., Flannery and Rangan 2006). As simple OLS estimation is not appropriate in this context, we apply the system-GMM estimator proposed by Blundell and Bond (1998).[17] Results are reported in Table A3. The estimated adjustment speed is similar to that in Öztekin and Flannery (2012), who analyze a worldwide, multi-industry sample. For production flexibility, we again find that higher flexibility increases leverage. Furthermore, we apply *Market leverage* and *Long-term book leverage* as alternative leverage definitions. Results are shown in Table A4. Overall, our result of a positive relationship between production flexibility and leverage does not depend on any specific leverage definition.

4. Identification Strategies

4.1. Deregulation and privatization

There are two reasons why privatization of energy utilities and the deregulation of electricity markets over the last decades can be used for identification. The first is that energy utilities have been mostly publicly owned before privatization (Dewenter and Malatesta 1997). They profited from loan guarantees and access to capital via the state. Thus, factors like political preferences, not financing constraints, determined the choice of production technologies of publicly owned energy utilities.[18] The second reason is related to the fact that many countries deregulated the energy industry in the 1990s. Before that, even the construction of very expensive power plants, for example, nuclear plants, was virtually riskless because markets were not competitive. Hence, costs could be recovered from costumers by cost-plus pricing. In such a business environment, financing constraints were unlikely because future

[17] Two- to four-period lags of the right-hand side variables are used as instruments. For the production flexibility variables, we use the values as of 1995 as instruments (cf. Section 4.1). We apply both the one-step and the asymptotically more efficient two-step system-GMM version. As standard errors might be downward biased in the latter case, they are adjusted with the finite sample correction proposed by Windmeijer (2005).

[18] For example, Dewenter and Malatesta (2001) state that energy utilities had "implicit or explicit loan guarantees enabling them to borrow at favorable rates, or they may borrow from the government itself at favorable rates" (312). Two important exceptions in this context are the United States and Japan. Investor-owned energy utilities accounted for the majority of electricity production in the United States since the 19th century (Masten 2010). Japan privatized energy utilities in 1951. Excluding these countries from our empirical tests leads to similar results.

cash flows were highly predictable. It is thus reasonable to assume that the production technology decision was not driven by financing constraints, but by other factors, such as political preferences. In this context, Peltzman and Winston (2000), 121, state that "[o]ne of the potential benefits of creating competitive decentralized markets for wholesale power is to bring these politicized resource planning process to an end [...]."

Both reasons indicate that financing constraints were unlikely to have had any impact on the production assets of state-owned and/or highly regulated energy utilities. Hence, using before-privatization and deregulation production assets to explain the after-privatization capital structure reduces endogeneity concerns as they are plausibly independent of financing decisions. In our empirical design, we perform an IV regression with flexibility measures as of 1995 as instruments.[19] Results are reported in Table 8, models 1 and 2. Production flexibility values as of 1995 have a high statistical and economic significance in explaining contemporaneous flexibility values. As before, higher production flexibility leads to higher financial leverage.

— Table 8 about here —

Alternatively, we consider only utilities located in the E.U. countries (plus Norway and Switzerland), which started electricity exchanges as a last step of liberalization between 1995 and 2003. We focus on E.U. countries because they underwent a rather homogeneous deregulation process (cf. Section 3.3.3 for a description). As the speed of deregulation was different across countries, we identify those countries that started a power exchange before 2003. Furthermore, we consider only firm-years after 2004 to ensure that the exchanges have been already in place for some time. The results in models 3 and 4 again provide strong evidence that higher production

[19]This year is chosen because power plants that were in operation in 1995 have been largely planned and constructed before the start of deregulation and privatization. Production assets for the year 1995 are derived from the 2002 edition of the WEPP database, which is the earliest edition available. All units with a start of commercial operation later than 1995 are excluded. Nevertheless, as argued in Section 2.2, using ownership information as of 2002 for 1995 can cause a bias. We argue, however, that this bias should be small.

flexibility leads to higher leverage.

However, one might still argue that endogeneity biases our results because we cannot "prove" that production flexibility before liberalization and deregulation was completely independent of financing decisions. Although we do not believe that this is likely, there might be reasons why, for example, governments aligned highly flexible production assets to energy utilities with high or low leverage ratios. Furthermore, high persistence of production assets and financial leverage over time may threaten this identification strategy. Consequently, we also present an alternative IV strategy in the next section.

4.2. Coal, gas, and oil reserves as instruments

Roberts and Whited (2013) argue that "[g]ood instruments come from biological or physical events or features" (514). As alternative instruments, we thus apply physical features of U.S. states, that is, their natural reserves of coal, gas, and oil.

We argue that the natural resources of a state influence the average production flexibility of the energy utilities located there. In particular, higher gas reserves are expected to increase the probability that gas-fired power plants are built, thus increasing local production flexibility. The opposite is true for coal reserves, which should lead to less flexible power plants. For oil reserves, we expect no direct impact on energy utilities' production facilities because oil-fired power plants are uncommon in the United States. By contrast, oil reserves may increase energy demand, for example, due to energy intensive refineries. Higher energy demand leads to more large-scale base-load power plants, which are less flexible. At the same time, reserves of natural resources are very unlikely to influence firms' financing decisions via other channels than via production flexibility. Using data for reserves as of 1995 further mitigates concerns about a direct impact.[20] To reduce a possible impact of regula-

[20]Data are obtained from the EIA. We rely on the U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves 1996 Annual Report and the Coal Industry Annual Report 1995. For oil and gas reserves, both on and offshore reserves of a state are considered. We focus on dry natural gas reserves. For coal, we exclude states for which data on reserves are withheld. If a state is listed as miscellaneous, we assume that there are no reserves.

tion, we restrict the sample to firms located in states with liquid wholesale markets for electricity (cf. Section 3.3.2). Furthermore, we include the yearly gross state product (GSP) and unemployment rate to control for differences in local economic conditions that may be related to natural reserves.

Results can be found in Table 9. First-stage regressions indicate that gas reserves increase production flexibility. Oil reserves have a contrary effect. For coal, we find no significant impact on production flexibility. All these findings are in line with our expectations. The Kleibergen-Paap rK Wald F statistic (Kleibergen and Paap 2006) indicates no weak instruments problems for both measures of production flexibility. The second-stage regressions confirm our prior findings. Thus, this test further mitigates endogeneity concerns.

— Table 9 about here —

4.3. Omitted variables of production technologies

So far, we presented two identification strategies that focus on a possible simultaneity bias. However, our results may also be affected by omitted factors of different power plant types that are correlated with production flexibility. For example, gas-fired power plants could increase leverage because they are less expensive and easier to sell in case of financial distress, and not because of their high production flexibility. Thus, we now investigate the impact of asset salability, regional diversification, technology concentration, asset lifetime, and asset age. Results for run-up time are reported in Table 10; similar findings for ramp-up cost can be found in Table A5.

— Table 10 about here —

4.3.1. Asset salability. Financing decisions may also be affected by asset salability (e.g., Shleifer and Vishny 1992; Benmelech 2009; Campello and Giambona 2013). If production flexibility is correlated with asset salability, our results may reflect an asset salability effect. As empirical proxy for asset salability, we use the capacity-weighted average salability of firms' power plants. A plant's salability is defined as the number of other firms in the same region and year that operate plants with the same technology. The idea behind this measure is that a higher number of potential buyers makes it easier to sell the asset. The results in model 1 provide no evidence for a significant impact of asset salability on financial leverage, but unreported results based on OLS indicate a significant positive impact. For all specifications, the influence of production flexibility remains strong.

4.3.2. Regional diversification and technology concentration. Next, we control for regional diversification and technology concentration. Higher geographical and technology diversification may reduce firm risk and thus affect financial leverage. *Regional diversification* is a dummy that equals one if a utility owns plants in more than one country. *Technology concentration* is a Herfindahl index that measures the concentration of production technologies. Results in model 2a show that regional diversification has no significant impact on financial leverage. For technology concentration, we find some evidence that firms with more concentrated production technologies have lower leverage ratios (model 2b). The impact of production flexibility, however, remains positive and highly significant in both models.

4.3.3. Asset lifetime and age. *Asset lifetime* controls for potential differences in plants' lifetimes. For instance, highly flexible plants may have shorter lifetimes, which could affect our findings for production flexibility. Asset lifetime is calculated using the historical lifetimes in the WEPP database.[21] For the empirical test, we consider two perspectives: total lifetime (i.e., at the beginning of commercial operation) and remaining lifetime. Total lifetime may have an impact due to financing decisions at the time of construction; remaining lifetime focuses on financing decisions during the plants' lifetimes. Results are reported in model 3. Neither of the two measures for asset lifetime has a significant impact. *Asset age* controls for differences in investment cycles and is defined as the capacity-weighted average age of the

[21]Therefore, we identify plants that became inactive, subtract the start year, and average across all plants of a particular technology class. The average capacity-weighted lifetime is then calculated in the same way as our proxies for production flexibility.

plant portfolio (model 4a). Additionally, we also include age quintiles in model 4b, allowing us to control for any nonlinear impact of age. Again, we find no evidence that plants' age has any impact on financial leverage. Unreported results based on OLS indicate a negative relationship between asset age and leverage. Our results for production flexibility, however, remain highly significant across all specifications.

4.4. Technological evolution of gas-fired plants

As an alternative test to mitigate concerns about omitted variables, we exploit the technological evolution of gas-fired power plants during our sample period. Gas-fired power plants experienced a massive increase in efficiency and flexibility during the 2000s. Based on EIA data for average operating heat rates, the efficiency of installed gas-fired power plants increased from about 37% in 2002 to 42% in 2009 (EIA 2012, 166). With increasing efficiency, the plants also became more flexible, that is, cycling times were reduced.[22] The efficiency of operated coal-fired plants remained rather unchanged throughout our sample period, with values of about 33%. Figure 3A provides a graphical illustration.

We expect there to be an increasing impact of gas-fired power plants on financial leverage over time due to the increased production efficiency and/or flexibility. For coal-fired plants, which we use as a placebo test, we expect no time pattern. For this test, we perform yearly regressions and explain leverage by the fraction of gas- or coal-fired power plants (and the usual control variables). After that, we plot the yearly coefficients for these fractions in Figure 3. The empirical results show that the positive impact of gas-fired power plants increased over time (Figure 3B). For coal-fired power plants, we find no time pattern (Figure 3C). Thus, the efficiency and flexibility of gas-fired power plants drive financial leverage, and not not the gas-fired power plants themselves.

To distinguish whether the increasing impact is driven by the increase in flexibility or efficiency, we exploit variation in gas and electricity prices across countries

[22] For example, Siemens started a special project called FACY (FAst CYcling) in the early 2000s to shorten plant start-up times.

and states. Data come from the IEA for all countries, except for the United States, for which data come from the EIA. We find that gas and electricity prices per se have little impact on the relationship between gas-fired power plants and financial leverage. As prices change the profitability and thus the implicit efficiency of power plants, the increasing impact of gas-fired power plants during our sample period is driven by an increase in production flexibility, not efficiency. As omitted variables are unlikely to be correlated with this increase, this test further reduces endogeneity concerns.[23]

— Figure 3 about here —

4.5. Electricity price and recapitalization cost

Next, we analyze how electricity price characteristics and recapitalization cost affect the impact of production flexibility on leverage. This helps to mitigate endogeneity concerns if our findings are in line with theoretical expectations, as alternative explanations/omitted variables are unlikely to lead to such results.

Mauer and Triantis (1994) argue that the impact of production flexibility on leverage increases with the volatility of the product price. The fact that energy utilities sell mainly one product, that is, electricity, allows us to test this empirically. Because there is no comprehensive database available, data on electricity prices around the world are obtained from the Web sites of electricity exchanges, directly from the exchanges, or from Thomson Reuters. Data on hourly spot prices, which provide a more comprehensive picture than daily prices, are available for electricity markets in twenty-three countries.[24] Firms are matched to these markets based on the location of their headquarters. The volatility of the hourly electricity price is

[23] In addition to the graphical analysis, we also perform statistical tests and find that the slopes of the linear fits in (c) and (d) are statistically not different from zero, whereas the slope of the linear fit in (b) is positive and statistically different from (c) and (d).

[24] These are Australia (AMEO New South Wales, AMEO Queensland, AMEO South Australia, AMEO Victoria), Austria, Belgium, Canada (AESO, MISO, OIESO), Denmark, Estonia, Finland, France, Germany, Italy, Netherlands, New Zealand, Norway, Portugal, Poland, Russia, Singapore, South Korea, Spain, Sweden, Switzerland, the United Kingdom, and the United States (ERCOT, ISO NE, MISO, NYISO, OIESO, and PJM).

then calculated separately for each firm over its fiscal year (*Volatility*). Results for the interaction with production flexibility are reported in Table 11, model 1. As expected, the impact production flexibility increases with volatility.

We also expect that the impact of flexibility on leverage is higher if electricity prices are similar to a firm's marginal production cost. Again, we can test this because we know the average electricity price in a market, and we have an approximation for firms' average variable production cost (cf. Section 3.4.3). Δ*Cost/price* is calculated as the natural logarithm of the absolute difference between the electricity price over a firm's fiscal year and its variable electricity production cost in the same time period. Results in model 2 show that the impact of production flexibility decreases if electricity prices are very different from variable cost.

Lastly, Mauer and Triantis (1994) predict that the impact of production flexibility increases with recapitalization cost. To approximate the cost of accessing external equity, we use the fraction of months in a country in which firms issued or repurchased shares from McLean et al. (2009) as the main measure (*Nonzero*).[25] Higher values of this proxy go along with lower recapitalization cost. Similar to the prior cross-market tests, we focus on firms that are located in regions with competitive wholesale markets for electricity to reduce concerns that our findings are driven by country-level regulation. Results are presented in model 3. Run-up time and ramp-up cost have, on average, a negative influence on leverage. As expected, this effect is reduced by low recapitalization cost.

Overall, we provide evidence that the impact of production flexibility increases with electricity price volatility and recapitalization cost and decreases with the absolute difference between electricity price and production cost. This further reduces endogeneity concerns as all these findings are in line with theoretical predictions.

— Table 11 about here —

[25] We also use alternative proxies: *Access* is a survey-based index measuring how easy it is for firms to issue equity (Schwab et al. 1999). Second, we calculate the number of SEOs of nonfinancial firms in a specific country during our sample period. Third, we use the LaPorta et al. (2006) protection index. Results in Table A6 support the main findings.

5. Channels

Next, we analyze the two channels in the models of Mauer and Triantis (1994) and Aivazian and Berkowitz (1998): a higher value of tax shields and lower distress risk.

5.1. Taxes

As explained in Section 1, both models predict that corporate taxes affect the impact of production flexibility on financial leverage. The reason is that production flexibility increases the (expected) value of interest tax shields. Our worldwide sample allows us to test whether production flexibility has a higher impact in regions with higher corporate tax rates.

To approximate corporate tax rates, we calculate the median effective tax rate for each country/state and year.[26] Results are reported in Table 12. Interacting this tax rate with production flexibility for the whole sample provides evidence that corporate taxes increase the impact of production flexibility (model 1). However, the effect is not statistically significant for run-up time. In a next step, we split the sample into more and less profitable firms by comparing their profitability with the median profitability of all firms in the same country/state and year. Now we find strong evidence for both flexibility measures that the impact of production flexibility increases with tax rate for the subsample of profitable firms (model 3). The coefficient for the interaction term approximately doubles compared to the full sample. Using nominal corporate tax rates confirms the findings for more profitable firms (see Table A7). Overall, these findings provide evidence that the tax channel is relevant, but mainly for more profitable firms.

— Table 12 about here —

[26]The effective tax rate (ETR) for each firm and year is calculated as income taxes divided by pre-tax income. We winsorize ETR at [0,1] (e.g., Chyz et al. 2013). As a robustness test, we also use nominal corporate tax rates.

5.2. Distress risk

Next, we investigate the impact of distress risk. Firms with inflexible production assets may choose lower leverage due to their higher expected cost of financial distress (cf. Section 1). If this holds true, we expect that the impact of production flexibility is more pronounced in markets with higher probability for financial distress. Intuitively, production flexibility should play no role for firms located in markets without significant distress risk. In markets with high distress risk, however, firms with more production flexibility can better react to adverse market conditions. This reduces their expected cost of financial distress and leads to higher leverage ratios in a classical trade-off model.

To test the default risk channel empirically, we first exploit the staggered deregulation across U.S. states. We focus on the introduction of electricity retail choice, which ends local monopolies of energy utilities and increases their default risk. In fact, default risk is virtually nonexistent without competition. Thus, firms with low production flexibility also face little risk in such markets. In competitive markets with retail choice, however, energy utilities face significant default risk. We obtain data on the historical state-level regulation of electricity markets from EIA. Overall, we find that consumers could choose their electricity supplier in nineteen states in at least one year between 1995 and 2009. Most of these states introduced retail choice around 2000; some states, such as California, suspended it again. The dummy *Deregulation* equals one in states and years with electricity retail choice.

Empirically, we start with the main sample period, which begins in 2002. As the first sample year is after most states had already introduced retail choice, identification mainly comes from changes of production flexibility in Table 13, model 1. We find evidence that the impact of production flexibility is stronger if retail choice is available. However, the choice of production assets itself may be affected by deregulation. Thus, we perform an additional difference-in-differences test with an extended sample period starting in 1995 (model 2). To avoid the possibility that production assets have been affected by deregulation, we use production flexibility values as of 1995 (cf. Section 4.1 for their construction). Again, we find that the introduction of retail choice (and thus default risk) led to a significantly higher impact of production flexibility on leverage. This provides the first evidence for the distress risk channel.

— Table 13 about here —

As an alternative test setting, we analyze the impact of the degree of default risk in competitive electricity markets around the globe. This also enables us to investigate how firms' profitability affects the importance of the default risk channel. This is not feasible in the staggered deregulation setting because the introduction of retail choice affected both default risk and profitability. We use three proxies for the degree of default risk in a power market. The first proxy is the level of generation-side competition within an electricity market. As before, higher competition is expected to increase default risk. Our empirical proxy for the level of generation-side competition in an electricity market and year is the Herfindahl index based on production capacities. Higher values of this index go along with higher concentration and lower levels of competition. Results are reported in Tables 14 and A8. Model 1 shows that the impact of production flexibility is higher in markets with higher levels of competition. However, when we split the sample in more/less profitable firms, we find that this effect is mainly relevant for less profitable firms.

As second aspect, we investigate the role of equity volatility, which we calculate as the natural logarithm of the average standard deviation of equity returns of all other firms in the same market and year. As expected, we find that production flexibility is more important for firms operating in markets with higher volatility of equity returns (model 2). Although we find a stronger impact for the subsample of less profitable firms, this difference is not statistically significant.

As a third aspect, we analyze the impact of opportunities to hedge the electricity price, which reduces firms' distress risk. We exploit the heterogeneity of power hedging opportunities across different markets for this test.[27] We define *Hedging* as the fraction of other firms in the same power market and year that engage in electricity price hedging. Data on the hedging behavior of individual firms are based on their annual reports.[28] Results in model 3 show that the impact of production flexibility on leverage is less pronounced in markets in which hedging of power prices is more common. Again, this mainly applies for less profitable firms.

— Table 14 about here —

Overall, our findings indicate that both the tax and the distress risk channel play a role. However, their importance differs across firms. Whereas the distress risk channel is of first-order importance for less profitable firms, the tax channel plays a significant role in more profitable firms.

6. Conclusion

In this paper, we examine the relationship between production flexibility and financial leverage based on a global sample of energy utilities. Detailed data on their power plants enable us to apply direct asset-level measures for production flexibility. Theoretically, production flexibility can increase tax benefits of debt financing and decrease expected cost of financial distress (Mauer and Triantis 1994; Aivazian and Berkowitz 1998). We find that firms with higher production flexibility rely more heavily on debt financing. This is also in line with the Van Horne (1977) hypothesis of a substitution effect between operating and financial leverage, as higher production flexibility is associated with lower operating leverage.

For identification, we first exploit the fact that production flexibility was unlikely to influence financing before deregulation and privatizations of energy utilities. Af-

[27] The liquidity of electricity future markets and thus hedging opportunities vary between different power markets. A comprehensive discussion about problems of electricity hedging in practice is, for instance, provided by Frestad (2012) and de Maere d'Aertrycke and Smeers (2013).

[28] Data come from Lievenbrück and Schmid (2014). This proxy has two desirable features: first, it is outcome based and thus implicitly considers market liquidity. This is important as the formal existence of derivatives may be an unreliable proxy for real hedging opportunities as liquidity is often low, especially for longer maturities. Second, this proxy does not consider the hedging decision of the firm itself to avoid endogeneity problems.

ter that, we use an instrumental variable approach based on natural reserves of coal, gas, and oil. These natural reserves are plausibly exogenous of financing decisions. To further reduce concerns about omitted variables, we investigate the impact of asset salability, regional diversification, technology concentration, asset lifetime, and asset age. Next, we exploit the technological evolution of gas-fired power plants and analyze their impact over time. Lastly, we analyze how electricity price characteristics and recapitalization cost affect the impact of production flexibility and find results in line with theoretical predictions.

To shed light on the channel, we exploit the staggered deregulation across U.S. states and regional differences in distress risk and corporate taxes. Overall, our findings indicate that production flexibility affects financial leverage via lower expected cost of financial distress and higher present value of tax shields. However, the relative importance of the channels depends on firms' profitability: whereas the tax channel is of first-order importance for more profitable firms, the distress risk channel is most relevant for less profitable firms.

These findings contribute to a better understanding of the interaction between nonfinancial firm characteristics like production assets and financing decisions. Most importantly, our results show that firms consider their production flexibility for the debt-equity choice. This may, for example, help to better understand the empirically observed debt conservatism (Graham 2000) or leverage stability (Lemmon et al. 2008). Furthermore, the findings reveal that the impact of firms' external environments on their financing decisions depends on production characteristics.

The focus on energy utilities and their power plants enables us to directly measure production flexibility, but this also comes with some limitations. The perfect identification strategy would rely on an exogenous shock that only shifts firms' production flexibility. As such a shock is—to the best of our knowledge—not available, our identification strategy is based on several alternative tests that mitigate endogeneity concerns. Another important limitation is that we focus on production flexibility as only one dimension of operating flexibility. Thus, the impact of other forms of real flexibility, for example, switching options, on capital structure decisions cannot be answered by this paper. Although we provide evidence that our results are not driven by utility-specific factors, the development of direct flexibility measures for other industries is also a promising area for future research.

Table 1: Descriptive statistics I/II: Power plants

	Total in database		Matched			
Year	Capacity [MW]	Plants [#]	Capacity [MW]		Plants [#]	
2009	4,732,739	114,664	2,468,897	52%	31,760	28%
2008	4,523,533	108,960	2,360,368	52%	29,960	27%
2007	4,307,153	103,853	2,276,957	53%	28,597	28%
2006	4,099,429	98,824	2,143,608	52%	26,976	27%
2005	3,985,039	95,541	2,060,653	52%	26,101	27%
2004	3,887,686	93,307	2,008,247	52%	25,146	27%
2003	3,787,428	90,248	1,884,869	50%	23,957	27%
2002	3,662,830	87,220	1,826,514	50%	22,327	26%

This table shows the total number and capacity of power plants in the edition of the Platts WEPP database in the respective year (Columns 1 and 2). The last four columns show these figures only for power plants that are matched to firms in our sample.

Table 2: Production technologies

Technology	**Run-up time** (hours)		**Ramp-up cost** (€ /MW)		**Fixed cost** (%)		**Fraction** (%)
Biogas	0.25	B	32.22	Z	31.2	Z	<1
Biomass	2.00	B	46.96	Z	61.0	G	<1
Coal	3.00	A	46.96	F	67.9	G	31.7
Hydro	0.08	E	0.00	Z	92.2	G	12.1
Gas	0.25	C	25.45	Z	32.4	G	15.3
Gas comb. cycle	1.50	A	32.22	E	31.2	G	8.5
Geothermal	0.00	Z	0.00	Z	100	G	<1
Lignite	6.00	A	35.75	F	70.0	Z	2.7
Nuclear	40.00	A	132.92	F	87.6	G	11.8
Oil	0.08	D	25.45	F	21.9	D	7.7
Pump storage	0.02	E	0.00	Z	92.2	Z	3.1
Solar	0.00	Z	0.00	Z	100	G	<1
Waste	12.00	B	46.96	Z	67.9	Z	4.5
Wind	0.00	Z	0.00	Z	100	G	2.3

Run-up time is measured in hours and refers to warm starts in the case of thermal power plants. Values are based on Eurelectric's "Flexible Generation: Backing-up Renewables," p. 19, (marked with A), Danish Energy Agency's "Technology Data for Energy Plants" (B), and Swider (2006) (C). The run-up time of oil power plants is based on company Web sites, e.g., life cycle power solutions provider Wärtsilä (D). The values for hydro and pump storage power plants are based on data from Duke Energy, FirstGen, and MWH Global (E). We also have to make some assumptions (marked with Z). The run-up time for solar and wind is zero because these plants are usually not actively dispatched and start to produce electricity as soon as sun or wind are available. Similarly, we assume a run-up time of zero for geothermal power plants.

Ramp-up costs are measured in € /MW and are mainly based on Boldt et al. (2012) (marked with F). We assume that ramp-up costs for gas power plants equal those of oil power plants and that ramp-up costs for geothermal, hydro, pump storage, solar, and wind power plants are zero. For biomass and waste power plants, we assume equal ramp-up costs as for coal plants. For biogas, we assume same cost as for gas cc.

Fixed cost is calculated as fixed cost divided by the sum of fixed and variable cost. Fixed cost includes O&M and financing cost. Variable cost includes fuel cost. Data are mainly obtained from EIA (marked with G) and refer to the estimated cost of electricity for new U.S. generation resources in 2019. We assume that the fixed cost of lignite-fired power plants equal those of coal plants and that variable cost are 10% lower. We also assume that biogas equals gas cc, waste equals coal, and pump storage equals hydro.

Fraction is based on the capacity of all power plants in our sample in 2009.

Table 3: Descriptive statistics II/II: Sample

	Mean	**SD**	**25%**	**50%**	**75%**
Run-up time	2.77	4.48	0.08	1.54	3.00
Ramp-up costs	28.05	19.46	14.95	27.88	40.26
Fixed cost [%]	0.61	0.23	0.41	0.61	0.80
Regional div.	0.22	0.41	0.00	0.00	0.00
Technology conc.	0.67	0.29	0.39	0.64	1.00
Asset lifetime_{total}	37.29	9.06	30.30	36.31	42.83
Asset age	19.89	13.56	7.99	19.75	29.08
Asset salability	7.27	6.73	2.20	4.97	10
Volatility	0.24	0.16	0.14	0.20	0.27
Price	48.35	25.36	27.43	44.00	61.56
Leverage	0.43	0.25	0.23	0.47	0.61
Size [US$ bn]	6.21	12.56	0.21	1.19	5.43
Profitability	0.10	0.10	0.07	0.11	0.14
Tangibility	0.56	0.26	0.40	0.62	0.77
Market-to-book	2.11	2.30	1.05	1.54	2.28

This table shows the mean, standard deviation (SD), and different percentiles for the most relevant variables. A detailed description of all variables can be found in Table A1.

Table 4: Capital structure and production flexibility

Model	1a	1b	1c	2a	2b	2c
Run-up time	**-0.0051*** **	**-0.0049*** **	**-0.0086*** **			
	(-3.49)	**(-3.38)**	**(-3.50)**			
Ramp-up cost				**-0.0010** **	**-0.0010** **	**-0.0017** **
				(-2.36)	**(-2.24)**	**(-2.23)**
Size	0.035***	0.035***	0.099***	0.035***	0.035***	0.098***
	(6.42)	(6.18)	(6.27)	(6.22)	(5.98)	(6.30)
Profitability	-0.24**	-0.20*	-0.26***	-0.23**	-0.18	-0.26***
	(-2.50)	(-1.76)	(-3.37)	(-2.38)	(-1.65)	(-3.41)
Tangibility	0.18***	0.19***	0.10*	0.18***	0.19***	0.10*
	(3.75)	(3.64)	(1.83)	(3.76)	(3.66)	(1.85)
Market-to-book	0.019***	0.020***	0.012***	0.018***	0.019***	0.012***
	(3.68)	(3.61)	(2.99)	(3.67)	(3.60)	(2.98)
Observations	2,242	2,242	2,242	2,242	2,242	2,242
Adjusted R^2	0.38	0.36	0.15	0.37	0.36	0.15
Year fixed effects	yes	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes	yes
Country year FE	no	yes	no	no	yes	no
Firm fixed effects	no	no	yes	no	no	yes

The dependent variable is *Leverage*. Estimation models are pooled OLS (models a and b) or firm fixed effects regressions (c). All independent variables are lagged by one period. *t*-statistics based on Huber/White robust standard errors clustered by firms are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. A detailed description of all variables can be found in Table A1.

Table 5: Power markets

Model	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Sample	Year with market		Market 02 to 10		Europe		Public ownership		Only <10% capa	
Run-up time	**-0.011***** **(-3.99)**		**-0.015***** **(-4.03)**		**-0.016***** **(-4.09)**		**-0.0085***** **(-3.43)**		**-0.012***** **(-4.26)**	
Ramp-up cost		**-0.0015*** **(-1.79)**		**-0.0024*** **(-1.94)**		**-0.0018*** **(-1.72)**		**-0.0017**** **(-2.12)**		**-0.0018**** **(-1.97)**
Size	0.059*** (2.99)	0.057*** (2.87)	0.062** (2.56)	0.060** (2.42)	0.073*** (2.93)	0.071*** (2.73)	0.091*** (5.12)	0.090*** (5.17)	0.10*** (5.60)	0.098*** (5.59)
Profitability	-0.15* (-1.75)	-0.15* (-1.78)	-0.16 (-1.49)	-0.16 (-1.52)	-0.092 (-0.93)	-0.096 (-0.97)	-0.25*** (-3.40)	-0.25*** (-3.49)	-0.25*** (-2.95)	-0.25*** (-2.99)
Tangibility	0.067 (0.83)	0.071 (0.86)	0.018 (0.18)	0.023 (0.23)	0.20* (1.77)	0.20* (1.79)	0.10 (1.54)	0.10 (1.55)	0.13** (2.13)	0.13** (2.15)
Market-to-book	0.010 (1.62)	0.011* (1.68)	0.012* (1.84)	0.013* (1.90)	0.022** (2.10)	0.023** (2.26)	0.011** (2.16)	0.011** (2.18)	0.0078** (2.14)	0.0081** (2.18)
Public ownership							-0.014 (-0.68)	-0.014 (-0.67)		
Observations	1,283	1,283	734	734	433	433	2,034	2,034	1,734	1,734
Adjusted R^2	0.086	0.075	0.10	0.089	0.14	0.12	0.13	0.13	0.15	0.14
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

The dependent variable is *Leverage*. Only firms located in countries for which the existence of a competitive wholesale market for electricity could be verified in the respective year are included in model 1. In model 2, we only include firms located in countries in which such a market exists since 2002. Figure 2 provides an overview on the existence of electricity markets around the world. Model 3 only includes observations from firms located in E.U. countries (plus Switzerland and Norway) with a competitive wholesale market. Additional controls for public ownership are included in model 4. Model 5 restricts the sample to firms which account for less than 10% of the production capacity in a country/state and year. All models are firm fixed effects regressions. All independent variables are lagged by one period. t-statistics based on Huber/White robust standard errors clustered by firms are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%. and 10% level, respectively. A detailed description of all variables can be found in Table A1.

Table 6: Excluding technologies

Model	1	2	3	4	5
Exclusion	Coal	Gas	Nuclear	Oil	Hydro/Wind/Solar
Run-up time	**-0.0100*** **	**-0.0079** **	**-0.011*** **	**-0.0084*** **	**-0.012*** **
	(-2.95)	**(-2.08)**	**(-3.39)**	**(-2.77)**	**(-3.35)**
Size	0.071***	0.088***	0.080***	0.064**	0.083***
	(3.03)	(3.90)	(4.42)	(2.46)	(2.82)
Profitability	-0.22**	-0.23**	-0.30***	-0.14	-0.44**
	(-2.00)	(-2.40)	(-3.25)	(-1.26)	(-2.06)
Tangibility	0.14*	0.28***	0.15**	0.21**	0.089
	(1.70)	(2.89)	(2.35)	(2.27)	(0.99)
Market-to-book	0.0064	0.0084**	0.0064**	0.0037	0.0029
	(1.50)	(2.35)	(2.09)	(0.73)	(0.46)
Observations	935	789	1,548	857	604
Adjusted R^2	0.085	0.12	0.12	0.092	0.17
Year fixed effects	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes

The dependent variable is *Leverage*. Firms owning any power plant with the respective technology are excluded. For example, only firms that do not own coal-fired power plants are included in model 1. Estimation models are firm fixed effects regressions. All independent variables are lagged by one period. *t*-statistics based on Huber/White robust standard errors clustered by firms are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%. and 10% level, respectively. Results for ramp-up cost are presented in Table A2. A detailed description of all variables can be found in Table A1.

Table 7: Measuring flexibility

Model	1a	1b	2a	2b	2c	2d	3a	3b	3c
	Age adjustment		Cost-based measures				Cash-flow-based measure		
Run-up time	**-0.0088*** **		**-0.0092*** **		**-0.0087*** **			**-0.0051*** **	
	(-3.59)		**(-3.19)**		**(-3.56)**			**(-2.81)**	
Ramp-up cost		**-0.0017** **		**-0.0028*** **		**-0.0025*** **			**-0.0014** **
		(-2.42)		**(-2.78)**		**(-2.97)**			**(-2.36)**
Operating cost			-0.040	-0.037					
			(-0.67)	(-0.61)					
Fix cost [%]					-0.021	-0.11**			
					(-0.54)	(-2.40)			
$abs[ln(\epsilon)]$							-0.0094	0.0056	0.0054
							(-0.94)	(0.34)	(0.32)
Size	0.099***	0.098***	0.11***	0.10***	0.100***	0.099***	0.036***	0.029***	0.031***
	(6.27)	(6.29)	(5.21)	(5.59)	(6.29)	(6.37)	(8.06)	(3.68)	(3.93)
Profitability	-0.26***	-0.26***	-0.26***	-0.26***	-0.26***	-0.26***	-0.47***	-0.44***	-0.43***
	(-3.37)	(-3.40)	(-3.03)	(-3.13)	(-3.36)	(-3.39)	(-4.08)	(-3.79)	(-3.66)
Tangibility	0.10*	0.10*	0.089	0.088	0.10*	0.10*	0.15***	0.097	0.11
	(1.83)	(1.84)	(1.54)	(1.56)	(1.83)	(1.83)	(3.49)	(1.40)	(1.55)
Market-to-book	0.012***	0.012***	0.013***	0.013***	0.012***	0.012***	0.016***	0.015	0.015
	(2.99)	(2.99)	(2.66)	(2.64)	(2.99)	(3.01)	(2.74)	(1.52)	(1.49)
Observations	2,242	2,242	1,519	1,519	2,242	2,242	2,663	1,097	1,097
Adjusted R^2	0.15	0.15	0.16	0.17	0.15	0.15	0.40	0.35	0.35
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes	no	no	no

The dependent variable is *Leverage*. The values for run-up time and ramp-up cost are adjusted for the age of the power plants in model 1. We additionally control for cost-based measures in model 2. In model 3, we control for $abs[ln(\epsilon)]$ as cash-flow-based measure of operating flexibility. Estimation models are firm fixed effects regressions in all models, except 4, where we apply pooled OLS regression. All independent variables are lagged by one period. T-statistics based on Huber/White robust standard errors clustered by firms are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. A detailed description of all variables can be found in Table A1.

Table 8: Flexibility values before deregulation and privatization as instruments

Model	1a	1b	2a	2b	3a	3b	4a	4b
Sample		full				Europe		
Run-up time$_{1995}$	0.91***				0.99***			
	(32.0)				(21.7)			
Run-up time$_{\mathbf{instr.}}$		**-0.0065*** **				**-0.014*** **		
		(-3.90)				**(-3.05)**		
Ramp-up cost$_{1995}$			0.85***				0.95***	
			(31.8)				(17.2)	
Ramp-up cost$_{\mathbf{instr.}}$				**-0.0013** **				**-0.0037** **
				(-2.05)				**(-2.09)**
Size	0.15**	0.038***	0.65*	0.036***	0.098	0.045**	0.31	0.049***
	(2.21)	(4.96)	(1.87)	(4.79)	(0.57)	(2.35)	(0.48)	(2.73)
Profitability	-0.27	-0.21*	1.16	-0.20*	-1.64	-0.25	-4.36	-0.18
	(-0.32)	(-1.94)	(0.27)	(-1.84)	(-1.06)	(-1.64)	(-0.92)	(-1.30)
Tangibility	0.32	0.12*	-3.61	0.13**	1.47	0.19	4.41	0.24
	(0.68)	(1.92)	(-1.48)	(2.06)	(1.44)	(1.12)	(1.17)	(1.45)
Market-to-book	0.0059	0.022***	-0.23	0.021***	0.065	-0.023	0.33	-0.023
	(0.16)	(3.52)	(-0.85)	(3.50)	(0.49)	(-1.50)	(0.67)	(-1.59)
Observations	1,505	1,505	1,505	1,505	177	177	177	177
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
K-P rk Wald F statistic	1,024		1,014		471		1,106	

This table shows IV regression with values as of 1995 as instruments for the flexibility measures. In models a (b), the flexibility measures (*Leverage*) are the dependent variables. Only firms that are located in European countries that introduced electricity power exchanges between 1995 and 2003 are included in models 3 and 4. Furthermore, these models only include observations after 2004. Independent variables are lagged by one period. *t*-statistics based on Huber/White robust standard errors clustered by firms are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. A detailed description of all variables can be found in Table A1.

Table 9: Coal, gas, and oil reserves as instruments

Model	1a	1b	2a	2b
Coal reserves		1.45		5.58
		(0.75)		(0.85)
Gas reserves		-0.26***		-0.51***
		(-5.63)		(-2.85)
Oil reserves		1.34***		1.46*
		(6.74)		(1.94)
Run-up time$_{\text{instr.}}$	**-0.029*** **			
	(-4.48)			
Ramp-up cost$_{\text{instr.}}$			**-0.014*** **	
			(-2.93)	
Size	0.098***	1.76***	0.13***	6.39***
	(4.79)	(4.16)	(4.35)	(5.41)
Profitability	0.35***	10.3**	0.45**	24.3**
	(3.10)	(2.08)	(2.46)	(2.18)
Tangibility	-0.16	-9.54**	-0.22	-20.7
	(-1.03)	(-2.47)	(-0.82)	(-1.44)
Market-to-book	0.019***	0.32**	0.023***	0.88
	(3.13)	(2.31)	(2.74)	(1.52)
GSP	-0.056	-1.52	-0.14*	-8.16**
	(-1.09)	(-1.10)	(-1.84)	(-1.98)
Unempl. rate	0.0090	-0.27	0.015	0.34
	(0.99)	(-0.77)	(1.15)	(0.32)
Observations	328	328	328	328
Year fixed effects	yes	yes	yes	yes
K-P rk Wald F statistic	97.51		46.08	
Hansen J p-value	0.42		0.72	

Models a(b) show the outcome of a first- (second-) stage IV regression. In models a(b), the flexibility measures (*Leverage*) are the dependent variables. The sample is restricted to U.S. firms located in states with liquid wholesale markets for electricity. Variation in coal, gas, and oil reserves across U.S. states is used as an instrument. Independent variables are lagged by one period in the second-stage regressions. K-P stands for Kleibergen-Paap (see Kleibergen and Paap 2006). t-statistics based on Huber/White robust standard errors clustered by firms and U.S. states are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. A detailed description of all variables can be found in Table A1.

Table 10: Other technology characteristics

Model	1	2a	2b	3a	3b	4a	4b
Run-up time	**-0.0083***** **(-3.45)**	**-0.0086***** **(-3.50)**	**-0.0091***** **(-3.59)**	**-0.0084***** **(-3.44)**	**-0.0096***** **(-3.65)**	**-0.0090***** **(-3.57)**	**-0.0090***** **(-3.54)**
Salability	0.0027 (0.93)						
Regional diversification		0.0086 (0.59)					
Technology concentration			-0.076* (-1.91)				
Asset lifetime$_{remaining}$				0.00058 (0.77)			
Asset lifetime$_{total}$					-0.0014 (-1.40)		
Asset age						-0.00098 (-1.38)	
Age quintile 2							-0.017 (-1.05)
Age quintile 3							-0.026 (-1.21)
Age quintile 4							-0.021 (-0.88)
Age quintile 5							-0.041* (-1.66)
Size	0.096*** (5.59)	0.099*** (6.25)	0.096*** (5.99)	0.099*** (6.28)	0.099*** (6.25)	0.098*** (6.18)	0.098*** (6.21)
Profitability	-0.25*** (-3.35)	-0.26*** (-3.37)	-0.25*** (-3.32)	-0.26*** (-3.33)	-0.26*** (-3.37)	-0.25*** (-3.28)	-0.25*** (-3.25)
Tangibility	0.10* (1.89)	0.10* (1.85)	0.10* (1.82)	0.10* (1.84)	0.098* (1.78)	0.100* (1.80)	0.10* (1.86)
Market-to-book	0.012*** (2.81)	0.012*** (2.99)	0.012*** (2.94)	0.012*** (2.98)	0.012*** (3.02)	0.012*** (2.97)	0.012*** (2.99)
Observations	2,242	2,242	2,242	2,242	2,242	2,222	2,222
Adjusted R^2	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Year fixed effects	yes	yes	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes	yes

The dependent variable is *Leverage*. Estimation models are firm fixed effects regressions. All independent variables are lagged by one period. *t*-statistics based on Huber/White robust standard errors clustered by firms are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. Results for ramp-up cost are presented in Table A5. A detailed description of all variables can be found in Table A1.

Table 11: Electricity price and recapitalization cost

Model	1a	1b	2a	2b	3a	3b
Run-up time (RuT)	-0.014***		-0.013**		-0.014***	
	(-3.18)		(-2.56)		(-4.93)	
Ramp-up cost (RaC)		-0.0031**		-0.0034**		-0.0023***
		(-2.22)		(-2.40)		(-3.22)
Volatility	0.042	0.053				
	(0.51)	(0.80)				
RuT/RaC x Vol	**-0.023****	**-0.0053****				
	(-2.36)	**(-2.26)**				
Δ Cost_price			-0.0075	-0.013*		
			(-1.14)	(-1.83)		
RuT/RaC x Δ cost_price			**0.0044*****	**0.0013*****		
			(5.08)	**(4.77)**		
RuT/RaC x Nonzero$_c$					**0.023*****	**0.0093*****
					(4.60)	**(3.30)**
Price	0.00057	0.00054	0.00055	0.00060		
	(1.26)	(1.19)	(1.21)	(1.30)		
Price x RuT/RaC	-0.000044	-0.000019	-0.00015*	-0.000048		
	(-0.59)	(-0.76)	(-1.76)	(-1.67)		
Size	0.045*	0.042	0.046*	0.041	0.061**	0.057**
	(1.84)	(1.70)	(1.84)	(1.57)	(2.56)	(2.34)
Profitability	-0.057	-0.060	-0.064	-0.064	-0.097	-0.098
	(-0.39)	(-0.42)	(-0.45)	(-0.46)	(-0.78)	(-0.79)
Tangibility	0.16	0.15	0.17	0.17	0.12	0.12
	(1.20)	(1.18)	(1.22)	(1.29)	(0.91)	(0.90)
Market-to-book	0.0055	0.0068	0.0064	0.0068	0.0060	0.0063
	(0.80)	(1.03)	(0.94)	(0.99)	(1.25)	(1.37)
Observations	717	717	717	717	706	706
Adjusted R^2	0.096	0.100	0.10	0.10	0.13	0.12
Year fixed effects	yes	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes

The dependent variable is *Leverage*. Estimation models are firm fixed effects regressions. Interacted variables are centered. RuT stands for run-up time; RaC stands for ramp-up cost. In models a(b), we interact RuT(RaC). Volatility of hourly power prices, Δcost/price, that is, the ln of the absolute difference between variable cost and power price, and nonzero are interacted with production flexibility over this time period. All other independent variables are lagged by one period. In model 3, we only include firms located in countries in which such a market exists since 2002. *t*-statistics based on Huber/White robust standard errors clustered by electricity markets are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. A detailed description of all variables can be found in Table A1.

Table 12: Tax rates

Model	1a	1b	2a	2b	3a	3b
	all		ROA < $Median_{csy}$		ROA > $Median_{csy}$	
Run-up time (RuT)	-0.0089***		-0.010***		-0.0023	
	(-2.98)		(-2.76)		(-0.60)	
Ramp-up cost (RaC)		-0.0018**		-0.0012		-0.0015
		(-2.13)		(-1.07)		(-1.43)
Tax $rate_{csy}^{ETR}$	0.044	0.032	0.14	0.14	0.020	0.0077
	(1.09)	(0.80)	(1.34)	(1.40)	(0.28)	(0.12)
RuT x Tax $rate_{csy}^{ETR}$	**-0.012**		**0.00065**		**-0.023****	
	(-1.39)		**(0.032)**		**(-2.60)**	
RaC x Tax $rate_{csy}^{ETR}$		**-0.0048*****		**0.0015**		**-0.0092*****
		(-2.80)		**(0.41)**		**(-3.53)**
Size	0.100***	0.099***	0.11***	0.11***	0.071***	0.073***
	(6.18)	(6.16)	(8.63)	(8.60)	(2.77)	(2.84)
Profitability	-0.25***	-0.25***	-0.19**	-0.20**	-0.22	-0.23
	(-2.86)	(-2.95)	(-2.05)	(-2.07)	(-1.38)	(-1.44)
Tangibility	0.11*	0.11*	0.23***	0.24***	0.054	0.046
	(1.73)	(1.73)	(3.37)	(3.45)	(0.60)	(0.51)
Market-to-book	0.012***	0.012***	0.015**	0.016**	-0.00010	0.00061
	(2.67)	(2.75)	(2.40)	(2.36)	(-0.034)	(0.21)
Observations	2,219	2,219	897	897	898	898
Adjusted R^2	0.15	0.15	0.23	0.22	0.092	0.10
Year fixed effects	yes	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes

The dependent variable is *Leverage*. Tax $rate_{csy}^{ETR}$ is the median effective tax rate in a country/state/year. Estimation models are firm fixed effects regressions. The sample split is based on the country/state/year specific median of ROA. The subsamples do not sum to the total sample as median observations are not considered. Interacted variables are centered. All other independent variables are lagged by one period. *t*-statistics based on Huber/White robust standard errors clustered by electricity markets are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. A detailed description of all variables can be found in Table A1.

Table 13: Distress risk: Staggered deregulation across U.S. states

Model	1a	1b	2a	2b
Sample period	2002 to 2009		1995 to 2009	
Run-up time	0.0015			
	(0.61)			
Ramp-up cost		0.00040		
		(0.60)		
RuT/RaC x deregulation$_{sy}$	**-0.0051*** **	**-0.00088**		
	(-3.20)	**(-1.21)**		
RuT/RaC$_{1995}$ x deregulation$_{sy}$			**-0.0056*** **	**-0.0017** **
			(-3.02)	**(-2.22)**
Size	0.017	0.016	0.051**	0.050*
	(1.12)	(1.08)	(2.05)	(1.98)
Profitability	-0.17**	-0.18**	-0.27*	-0.27*
	(-2.51)	(-2.52)	(-1.96)	(-1.93)
Tangibility	-0.14*	-0.14*	0.012	0.014
	(-1.81)	(-1.85)	(0.16)	(0.18)
Market-to-book	0.0078***	0.0077***	0.010***	0.0097***
	(4.17)	(4.22)	(4.13)	(3.99)
Observations	530	530	920	920
Adjusted R^2	0.21	0.20	0.29	0.29
Year fixed effects	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes

The dependent variable is *Leverage*. Estimation models are firm fixed effects regressions. All independent variables are lagged by one period. The sample is restricted to U.S. firms. Deregulation$_{sy}$ equals one for U.S. states and years with electricity retail choice. The sample period in model 1 is 2002 to 2009 and 1995 to 2009 in model 2. RuT$_{1995}$ and RaC$_{1995}$ refer to the production flexibility values as of 1995. The coefficients for time-constant RuT$_{1995}$ and RaC$_{1995}$ are omitted in firm fixed effects regressions. *t*-statistics based on Huber/White robust standard errors clustered by firms are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. A detailed description of all variables can be found in Table A1.

Table 14: Distress risk: Electricity markets

Model	1a	1b	1c	2a	2b	2c	3a	3b	3c
		all			ROA < median_{my}			ROA > median_{my}	
Run-up time (RuT)	-0.0076	-0.0094**	-0.013**	-0.0033	-0.0035	-0.014**	-0.015**	-0.015**	-0.027***
	(-1.21)	(-2.35)	(-2.77)	(-0.37)	(-0.27)	(-2.65)	(-2.17)	(-2.34)	(-4.39)
Herfindahl index $(\text{HHI})_{my}$	-0.044			0.18			-0.15		
	(-0.48)			(1.21)			(-1.27)		
RuT x HHI_{my}	**0.037*** **			**0.081*** **			**0.014**		
	(3.23)			**(3.39)**			**(0.92)**		
Equity vol_{my}		0.028			0.043			0.029	
		(0.91)			(0.62)			(0.84)	
RuT x Equity vol_{my}		**-0.0053***			**-0.0075**			**-0.0035**	
		(-1.82)			**(-0.86)**			**(-1.14)**	
Hedging_{my}			-0.075*			-0.10*			-0.070
			(-1.90)			(-1.92)			(-1.26)
RuT x Hedging_{my}			**0.011***			**0.012*** **			**-0.000055**
			(1.90)			**(2.92)**			**(-0.018)**
Size	0.051***	0.047*	0.093**	0.067**	0.037	0.13**	0.042*	0.084**	0.099***
	(2.84)	(1.92)	(2.39)	(2.46)	(1.23)	(2.26)	(1.90)	(2.80)	(3.83)
Profitability	-0.11	-0.19*	-0.12	-0.15	-0.27	-0.19*	-0.043	-0.38	-0.041
	(-0.86)	(-1.81)	(-1.22)	(-1.28)	(-1.61)	(-2.01)	(-0.21)	(-1.56)	(-0.22)
Tangibility	0.14	0.17	0.15	0.14	0.16	-0.0076	-0.0094	0.10	0.27*
	(1.29)	(1.08)	(1.02)	(0.89)	(0.88)	(-0.047)	(-0.10)	(0.79)	(1.93)
Market-to-book	0.0069	0.0072***	0.010**	0.010	0.013*	0.018***	-0.0048	-0.0016	0.00028
	(1.67)	(3.61)	(2.89)	(1.38)	(1.90)	(3.18)	(-1.23)	(-0.29)	(0.054)
Observations	907	647	485	404	298	221	404	298	221
Adjusted R^2	0.099	0.096	0.16	0.15	0.14	0.32	0.090	0.11	0.26
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes

The dependent variable is *Leverage*. Estimation models are firm fixed effects regressions. The sample split is based on the market/year-specific median of ROA. The subsamples do not sum to the total sample as median observations are not considered. Interacted variables are centered. The Herfindahl index HHI, that is, the concentration of firms in a power market/year, the equity volatility, that is, the ln of the average standard deviation of (other) firms' equity returns in the same power market and year, and hedging, that is, the average fraction of firms hedging electricity in a market/year, are interacted with production flexibility over this time period. All other independent variables are lagged by one period. *t*-statistics based on Huber/White robust standard errors clustered by electricity markets are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. Results for ramp-up cost are presented in Table A8. A detailed description of all variables can be found in Table A1.

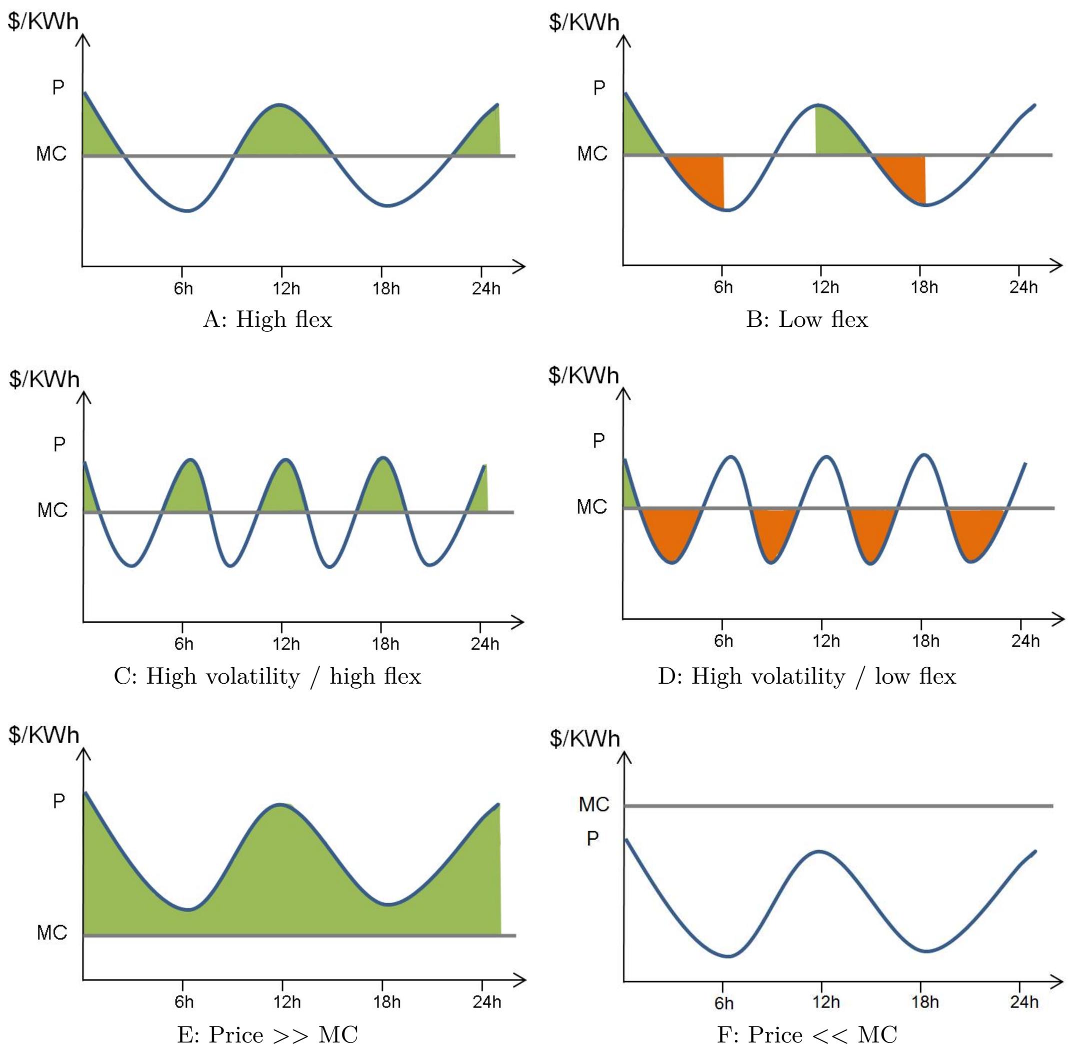


Figure 1: Electricity production and production flexibility.
This figure shows how firms' actual electricity production depends on the power price and their production flexibility, that is, run-up time. We assume an exemplary stochastic electricity price P over a 24-hour period (blue line) and marginal cost (MC; gray line) of electricity production. Whenever P>MC (P<MC), the firm decides to start (stop) production. Firms with high production flexibility (i.e., low run-up time) can start and stop production without delay. For firms with low production flexibility (i.e., high run-up time), there is a three-hour delay between the decision to start/stop production and actual start/stop. Situations in which a surplus (loss) is generated due to electricity production are green (orange).

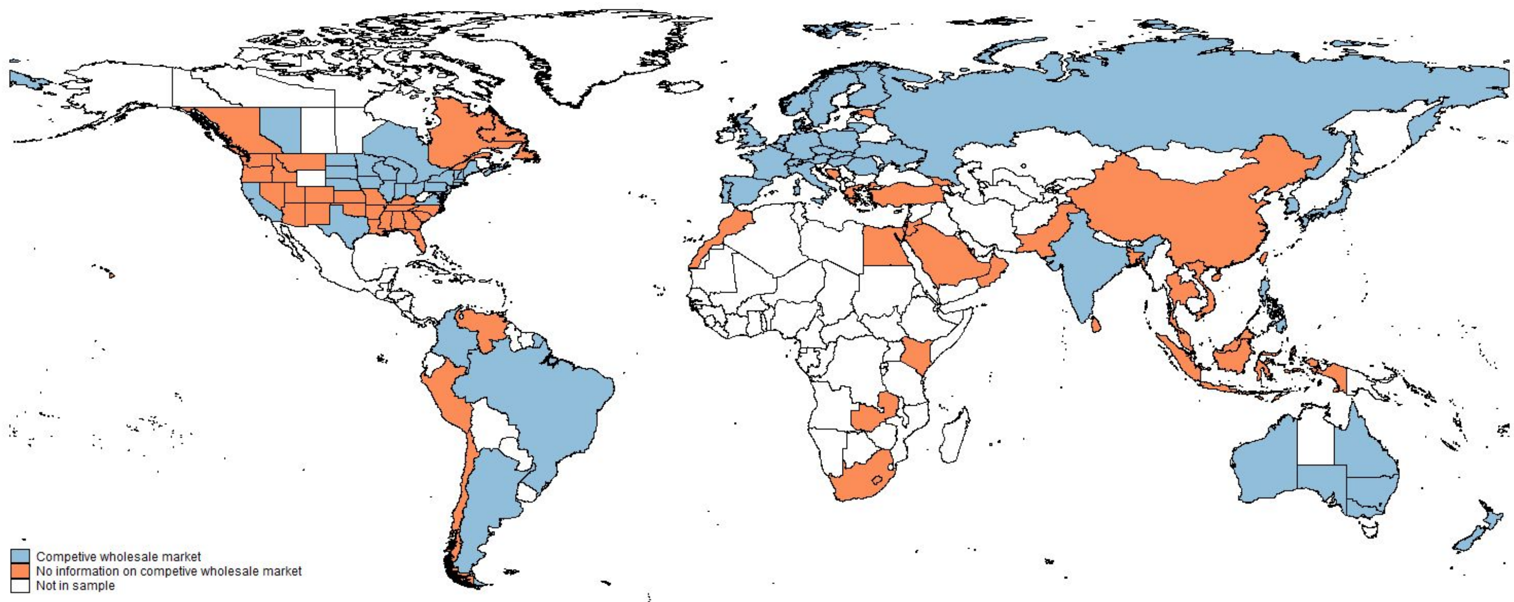
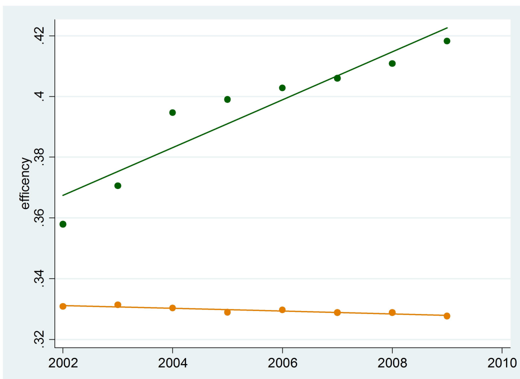
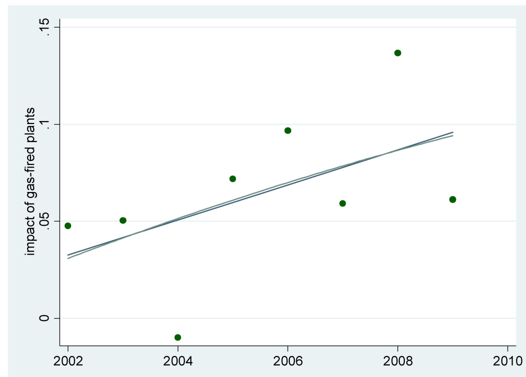


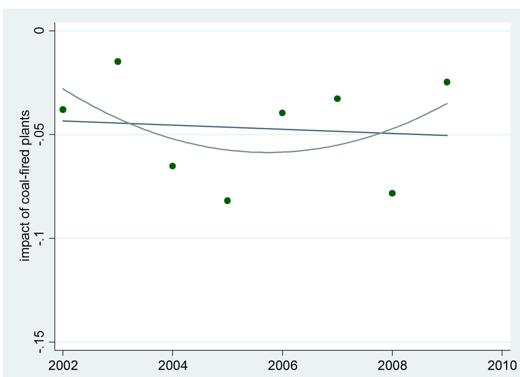
Figure 2: Competitive wholesale markets for electricity (in at least one sample year)



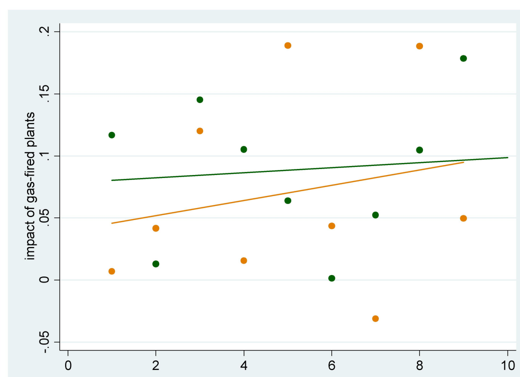
A: Technology efficiency



B: Gas-fired plants



C: Coal-fired plants



D: Gas / electricty price deciles

Figure 3: Evolution of gas-fired power plants.
This figure shows how the impact of gas and coal-fired power plants on financial leverage changed over time. The development of the average efficiency of gas-fired plants (green) and coal-fired plants (orange) over time based on EIA (2012), p. 166, is shown in (a). The estimated impact of both production technologies on financial leverage over time is visualized in (b) and (c). The light and dark blue lines are linear and quadratic fits. The estimated impact of gas-fired plants on leverage for different deciles of gas (green) and electricity prices (orange) is investigated in (d). The slopes of the fitted lines in (c) and (d) are not statistically different from zero, whereas the slope of the linear fit in (b) is positive and statistically different from (c) and (d).

Appendix

Appendix A. Production Flexibility Measures Example

This section provides an example of how to calculate the main variables. For the following example, we assume that we matched the following power plants to the energy utility X in 2008:

Plant	**Capa**	**Technology**	**COD**	**Run-up**	**Ramp-up**
Name	MW	n/a	year (y)	hours (h)	€/MW
A	6	wind	2006	0	0
B	100	biomass	1990	2.00	46.96
C	2,000	nuclear	1980	40.00	132.92
D	1,000	gas	1975	0.25	32.22
E	1,500	gas	1990	0.25	32.22

Run-up time is defined as the average run-up time of all power plants in the company's portfolio. Each power plant is weighted by its capacity. The run-up time of each power plant is based on its technology and defined in Table 2. Thus, the variable RUN-UP TIME for firm X in 2008 is calculated as follows:

$$\begin{aligned}\text{RUN-UP TIME}_X &= \frac{\sum_{k=1}^{M} \text{Capacity}_k \cdot \text{Run-up time}_k}{\text{Total capacity}} \\ &= \frac{(6 \cdot 0 + 100 \cdot 2 + 2,000 \cdot 40 + (1,000 + 1,500) \cdot 0.25)\text{MW} \cdot h}{(6 + 100 + 2,000 + 1,000 + 1,500)\text{MW}} \\ &= \frac{80,825\text{MW} \cdot h}{4,606\text{MW}} = 17.55h.\end{aligned}$$

Ramp-up costs are calculated in the same way as run-up time. The only difference is that ramp-up costs are used in the above formula instead of run-up times.

$$\begin{aligned}\text{RAMP-UP COSTS}_X &= \frac{\sum_{k=1}^{M} \text{Capacity}_k \cdot \text{Ramp-up costs}_k}{\text{Total capacity}} \\ &= \frac{(6 \cdot 0 + 100 \cdot 46.96 + 2,000 \cdot 132.92 + (1,000 + 1,500) \cdot 32.22) \cdot \frac{\text{MW €}}{MW}}{(6 + 100 + 2,000 + 1,000 + 1,500)\text{MW}} \\ &= \frac{351,086\text{MW} \cdot €/MW}{4,606\text{MW}} = 76.22€/\text{MW}\end{aligned}$$

Appendix tables

Table A1: Definition of variables

Variable	Description
Main variables	
Run-up time	Capacity-weighted average time which is necessary to start-up a power plant in hours. Based on the production technologies of the firms' power plants. Source: Our own calculations based on the WEPP database.
Ramp-up cost	Capacity-weighted average cost for a hot start of power plant in €/MW. Based on the production technologies of the firms' power plants. Source: Our own calculations based on the WEPP database.
Leverage	Total debt [wc03255] / (Total debt [wc03255] + book value of common equity [wc03501]). Source: Worldscope.
Control variables	
Size	Natural logarithm of total assets [wc029999] in U.S. dollar.
Profitability	Earnings before interest, taxes, depreciations, and amortizations (EBITDA) [wc18198] / total assets [wc02999].
Tangibility	Property, plant and equipment [wc02501] / total assets [wc02999].
Market-to-book	Market capitalization [wc08001] / book value of common equity [wc03501].
Market/country characteristics	
Volatility	Standard deviation of log returns of hourly electricity prices during the firm's fiscal year. Source: Calculations based on hourly electricity prices.
Δcost/price	Natural logarithm of the absolute difference between the mean electricity price and the firm's average variable cost for electricity production. Source: Calculations based on hourly electricity prices and EIA data.
Price	Mean of the hourly electricity spot price in USD/MWh over the firm's fiscal year. Source: Calculations based on hourly electricity prices.
Non-zero$_c$	Fraction of months in a country in which firms issued or repurchased shares. Source: McLean et al. (2009).
ln(SEO)$_c$	Natural logarithm of the number of SEOs of nonfinancial firms in a specific country during the sample period. Source: Calculations based on Thomson-Reuters.
Access$_c$	Survey-based index measuring how easy it is for firms to issue equity. Source: McLean et al. (2012) based on Schwab et al. (1999).
Protection$_c$	Principal component of the indices disclosure requirements, liability standards, and antidirector rights. Source: McLean et al. (2012) based on La-Porta et al. (2006).
Tax rate$_{csy}^{ETR}$	Median effective tax rate in a country/state and year. Effective tax rate is calculated as income taxes [wc01451] divided by pretax income [wc01401]. It is winsorized at [0,1].
Tax rate$_{cy}^{NOM}$	Nominal corporate tax rate in a country/year. We use the yearly values from 2006 on; before that, we use the tax rate as in 2006. Source: KPMG.
Deregulation$_{sy}$	Equals one in U.S. states and years with electricity retail choice. Source: Based on EIA data.

Definition of Variables - continued

Variable	Description
HHI_{my}	Herfindahl index for competition in a power market. Calculated as the sum of the squared capacity fractions of all sample firms in a specific power market and year. Source: Calculations based on the WEPP database.
Equity volatility$_{mkt}$	Natural logarithm of the average standard deviation of equity returns of all other firms in the same power market and year. Calculated if at least three observations are available. Source: Datastream.
Hedging$_{my}$	Fraction of other firms in the same power market (and year) which engage in power hedging. Calculated if at least three observations are available. Source: Hand-collected.
Other plant-related variables	
Operating cost	Costs of goods sold [wc01051] plus selling, general, and administrative expenses [wc01101] divided by total assets. Source: Worldscope.
Fixed cost [%]	Total fixed cost, that is, fixed O&M cost and capital cost, divided by total fixed cost plus total variable cost. Source: Our own calculations based on EIA data.
Variable cost	Average variable cost for electricity production in USD/MWh. Source: Our own calculations based on EIA data.
Salability	Capacity-weighted average salability of plants. Plant-specific salability is defined as the number of firms in the same country/state and year which operate plants with the same technology. Source: Our own calculations based on the WEPP database.
Regional diversificat.	Equals one if company has power plants in more than one country. Source: Our own calculations based on the WEPP database.
Technology concentr.	Herfindahl index which measures concentration of production technologies. Value of one means that the firm only has one single production technology. Source: Our own calculations based on the WEPP database.
Asset lifetime	Capacity-weighted average expected lifetime of the firm's assets in the respective year in years. Calculated as total and remaining lifetime. Source: Our own calculations based on the WEPP database.
Asset age	Capacity-weighted average age of the firm's assets in the respective year in years. Source: Our own calculations based on the WEPP database.
Misc	
Public ownership	Dummy variable which equals one if the state or a federal entity are among the three largest shareholders in a specific year and zero otherwise. Source: Thomson Reuters Global Ownership database.
Market leverage	Total debt [wc03255] / (Total debt [wc03255] + book value of common equity [wc08001])
Long-term book lev.	Long term debt [wc03251] / (Total debt [wc03255] + book value of common equity [wc03501])
$abs[ln(\epsilon)]$	Empirical proxy for volume flexibility (MacKay 2003). Calculation is based on the following estimation for each firm with more than two observations: $ln(cashflow)_t = \alpha + \epsilon\, ln(output)_t + u_t$. Source: Our owwn calculation.
Coal reserves	Recoverable coal reserves at producing mines in 1995. Measured in billion short tons. Source: EIA, Coal Industry Report 1995.

Definition of Variables - continued

Variable	Description
Gas reserves	Dry natural gas proved reserves in 1995. Measured in trillion cubic feet. Source: EIA, U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves 1996 Annual Report.
Oil reserves	Crude oil proved reserves in 1995. Measured in billion barrels of 42 U.S. gallons. Source: EIA, U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves 1996 Annual Report.
GSP	Natural logarithm of the yearly gross state product for U.S. states, in chained 2009 dollars. Source: Bureau of Economic Analysis.
Unemployment rate	Yearly, nonseasonally adjusted average unemployment rate for U.S. states. Source: Bureau of Labor Statistics.

Table A2: Excluding technologies: Ramp-up cost

Model	1	2	3	4	5
Exclusion	Coal	Gas	Nuclear	Oil	Hydro/Wind/Solar
Ramp-up cost	**-0.0015****	**-0.0014***	**-0.0019*****	**-0.0014****	**-0.0033*****
	(-2.06)	**(-1.71)**	**(-3.04)**	**(-1.98)**	**(-3.68)**
Size	0.067***	0.087***	0.077***	0.062**	0.080***
	(2.86)	(3.85)	(4.24)	(2.35)	(2.75)
Profitability	-0.21**	-0.23**	-0.30***	-0.14	-0.44**
	(-1.97)	(-2.38)	(-3.23)	(-1.23)	(-2.07)
Tangibility	0.15*	0.28***	0.15**	0.21**	0.097
	(1.73)	(2.91)	(2.37)	(2.29)	(1.06)
Market-to-book	0.0062	0.0085**	0.0062**	0.0034	0.0030
	(1.45)	(2.38)	(2.05)	(0.66)	(0.46)
Observations	935	789	1,548	857	604
Adjusted R^2	0.082	0.12	0.12	0.090	0.17
Year fixed effects	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes

The dependent variable is *Leverage*. Firms owning power plants with certain technologies are excluded. For example, only firms that do not own coal-fired power plants are included in model 1. Estimation models are firm fixed effects regressions. All independent variables are lagged by one period. t-statistics based on Huber/White robust standard errors clustered by firms are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%. and 10% level, respectively. A detailed description of all variables can be found in Table A1.

Table A3: System-GMM estimation

Model	1a	1b	2a	2b
System-GMM	1-step		2-step	
Run-up time	**-0.011*** **		**-0.0091***	
	(-2.90)		**(-1.88)**	
Ramp-up cost		**-0.0037*** **		**-0.0026***
		(-3.37)		**(-1.87)**
Leverage	0.73***	0.72***	0.72***	0.70***
	(17.6)	(15.0)	(11.8)	(9.91)
Size	0.021***	0.034***	0.019**	0.028**
	(2.63)	(3.33)	(2.00)	(2.06)
Profitability	-0.37**	-0.37**	-0.34**	-0.37**
	(-2.28)	(-2.28)	(-2.12)	(-2.24)
Tangibility	0.056	0.044	-0.013	0.0050
	(0.86)	(0.62)	(-0.19)	(0.062)
Market-to-book	0.012**	0.010**	0.0078	0.0064
	(2.54)	(2.08)	(1.50)	(1.13)
Observations	2,243	2,243	2,243	2,243
Hansen-J p-value	0.36	0.41	0.36	0.41
Year fixed effects	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes

The dependent variable is *Leverage*. All models are system-GMM estimations (Blundell and Bond 1998). Two- to four-period lags of the right-hand-side variables are used as instruments. Values as of 1995 are used as instruments for production flexibility. Robust standard errors are applied in the one-step system-GMM version. As standard errors might be downward biased in the asymptotically more efficient two-step system-GMM version, they are corrected for the finite sample bias (Windmeijer 2005). t-statistics are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%. and 10% level, respectively. A detailed description of all variables can be found in Table A1.

Table A4: Leverage definition

Model	1a	1b	2a	2b
	Market leverage		Long-term book leverage	
Run-up time	**-0.0056****		**-0.0079*****	
	(-2.04)		**(-3.43)**	
Ramp-up cost		**-0.0013**		**-0.0017****
		(-1.60)		**(-2.32)**
Size	0.11***	0.10***	0.068***	0.067***
	(6.00)	(6.04)	(5.07)	(5.17)
Profitability	-0.36***	-0.36***	-0.18***	-0.19***
	(-3.97)	(-4.00)	(-3.30)	(-3.38)
Tangibility	0.035	0.035	0.11**	0.11**
	(0.61)	(0.62)	(2.05)	(2.06)
Market-to-book	-0.0029	-0.0028	0.0066*	0.0066**
	(-0.71)	(-0.70)	(1.96)	(1.97)
Observations	2,248	2,248	2,250	2,250
Adjusted R^2	0.27	0.27	0.096	0.095
Year fixed effects	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes

The dependent variable is *Market leverage* in model 1 and *Long-term book leverage* in model 2. Estimation models are firm fixed effects regressions. All independent variables are lagged by one period. t-statistics based on Huber/White robust standard errors clustered by firms are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%. and 10% level, respectively. A detailed description of all variables can be found in Table A1.

Table A5: Other technology characteristics: Ramp-up cost

Model	1	2a	2b	3a	3b	4a	4b
Ramp-up cost	**-0.0017****	**-0.0017****	**-0.0020****	**-0.0016****	**-0.0022****	**-0.0019****	**-0.0019****
	(-2.15)	**(-2.26)**	**(-2.54)**	**(-2.17)**	**(-2.47)**	**(-2.39)**	**(-2.39)**
Salability	0.0029						
	(1.01)						
Regional diversification		0.0095					
		(0.63)					
Technology concentration			-0.085**				
			(-2.03)				
Asset lifetime$_{remaining}$				0.00042			
				(0.54)			
Asset lifetime$_{total}$					-0.0020		
					(-1.59)		
Asset age						-0.0011	
						(-1.44)	
Age quintile 2							-0.014
							(-0.93)
Age quintile 3							-0.023
							(-1.08)
Age quintile 4							-0.020
							(-0.83)
Age quintile 5							-0.041
							(-1.65)
Size	0.094***	0.097***	0.094***	0.098***	0.097***	0.097***	0.097***
	(5.58)	(6.28)	(6.01)	(6.29)	(6.28)	(6.21)	(6.23)
Profitability	-0.26***	-0.26***	-0.25***	-0.26***	-0.26***	-0.26***	-0.25***
	(-3.39)	(-3.42)	(-3.36)	(-3.39)	(-3.43)	(-3.33)	(-3.30)
Tangibility	0.10*	0.10*	0.10*	0.10*	0.098*	0.10*	0.10*
	(1.90)	(1.86)	(1.84)	(1.85)	(1.77)	(1.82)	(1.87)
Market-to-book	0.012***	0.012***	0.012***	0.012***	0.012***	0.012***	0.012***
	(2.80)	(2.99)	(2.93)	(2.98)	(3.02)	(2.96)	(2.99)
Observations	2,242	2,242	2,242	2,242	2,242	2,222	2,222
Adjusted R^2	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Year fixed effects	yes	yes	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes	yes

The dependent variable is *Leverage*. Estimation models are firm fixed effects regressions. All independent variables are lagged by one period. t-statistics based on Huber/White robust standard errors clustered by firms are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%. and 10% level, respectively. A detailed description of all variables can be found in Table A1.

Table A6: Recapitalization cost: Additional measures

Model	1a	1b	2a	2b	3a	3b
Run-up time (RuT)	-0.018***		-0.020***		-0.012***	
	(-5.32)		(-5.76)		(-3.16)	
Ramp-up cost (RaC)		-0.0029**		-0.0033**		-0.0017**
		(-2.74)		(-2.50)		(-2.65)
RuT/RaC x ln(SEO)$_c$	**0.0036**	**0.0014***				
	(1.70)	**(1.91)**				
RuT/RaC x Access$_c$			**0.015*** **	**0.0031***		
			(3.22)	**(1.85)**		
RuT/RaC x Protection$_c$					**0.014*** **	**0.0070*** **
					(3.42)	**(5.47)**
Size	0.059**	0.055**	0.061**	0.057**	0.061**	0.058**
	(2.54)	(2.28)	(2.68)	(2.35)	(2.58)	(2.43)
Profitability	-0.088	-0.089	-0.089	-0.093	-0.094	-0.093
	(-0.72)	(-0.73)	(-0.72)	(-0.77)	(-0.75)	(-0.75)
Tangibility	0.12	0.11	0.10	0.11	0.11	0.11
	(0.97)	(0.91)	(0.83)	(0.83)	(0.88)	(0.87)
Market-to-book	0.0067	0.0071	0.0068	0.0076	0.0065	0.0069
	(1.44)	(1.58)	(1.50)	(1.68)	(1.37)	(1.49)
Observations	727	727	694	694	694	694
Adjusted R^2	0.11	0.10	0.13	0.12	0.13	0.12
Year fixed effects	yes	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes

The dependent variable is *Leverage*. Estimation models are firm fixed effects regressions. Interacted variables are centered. RuT stands for run-up time; RaC stands for ramp-up cost. In models a(b), we interact RuT(RaC). Measures for recapitalization cost are interacted with production flexibility over this time period. All other independent variables are lagged by one period. We only include firms located in countries in which such a market exists since 2002. *t*-statistics based on Huber/White robust standard errors clustered by electricity markets are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%. and 10% level, respectively. A detailed description of all variables can be found in Table A1.

Table A7: Tax rates: Nominal tax rates

Model	1a	1b	2a	2b	3a	3b
	all		ROA < median_{cy}		ROA > median_{cy}	
Run-up time (RuT)	-0.0092***		-0.011***		0.0024	
	(-2.97)		(-2.84)		(0.62)	
Ramp-up cost (RaC)		-0.0017**		-0.0014		-0.00059
		(-2.12)		(-1.24)		(-0.77)
Tax rate_{cy}^{NOM}	-0.55***	-0.53***	-0.54	-0.46	-0.34	-0.36*
	(-3.03)	(-3.09)	(-1.50)	(-1.42)	(-1.60)	(-1.76)
RuT x Tax rate_{cy}^{NOM}	**0.025**		**0.064**		**-0.11*** **	
	(0.69)		**(1.08)**		**(-2.83)**	
RaC x Tax rate_{cy}^{NOM}		**-0.0028**		**0.0080**		**-0.022*** **
		(-0.43)		**(0.89)**		**(-3.75)**
Size	0.097***	0.095***	0.10***	0.10***	0.062***	0.062***
	(5.93)	(5.92)	(7.49)	(7.47)	(2.76)	(2.80)
Profitability	-0.25***	-0.25***	-0.23**	-0.23**	-0.20	-0.19
	(-3.16)	(-3.19)	(-2.60)	(-2.61)	(-1.35)	(-1.31)
Tangibility	0.11*	0.11*	0.19**	0.19**	0.059	0.062
	(1.71)	(1.75)	(2.52)	(2.58)	(0.72)	(0.76)
Market-to-book	0.012***	0.012***	0.017**	0.019**	-0.00041	-0.00059
	(2.69)	(2.68)	(2.47)	(2.49)	(-0.13)	(-0.19)
Observations	2,227	2,227	1,003	1,003	1,003	1,003
Adjusted R^2	0.16	0.16	0.20	0.19	0.10	0.11
Year fixed effects	yes	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes

The dependent variable is *Leverage*. Tax rate_{cy}^{NOM} is the nominal corporate tax rate in a country/year. Estimation models are firm fixed effects regressions. The sample split is based on the country/year-specific median of ROA. The subsamples do not sum up to the total sample as median observations are not considered. Interacted variables are centered. All other independent variables are lagged by one period. t-statistics based on Huber/White robust standard errors clustered by electricity markets are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%. and 10% level, respectively. A detailed description of all variables can be found in Table A1.

Table A8: Distress risk - ramp-up cost: Electricity markets

Model	1a	1b	1c	2a	2b	2c	3a	3b	3c
		all			ROA < median_{my}			ROA > median_{my}	
Ramp-up cost (RaC)	-0.0019	-0.0024**	-0.0043***	-0.0021	-0.00044	-0.0057***	-0.0034*	-0.0027	-0.0036
	(-1.24)	(-2.50)	(-3.25)	(-0.92)	(-0.40)	(-3.32)	(-2.04)	(-1.55)	(-1.46)
Herfindahl index $(\text{HHI})_{my}$	-0.061			0.26*			-0.16		
	(-0.66)			(1.74)			(-1.37)		
RaC x $\textbf{HHI}_{my}$	**0.0065****			**0.014****			**0.0018**		
	(2.42)			**(2.45)**			**(0.48)**		
Equity vol_{my}		0.034			0.050			0.025	
		(1.07)			(0.77)			(0.71)	
RaC x Equity $\textbf{vol}_{my}$		**-0.0017***			**-0.0016**			**-0.0015**	
		(-2.05)			**(-1.07)**			**(-1.26)**	
Hedging_{my}			-0.090**			-0.12**			-0.074
			(-2.14)			(-2.13)			(-1.24)
RaC x $\textbf{Hedging}_{my}$			**0.0059****			**0.0045*****			**0.00044**
			(2.45)			**(3.20)**			**(0.24)**
Size	0.055**	0.060*	0.095**	0.067**	0.035	0.13**	0.036*	0.084**	0.099***
	(2.79)	(1.97)	(2.51)	(2.44)	(1.11)	(2.25)	(1.90)	(2.70)	(3.77)
Profitability	-0.093	-0.18	-0.15	-0.17	-0.27	-0.22**	-0.036	-0.38	-0.027
	(-0.72)	(-1.70)	(-1.47)	(-1.38)	(-1.61)	(-2.45)	(-0.18)	(-1.59)	(-0.17)
Tangibility	0.16	0.20	0.16	0.13	0.15	-0.0014	-0.023	0.095	0.30**
	(1.40)	(1.24)	(1.15)	(0.84)	(0.86)	(-0.0087)	(-0.26)	(0.73)	(2.31)
Market-to-book	0.0086*	0.0089***	0.0099**	0.012	0.012	0.018**	-0.0044	-0.0019	-0.0010
	(2.03)	(3.16)	(2.81)	(1.36)	(1.72)	(2.78)	(-1.17)	(-0.34)	(-0.18)
Observations	908	648	485	404	298	221	404	298	221
Adjusted R^2	0.10	0.11	0.19	0.14	0.14	0.35	0.091	0.11	0.21
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes

The dependent variable is *Leverage*. Estimation models are firm fixed effects regressions. The sample split is based on the market/year-specific median of ROA. The subsamples do not sum to the total sample as median observations are not considered. Interacted variables are centered. The Herfindahl index (HHI), that is, the concentration of firms in a power market/year, the equity volatility, that is, the ln of the average standard deviation of (other) firms' equity returns in the same power market and year, and hedging, that is, the average fraction of firms hedging electricity in a market/year, are interacted with production flexibility over this time period. All other independent variables are lagged by one period. t-statistics based on Huber/White robust standard errors clustered by electricity markets are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%. and 10% level, respectively. A detailed description of all variables can be found in Table A1.

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