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Regulatory Imperfections in the Electricity and Natural Gas Industries: Evidence from the Pricing and Investment Decisions of Single and Multi-Product Electricity Firms

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Regulatory Imperfections in the Electricity and Natural Gas Industries: Evidence from the Pricing and Investment Decisions of Single and Multi-Product Electricity Firms

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Work in Progress — Comments Welcomed

Abstract

Electricity and natural gas markets have traditionally been serviced by one of two market structures. In some markets, electricity and natural gas are sold by a dual-product regulated monopolist, while in other markets, electricity and natural gas are sold by separate single-product regulated monopolies. This paper analyzes the relative pricing and investment decisions of electricity firms operating in the two market structures. The unique relationship between these two products, namely that electricty and natural gas are substitutes in consumption and natural gas is an input into the generation of electricity, imply that the relative incentives of single and dual-product firms are likely to differ. However because these firms are regulated, these differing incentives would only be acted upon if regulation is imperfect in some way. In this paper, I analyze these issues. In particular, I estimate equilibrium pricing and investment equations that capture the relative incentives of single and dual-product electricity firms. The results imply that both electricity prices and reliance on natural gas generation are higher in a dual-product setting, both suggestive that regulators respond to the relative incentives of electricity and natural gas firms.

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1 Introduction

United States electricity and natural gas retail markets have developed into two distinct structures. In some jurisdictions, electricity and natural gas are supplied by a dual-product monopolist, while in others, electricity and natural gas are offered by two single-product monopolists. The unique relationship between these two products, namely that electricity and natural gas are substitutes in consumption and natural gas is also an input into the generation of electricity, raise a number of interesting questions with respect to the relative pricing and investment decisions of the two market structures.

It is a standard result that an unregulated dual-product monopolist selling substitutes, will set higher prices relative to those of two single-product monopolists. However, natural gas is also an input to the generation of electricity, therefore if the market for natural gas is imperfect a vertically integrated dual-product firm will face the marginal *cost* of natural gas, while a single-product electricity firm faces the marginal *price* of natural gas set by the natural gas firm. The cost savings from vertical integration may act to mitigate the incentive for the dual-product firm to set higher prices. This effect is compounded by the incentive of the single-product natural gas firm to keep natural gas prices high in order to raise the costs of its rival – the single-product electricity firm. However, electricity firms have a choice as to the input mix when generating electricity. Therefore, one strategy a single-product electricity firm can take in order to minimize the impact of the increase in costs is to rely less on natural gas generation than a dual-product monopolist would.

However, these industries are tightly regulated. If this regulation is perfect (meaning prices are set to marginal cost) then we would not expect to observe systematic price differences under the two market structures.

This paper analyzes whether these differing incentives holds true in a regulated environment. In particular, the paper tests whether the differences in the market structures for electricity and natural gas lead to differences in equilibrium prices for electricity and whether single-product electricity firms substitute away from natural gas generation as a means of insulating themselves from the single-product natural gas firm's incentive to raise its rivals costs. To answer these questions, the paper employs an unbalanced panel data set of electricity firm's pricing and investment behavior. The results suggest that after controlling for cost and demand differences the rates of dual-product firms are higher than those of single-product firms, and after controlling for the relative costs of generation technologies, dual-product firms rely more heavily on natural gas generators than their single-product firm counterparts. These results would imply that regulation of both electricity and natural gas firms is imperfect.

The remainder of the paper is organized as follows. Section 2 provides a background of the electricity and natural gas industries. Section 3 discusses the related literature. In section 4 a simple theoretical model is developed that captures the underlying pricing incentives of the single and dual-product firms. Section 5 outlines the empirical model used and discusses the results. Section 6 is reserved for concluding remarks.

2 Background

2.1 Electricity Industry

Until very recently, the market structure of the electricity industry within the United States was rather homogenous across states. Even with recent regulatory restructuring in a number of states, the vast majority of electricity companies remain regulated. In the traditional structure, electricity firms are vertically integrated, across the four major components of electricity production: electricity generation, distribution to different portions of the firm's service area, transmission to its consumers, and billing.

The generation of electricity takes place using a variety of technologies – all of which use some form of energy to spin a turbine, which in turn produces electricity. The two most common technologies (accounting for 87 percent of the capacity in the data used for this study[1]) are steam and hydroelectric. Other examples are wind and geothermal generation. Hydroelectric generators use the energy of water flowing down a river, or trapped in a reservoir, to turn a turbine. Steam generators, in contrast, burn some fuel (except for nuclear generators – which use the heat created from nuclear reactions) in order to heat a water boiler which in turn produces steam. The force of the steam turns a turbine. Steam generators can use different fuels. In particular, coal, natural gas, oil, jet fuel and nuclear fuels are used.

Hydroelectric generation clearly dominates steam generation for two reasons. First, because typically only one generating unit is placed on a particular water source, and the owner of the generator has the property rights to this water, given a water supply the marginal *operating* cost of hydroelectric resources is near zero.[2] Therefore, a firm's decision to operate a plant is dependent

[1] This figure includes coal burning, oil burning, natural gas burning, and nuclear units, and does not include combustion and combined turbine generation.

[2] On any given water source there are usually limitations on the use of the water source. For example, minimum

on the intertemporal shadow values of water use – since the water source maybe scarce. However, if water resources are sufficiently abundant, even the shadow value is near zero. Second, unlike steam plants, hydroelectric plants are much more flexible in operating the plant. This is the case since it takes a considerable amount of time to heat a steam plant's boiler to the necessary temperature, a steam plant that is not currently generating electricity may take a number of days before it is functional.

Despite this dominance, the use of hydroelectric generation is largely limited by geographical location and conservation concerns. Hydroelectric resources obviously require a large enough river system. Therefore, many locations are unable to use hydroelectric resources, and must instead rely on other technologies.

Other than hydroelectric generation, no one technology clearly dominates the others. This is true for both geographical reasons, since the relative prices of fuels may differ across the country, and also because of the nature of electricity demand. The demand for electricity varies considerably across a given day and a particular year. Because of this, firms carry a portfolio of generation technologies, which vary in the level of fixed costs and marginal costs of operation. For example, nuclear units are high fixed cost/low marginal cost units which run almost continuously, whereas oil burning plants are low fixed cost/high marginal cost units that generate electricity only during peak time periods. Between these technologies rest coal and natural gas burning units.

Regulation of electricity firms has a long history dating back to the late 1800s. The regulatory structure a firm operates under depends on the ownership structure of the firms. The most common ownership structure is an investor owned utility (IOU), where the firm is privately held by shareholders. In some areas, however, municipality owned companies exist, where the firm is owned and operated by the locality. Still in other areas, federally owned firms operate.

The majority of regulation takes place at the state level, although the Federal Energy Regulatory Commission (the FERC) oversees some aspects of the industry – mostly interstate trading. Rate-of-return regulation remains the most common form of regulation. In such a system, rate hearings are periodically held where the regulators calculate the value of capital the firm employees and sets rates such that the firm earns some desired rate of return on this capital. However, a number of authors have commented, on the lax-nature of the regulators.[3] Specifically, the regulatory constraints appears to only bind during periods of cost increases. This implies that while the rates

flow constraints are set so as to assure the health of the downstream fish, and maximum flow constraints are set so as to limit the possibility of floods.

[3]The most notable of these studies is Joskow (1974).

of IOUs may be held below the profit maximizing level, they will, in some degree, mirror the relative incentives of firms.

2.2 The Natural Gas Industry

Although the use of gas as an energy source dates back to the 19th century, large-scale harnessing of *natural* gas as a energy source did not take place until the 1950s. Prior to the use of natural gas, synthetic gas – made from such sources as coal – was used. Because of the similar infrastructure in distributing synthetic gas and natural gas, natural gas distribution was a natural extension of existing gas firms, and many of the distribution companies today have their roots in this time period.

The current structure of the industry is comprised of three sectors; "producers", pipelines and distributors. "Producers" of natural gas locate natural gas reserves under the ground and sell it at what is known as the wellhead – these transactions are known as *first sales*. Pipeline companies purchase the gas at the wellhead and ship the gas through pipelines to a distribution company – these are often interstate shipments. The distribution company is the retail arm of the industry (the IOUs in the case of dual-product firms), selling natural gas to end-use consumers – such as industrial, commercial and residential consumers. The firms are known as the local distribution companies (LDCs). Unlike the electricity industry, although vertical integration does exist, it does not dominate the industry.

The current regulatory structure varies by the sector. The 1978 Natural Gas Policy Act largely deregulated the first sales of natural gas, and this sector is largely considered competitive. Pipelines and transmission firms buy natural gas at the wellhead for shipment elsewhere. The interstate transport of natural gas to the LDCs is regulated by the FERC. Regulated utilities purchase natural gas at the well-head and then distributed it to end-users.

The regulatory structure of the LDCs is much like that of the electricity industry. Indeed, the regulatory institutions are, more often than not, the same as those for electricity firms, i.e. the state public utility commissions. Rates for distribution and transmission are set using a cost-based method, where the rates are designed for the firm to earn a specific rate-of-return on capital.

2.3 Electricity and Natural Gas Integration

The integration of electricity and natural gas firms dates back to the beginning of the electricity industry in the late 1800s. Initially electricity was used for little more than lighting streets and competed against the existing synthetic gas lighting systems. Many of these competing companies later merged.

However, not all areas integrated. United States electricity and natural gas retail markets have developed into two distinct structures. In some jurisdictions, electricity and natural gas are supplied by a dual-product monopolist, while in others, electricity and natural gas are offered by two single-product monopolists. In fact, both market structures may exist in the same state. For example in northern California, Pacific Gas and Electric sells both electricity and natural gas, while in southern California electricity is sold by Southern California Edison, while natural gas is sold by Southern California Gas Corporation.

The distribution of market structures is somewhat of an economic puzzle, as it does not seem to follow a specific pattern. California is an excellent example. One might expect that the benefits from integration would be highest in areas where there are lower levels of competition for natural gas, which is likely to be correlated with the distance from the well-head. However, it is exactly the opposite in California where separation exists in south, where the majority of natural gas reserves exist, but not in the north.

Figure 1 illustrates the distribution of single and dual-product electricity firms for the IOUs in the data used for this study. The first thing to note is that many states have both single and dual-product IOUs within their state lines. This would tend to argue that the reason for integration is not geographical in nature, since many of the states that have both single and dual-product firms are quite small. Second, while the southeast tends to be dominated by single-product firms, the rest of the US is rather mixed.

3 Related Literature

The issue of relative pricing of single and dual-product electricity firms was analyzed by Owen (1970) and Landon (1973) in the early 1970s. However, their results were ambiguous. Owen (1970) estimates a reduced form pricing equation, controlling for cost and demand variables, and includes a dummy variable equal to one if the firm sells both electricity and natural gas. His results suggest that dual-product firms have higher electricity prices. His results were subsequently questioned by Landon (1973), who included additional cost and demand variables, as well as regional dummy variables. The inclusion of these variables negated the effect of dual-product firms. The issue has been left unaddressed after this.

Landon interprets this as evidence that regulators do not respond to the incentives of firms.

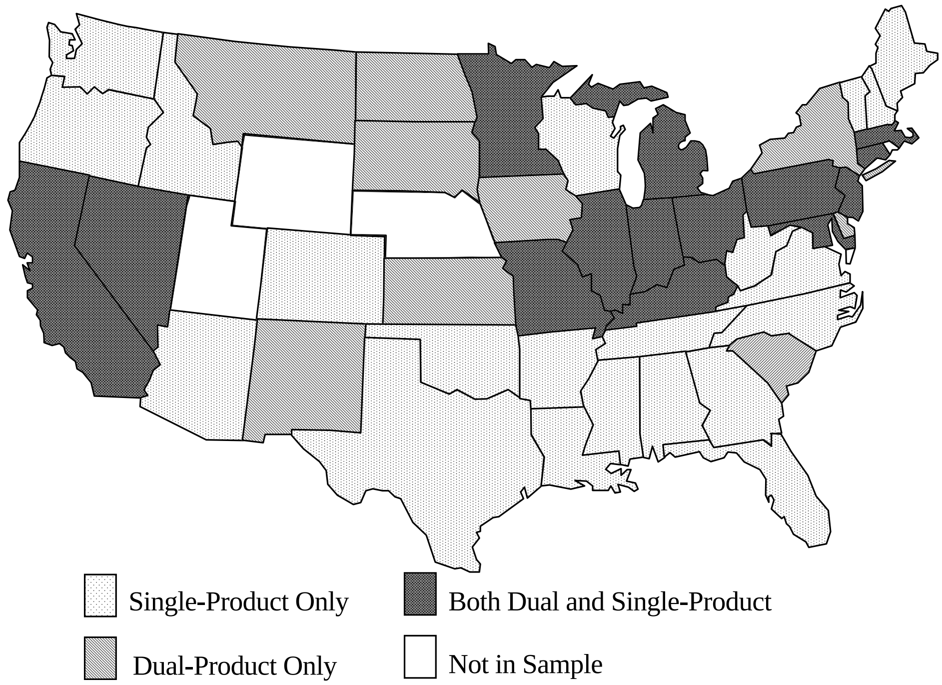

Figure 1: Distribution of Single and Dual-Product Electricity Monopolies

However, as I show in the next section, if both electricity and natural gas regulation is imperfect then the relative prices of the two market structures is ambiguous, implying that little can be gained, with respect to the efficacy of regulation, by a results that suggest the relative prices of the two market structures do not differ. However the relative investment decisions of the electricity firms will differ. Therefore, a more accurate test is to analyze both the relative pricing and investment decisions of single and dual-product firms.

Therefore, this paper differs from these analyses in two respects. First, the paper also studies the generation choice of electricity firms. If single-product natural gas firms are able to act on their incentive to raise their rivals costs, then a natural defense to such action is for the electricity firm to substitute away from natural gas generation and into alternative fuel sources, e.g. coal and nuclear. Second, the paper differs from that of Owen (1970) and Landon (1973) in that it performs the tests on data from the 1990s.

4 Relative Incentives in an Unregulated Market

In this section, I analyze the relative pricing incentives of single and dual-product firms operating in an unregulated market structure. Although electricity and natural gas firms operate in a regulated environment, if regulation is imperfect, we may expect prices to correlate with the incentives of unregulated firms. In particular, if regulators respond to lobbying pressure, then firms would equate the marginal benefit from additional lobbying effort with the marginal cost of that effort. As long as the lobbying cost functions for dual-product firms do not systematically differ from those of single-product firms, then – while rates would be kept below their profit maximizing levels – they would still reflect the relative incentives of unregulated firms. In contrast, if regulators did not respond to such lobbying pressure, rates would not reflect the differing incentives of single and dual-product firms. With this in mind, the empirical section can, in some sense, be thought of as a test of the efficacy of regulation.

Let $Q^e(P^e, P^g)$ and $Q^g(P^g, P^e)$ represent the retail demand function for electricity and natural gas, respectively. For simplicity, assume constant marginal costs of production for natural gas, represented by MC^g. The marginal cost of electricity is also assumed to be constant, but dependent on the price of natural gas faced by the firm, i.e. $MC^e(P^g)$ in the single-product setting and $MC^e(MC^g)$ in the dual-product monopolist setting. The choice variables are assumed to be the prices of electricity and natural gas.

4.1 Single-Product Structure

The single-product electricity monopolist solves the following:

$$\max_{P^e} \left(P^e - MC^e\left(P^g\right)\right) Q^e\left(P^e, P^g\right) \tag{1}$$

The firm takes the price of natural gas as given, implying the following first order condition:

$$Q^e\left(P^e, P^g\right) + \left(P^e - MC^e\left(P^g\right)\right) \frac{\partial Q^e\left(P^e, P^g\right)}{\partial P^e} = 0 \tag{2}$$

In contrast, the single-product natural gas firm not only takes into account the impact of a marginal change in the price of natural gas on the demand for natural gas, but also how such a change impacts the costs of the rival electricity firm. Therefore, the natural gas firms solves the following:[4]

$$\max_{P^g} \left(P^g - MC^g\right) Q^g \left(P^g, P^e \left(MC^e \left(P^g\right)\right)\right) \quad (3)$$

The first order condition is as follows:

$$Q^g \left(P^g, P^e \left(P^g\right)\right) + \left(P^g - MC^g\right) \left[\frac{\partial Q^g \left(P^g, P^e \left(P^g\right)\right)}{\partial P^g} + \frac{\partial Q^g \left(P^g, P^e \left(P^g\right)\right)}{\partial P^e} \frac{\partial P^e}{\partial MC^e} \frac{\partial MC^e}{\partial P^g}\right] = 0 \quad (4)$$

Here we see the impact of the "raising your rivals costs" incentive. The single-product natural gas firm not only views the impact of a marginal change in price on the demand for natural gas, but it also is aware that a marginal change in the price will also impact the price of electricity, since natural gas is an input to electricity generation. Therefore, by raising its rivals costs, the natural gas firm increases its own demand, increasing the equilibrium price for natural gas.

4.2 Dual-Product Structure

In the dual-product setting, the monopolist solves the following objective function:

$$\max_{P^e, P^g} \left(P^e - MC^e \left(MC^g\right)\right) Q^e \left(P^e, P^g\right) + \left(P^g - MC^g\right) Q^g \left(P^g, P^e\right) \quad (5)$$

The first order conditions are:

$$\begin{aligned} Q^e \left(P^e, P^g\right) + \left(P^e - MC^e \left(MC^g\right)\right) \frac{\partial Q^e \left(P^e, P^g\right)}{\partial P^e} + \left(P^g - MC^g\right) \frac{\partial Q^g \left(P^g, P^e\right)}{\partial P^e} &= 0 \quad (6) \\ Q^g \left(P^g, P^e\right) + \left(P^g - MC^g\right) \frac{\partial Q^g \left(P^g, P^e\right)}{\partial P^g} + \left(P^e - MC^e \left(MC^g\right)\right) \frac{\partial Q^g \left(P^g, P^e\right)}{\partial P^g} &= 0 \end{aligned}$$

In the two-product setting, the firm internalizes the impact of a marginal change in the price of one good on the demand for the other good. In particular, because electricity and natural gas are substitutes, implying that $\frac{\partial Q^i(P^g,P^e)}{\partial P^j} > 0$ for $i \neq j$, the firm has an incentive to price both goods higher, relative to the single-product firms.

[4] In practice, the natural gas firm is able to price discriminate among retail consumers and electricity firms. I abstract from this by assuming they charge one price. Because of political constraints it is likely that the two prices correlate to some degree, supporting this assumption.

However, unlike most cases in which a firm sells substitutes, the"substitute effect" is mitigated. In particular, for pricing electricity the dual-product firm does not face a natural gas competitor that may have market power enabling it to increase its rivals costs by increasing the price of natural gas. Therefore, the dual-product firm faces the true marginal cost of natural gas, and does not suffer from any double marginalization issues, as in the single-product case. This reduction in the marginal cost of the dual-product firm tends to decrease the price of electricity.

4.3 Relative Pricing Incentives

To get a feel for the relative incentives under the different structures, I compare the first order conditions under the different structures. We can rewrite the first order conditions for the dual-product firm as follows:

$$\begin{aligned} \frac{P^e - MC^e\left(MC^g\right)}{P^e} &= \frac{1}{\epsilon_e}\left(1 - \frac{\left(P^g - MC^g\right)Q^g\left(P^g, P^e\right)\epsilon_{e,g}}{P^e Q^e\left(P^e, P^g\right)}\right) \\ \frac{P^g - MC^g}{P^g} &= \frac{1}{\epsilon_g}\left(1 - \frac{\left(P^e - MC^e\left(MC^g\right)\right)Q^e\left(P^e, P^g\right)\epsilon_{g,e}}{P^g Q^g\left(P^g, P^e\right)}\right) \end{aligned} \tag{7}$$

where $\epsilon_{e,g}$ is the electricity's cross price elasticity to natural gas.

The first order condition for the single-product electricity firm can be rewritten as:

$$\frac{P^e - MC^e\left(P^g\right)}{P^e} = \frac{1}{\epsilon_e} \tag{8}$$

In comparing those of the single-product electricity firm with the dual-product firm, there are two things to note. First, because natural gas and electricity are substitutes, implying $\epsilon_{e,g} > 0$, we have:

$$\frac{1}{\epsilon_e}\left(1 - \frac{\left(P^g - MC^g\right)Q^g\left(P^g, P^e\right)\epsilon_{e,g}}{P^e Q^e\left(P^e, P^g\right)}\right) > \frac{1}{\epsilon_e} \tag{9}$$

If $P^g = MC^g$, this condition would imply that the price of electricity, when sold by a dual-product firm, would be relatively greater than when sold by a single-product firm. This is the "substitute effect." However, if regulation is imperfect, then in practice P^g is likely to be greater than MC^g.[5] Because in the dual-product setting, vertical integration allows the firm to see the true marginal cost of natural gas, and this is likely to be lower than the rate charged by the single-product natural gas firm, the dual-product firm faces a lower marginal cost of production for electricity. Therefore,

[5] The simple fact that natural gas firms remain regulated is evidence that, left alone, they would exercise market power. Therefore, assumption that the firms have market power seems to be appropriate.

although the price-cost margin in the dual-product setting is higher, the net effect on the level of prices for electricity is ambiguous.[6]

The first order condition for the single-product natural gas firms is not as clean. However, we can rewrite it as:

$$\frac{P^g - MC^g}{P^g}\left(1 + \frac{\partial P^e}{\partial MC^e}\frac{\partial MC^e}{\partial P^g} \cdot \frac{\frac{\partial Q^g(P^g,P^e)}{\partial P^e}}{\frac{\partial Q^g(P^g,P^e)}{\partial P^g}}\right) = \frac{1}{\epsilon_g} \tag{10}$$

The expression,

$$\frac{\partial P^e}{\partial MC^e}\frac{\partial MC^e}{\partial P^g} \cdot \frac{\frac{\partial Q^g(P^g,P^e)}{\partial P^e}}{\frac{\partial Q^g(P^g,P^e)}{\partial P^g}}$$

captures the single-product natural gas firm's incentive to increase the costs of its rival. These derivations imply that the relative incentives for both pricing and price cost margins are ambiguous in the case of natural gas. One the one hand, the dual-product firm has an incentive to increase its price because the two goods are substitutes. On the other hand, the single-product firm has an incentive to raise its rivals costs. Since, the marginal costs of the two firms do not differ, these competing incentives remain in their relative price cost margins.

4.4 Testable Implications

The above results suggest that if regulation is imperfect, then the relative pricing of single and dual-product firms is likely to differ. Although, with respect to prices, the relative incentives are ambiguous, by also examining relative investment decisions we are able to draw conclusions regarding the efficacy of regulation in both markets. This is true because if the regulation of natural is imperfect and prices reflect the relative incentives of unregulated firms, then the single-product natural gas firm will have an incentive to increase its price in order to increase the costs of its electricity competitor. This would imply that the marginal cost of natural gas electricity generation for single-product firms would be higher than units operating in a dual-product firm setting. Therefore, *ceteris paribus*, single-product electricity firms would rely less on natural gas burning generation. In additional, conditional on the nature of natural gas regulation, the nature of electricity regulation will have specific implications with respect to the relative prices of the market structures.

[6] One method for curbing the effect of $P^g > MC^g$ in the single product firm setting is for the electricity firm to rely less on natural gas generation units and more on alternative technologies. In the empirical section, I test for this.

	Electricity Regulation Perfect	Electricity Regulation Imperfect
Gas Regulation Perfect	$P^e_{dual} = P^e_{single}$ $I^{gas}_{dual} = I^{gas}_{single}$	$P^e_{dual} > P^e_{single}$ $I^{gas}_{dual} = I^{gas}_{single}$
Gas Regulation Imperfect	$P^e_{dual} < P^e_{single}$ $I^{gas}_{dual} > I^{gas}_{single}$	$P^e_{dual} \lesseqgtr P^e_{single}$ $I^{gas}_{dual} > I^{gas}_{single}$

Table 1: Impact of Regulation Imperfections on Electricity Prices and Natural Gas Generation Use

Table 1 illustrates how different permutations of electricity and natural gas regulation imperfections lead to different relative pricing and investment outcomes. P^e_j and I^{gas}_jrepresent the price of electricity and investment in natural gas generation in market structure j, respectively. If the regulation of both electricity and natural gas is perfect then the relative pricing and investment decisions will be indistinguishable. However, if natural gas regulation is imperfect and electricity regulation is perfect then prices in the dual-product setting will be lower, since the divergence of natural gas prices from marginal cost is internalized by the dual-product firm, but not by the single-product electricity firm. The internalization of natural gas prices also implies that natural gas generation is relatively more attractive to the dual-product firms, relative to the single-product firm, implying dual-product firms will rely more on natural gas generation.

If electricity regulation is imperfect and natural gas regulation is perfect (the northeast quadrant), then the "selling substitutes incentive" will be captured in the relative prices, while the "raising your rivals costs" will be held in check. This implies that electricity prices in the dual-product setting with be higher than those in the single-product setting. However, because natural gas prices are the same in both market structures, the relative attractiveness of natural gas electricity generators will be the same. Finally, if both natural gas and electricity regulation is imperfect, then both the "selling substitutes incentive" and "raising your rivals costs incentive" will be acted upon. This implies that the relative pricing of the two market structures is ambiguous. However, the existence of the "raising your rivals costs incentive" implies that the dual-product firms will rely more heavily on natural gas generation.

Of course, the empirical analysis presented below operates in the opposite logical direction, since we will infer the degree of regulation imperfection using the relative pricing and investment decisions. Therefore, I invert the above "outcome box" to represent the inferences that can made conditional on the results below. While, the number of possibilities increases, it turns out that because there does not exist a scenario where we would expect to see $I^{gas}_{dual} < I^{gas}_{single}$, thereby limiting the number of feasible outcomes. This gives rise to the following "outcome box" in Table

2.

If we find that $I^{gas}_{dual} = I^{gas}_{single}$ then we can draw the conclusion that natural gas regulation is perfect. This is the case, since both single and dual-product firms must face the same marginal cost for natural gas, and because the dual-product firm faces the true marginal cost of natural gas, both the marginal cost and the price charged by the single-product natural gas firm must be equal.[7] Furthermore, if $I^{gas}_{dual} > I^{gas}_{single}$ then the marginal cost of natural gas for the dual-product firm must be lower than that of the single-product firm, implying that the price of natural gas is set above its marginal cost, i.e. natural gas regulation is imperfect.

The relative investment decisions of firms coupled with the relative pricing allows us to also make inferences regarding imperfections in electricity regulation. Working down the first column, if both investment and pricing are the same in both market structures, then we can safely conclude that the regulation of both natural gas and electricity are perfect. It is unlikely that we would ever find that investment decisions are the same, implying natural gas is sold at marginal cost, and dual-product firms price lower than single-product firms. Recall dual-product firms could price lower than single-product firms if *only* the "raising your rivals cost" incentive was acted upon, however this would also lead dual-product firms to rely less on natural gas generation. Finally, if investment decisions are the same, but the dual-product firm sets a higher price for electricity, then we can conclude that *only* the "selling substitutes" incentive is acted upon, implying that electricity regulation is imperfect.

Now focusing on the second column. If dual-product firms rely more on natural gas generation, then we know natural gas regulation is imperfect. The relative strength of the "raising you rivals costs" and "selling substitutes" incentives will be borne out in the relative pricing of the two market structures. If we see that the relative pricing are the same, then this would imply that electricity regulation is also imperfect. The regulated price of electricity is set conditional, among other things, on the marginal cost of natural gas faced by the firm. If natural gas regulation is imperfect, then the marginal cost of natural gas faced by the single-product electricity firm is greater than its true marginal cost. This implies that, *ceteris paribus*, the price of electricity for single-product firms will be higher. Therefore, the only way the prices can be equal is if the dual-product electricity firm possesses a greater degree of market power because of the selling substitutes incentive and this negates the raising your rivals cost incentive.

[7] Because natural gas firms are able to price discriminate between consumer classes, we are only able to make inferences regarding the regulation of prices charged to electricity firms. As noted, however, these prices are likely to be strongly correlated and imperfection in the pricing for one consumer class are likely to correlate with imperfections for other consumer classes.

If dual-product firms have higher electricity prices, then this would imply that both natural gas and electricity regulation is imperfect and the selling substitutes incentive is stronger than the raising your rivals cost incentive. Only if dual-product firms have lower electricity prices can it be the case that electricity regulation is perfect. However, it may also be imperfect and the raising your rivals costs incentive is simply stronger than the selling substitutes incentive.

	$\mathbf{I}^{gas}_{dual} = \mathbf{I}^{gas}_{single}$	$\mathbf{I}^{gas}_{dual} > \mathbf{I}^{gas}_{single}$	$\mathbf{I}^{gas}_{dual} < \mathbf{I}^{gas}_{single}$
$\mathbf{P}^{e}_{dual} = \mathbf{P}^{e}_{single}$	Both Elec and Gas Perfect	Both Elect and Gas Imperfect	Unlikely
$\mathbf{P}^{e}_{dual} < \mathbf{P}^{e}_{single}$	Unlikely	Elec Perfect, Gas Imperfect or Both Elect and Gas Imperfect	Unlikely
$\mathbf{P}^{e}_{dual} > \mathbf{P}^{e}_{single}$	Elec Imperfect, Gas Perfect	Both Elect and Gas Imperfect	Unlikely

Table 2: Electricity Prices, Natural Gas Generation Use and Implied Regulatory Imperfections

5 Econometric Analysis

5.1 The Data

To test the relative incentives of single and dual-product firms, I make use of an unbalanced panel data set on electricity IOUs. The data span the years of 1990 to 1995 and are for vertically integrated IOUs. The sources of the data are described in Appendix A. The data report the total revenue from electricity and natural gas sales, the total output of electricity, output by demand class (e.g. residential, commercial), and the capacity mix of the firm.

Additional data were collected on marginal cost, demand and resource availability determinants. In particular, data on regional average prices for delivered natural gas, coal and oil to electricity firms was collected. These data control for changes/differences in input costs associated with geographic location. In addition, I collected data on the average annual income for the home state of the firm. These data control for changes/differences in demand.

5.2 Empirical Model

I analyze whether, controlling for differences in marginal costs, the price for electricity differs under the two market structures and whether, controlling for the relative costs of technologies, the choices of generation mix depends on the market structure. To answer these questions, I estimate equilibrium prices and natural gas generation investment equations. In particular let:

$$\begin{aligned} P^e_{it} &= f^1\left(X^1_{it}, W^1_{it}, Market\ Structure_i, \varepsilon^1_{it}\right) \\ \%NatgasSteamCap_{it} &= f^2\left(X^2_{it}, W^2_{it}, Market\ Structure_i, \varepsilon^2_{it}\right) \end{aligned} \tag{11}$$

where P^e_{it} is the price of electricity, $\%NatgasSteamCap_{it}$ is the percentage of steam generation that utilizes natural gas as its fuel, X_{it} is a matrix of demand determinants for market i at time t, W_{it} is a matrix of cost determinants for market i at time t and ε_{it} is an error term.

5.2.1 Price Equation

Dependent Variable: The dependent variable for the first equation is the average revenue from electricity sales, measured in dollars per megawatt hour.

Market Structure: The market structure is measured as an indicator variable, $D^{i=j}$, equal to one if the electricity firm also sells natural gas is included.[8]

Marginal Cost Determinants: Electricity firms have a choice from a wide-array of generation technologies and fuel sources for those technologies. For example, if a firm can chose to build a steam generator, i.e. one that uses steam to turn the generation turbine, the fuel source may either be natural gas, coal, oil, or nuclear. The marginal cost of these different technologies will, in part, depend on the cost of the fuel. In addition, the impact changes in the costs of these fuels has on electricity prices will depend on the amount of generation the firm employs that uses the respective fuel. For example, changes in the price of coal should not impact a firm's electricity price if the firm does not use coal generation. To control for this, I include the following variables: $\%Gas\times P^g_{it}, \%Coal \times P^{coal}_{it}$ and $\%Oil \times P^{oil}$, which are the regional price of input k interacted with the percentage of the firm's generation that uses the fuel k.[9] Because changes in the regional price of natural gas may impact a dual-product firm differently from single-product firm, I also include the variable: $\%Gas\times\ P^g_{it} D^{i=j}_i$.

While the relative use of most generation technologies is endogenous, the availability of hydroelectric resources is largely exogenous, driven instead by the availability of water resources in the operating area. Because the marginal cost of hydroelectricity generation is lower than that of other technologies, we would expect the availability of hydro resources to have a negative impact

[8]Given that the market structures have been in place for quite some time, typically dating back to the initial formation of these companies, near the turn of the century, I treat it as exongenous.

[9]These data were collected from the Natural Gas Institute and are split into 12 regional prices.

on price of electricity. Therefore, I include the percentage of electricity that was produced using hydroelectric resources, $\%Hydro_{it}$.

Finally, I include the percentage of generation capacity that utilizes nuclear fuel, $\%Nuke_{it}$. Although, nuclear generation units are low marginal cost units, they carry high sunk costs in their construction. Although pricing efficiency would entail these sunk costs to not have an impact on electricity rates, the majority of public utility commissions have incorporated them in setting rates. Therefore, we would expect jurisdictions that rely more heavily on nuclear power to have, *ceteris paribus,* higher rates.

Demand Determinants: Electricity firms service a wide array of consumer types. It is likely that the demand functions for these types of consumers differ. Although it is not possible to control for every consumer type, data are available on the percentage of electricity purchased by residential, commercial and industrial consumers. Because, the price is measured as the average price paid by all consumers, it will be a function of the relative demand elasticities of the different groups. Because by-passing the IOU is only economical for consumers who purchase a large amount electricity, industrial demand is largely considered more elastic than residential and commercial demand. In addition, regulatory restrictions often make by-pass for residential consumers illegal. Therefore, I include the percentage of electricity that was purchased from residential consumers and the percentage that was purchased from industrial consumers.[10]

The relative mixture of consumers is also likely to impact the cost of electricity production. The variability of industrial demand is less than that of residential consumers. This increased predictability of demand reduces the need for generation units that operate infrequently, thereby reducing the costs of generation.

The average price of electricity, across a given time period, will also be a function of the intertemporal nature of demand. The demand for electricity clearly changes across hours in a day and across seasons in a year. This variation in demand will likely impact both the price and generation choice of an IOU. Optimal peak load pricing would imply that the more variable demand is across a given time period, the greater the average price.[11] While an obvious choice would be the variance of demand across a given year, these data are not available. Instead, I included two related variables; $Peak/AvgDemand_{it}$ which is the ratio of the peak demand hour in a given year

[10]Because the sum of the percentage from residential, commercial, and industrial consumers is near one, the percentage consumed by commercial consumers is omitted.

[11]For example, if demand takes on two values, high with probability p and low with probability $1 - p$, then as p increases, while the level capacity level increase, the average price also increases.

to the average hourly demand, and $PeakStdDev_{it}$ which is the standard deviations of the monthly peak demand levels.

Finally, to control for changes in residential demand, the average yearly personal income for the state in which the firm operates is also included. This variable is included for two reasons. For one, although in the long-run, the level of demand should not impact price, since the capacity of the system would be built to cater to that level of demand, short term fluctuations in demand, caused by changes in the average income, may impact price. Secondly, it could be argued that more wealthy customers demand higher quality electricity service than do less wealthy consumers, either through lower levels of interruptions or better billing services. These considerations would tend to increase the average price of electricity.

Long Run Determinants: To control for demand and cost determinants that vary across region, but are not captured by the above variables, include 12 regional indicator variables.

5.2.2 Capacity Equation

Dependent Variable: The dependent variable in the second equation is the percentage of steam capacity that utilizes natural gas as its fuel. I limit the denominator to steam generation because, as noted above, the reliance on hydroelectric units is largely driven not by the firm, but rather the geographical location of the firm, i.e. the river system.

Relative Cost Determinants: A firm's relative capacity mixture will depend on the relative marginal and construction costs of the different technologies. It is unlikely that the relative construction costs vary by geographic location, however fuel costs do vary by region. Because these decisions are long run decision, the mixture will depend on both past and expectations of future fuel prices. To control for the costs of other technologies, $P^{g}_{it}, P^{coal}_{it}$, P^{oil} are included. These variables are regional prices for electricity companies of delivered natural gas (dollars per msf of natural gas), coal (dollars per tonnage) and oil (dollars per barrel), respectively. In addition, because of the dynamics of natural resource pricing, the current price should reflect all of the relevant information regarding expectations of future pricing.

Long Run Determinants: The choice of generation technology is by nature a long run decision, and therefore a function of long-run price differences among the different fuels. While current prices for these fuels will be correlated with these long-run (and previous price) differences, short run shocks to these prices may be present in the data. To control for these issues, I also include regional

Table 3: Expected Signs of Included Variables

Variable	**Equation**			
	P^e_{it}		$\%Natgas_{it}$	
	Imperfect Reg	Perfect Reg	Imperfect Reg	Perfect Reg
$D_i^{i=j}$	?	0	+	0
$\%Gas_{it} \times P^g_{it}$	+	+		
$\%Gas_{it} \times P^g_{it} D_i^{i=j}$	?	0		
$\%Coal_{it} \times P^{coal}_{it}$	+	+		
$\%Oil_{it} \times P^{oil}_{it}$	+	+		
P^g_{it}			−	−
$P^g_{it} \times D_i^{i=j}$			−	0
P^{coal}_{it}			+	+
P^{oil}_{it}			+	+
$Peak/AvgDemand_{it}$	+	+	+	+
$PeakStdDev_{it}$	+	+	+	+
$\%Res_{it}$	+	+		
$\%Hydro_{it}$	−	−		
$\%Nuke_{it}$	+	+		
$\%Ind_{it}$	−	−		
$Income_{it}$	+	+		

indicator variables.[12]

The inclusion of these variables implies:

$$
\begin{aligned}
P^e_{it} &= f^1\Big(D_i^{i=j}, P^g_{it},\ P^g_{it} D_i^{i=j}, P^{coal}_{it}, P^{oil}_{it}, \%Gas_{it} \times P^g_{it}, \%Coal_{it} \times P^{coal}_{it}, \\
&\quad \%Oil_{it} \times P^{oil}_{it}, \%Hydro_{it}, Peak/AvgDemand_{it}, \%Res_{it}, \\
&\quad \%Ind_{it},\ Income_{it}, \{Reg_1, ..., Reg_{12}\}, \varepsilon^1_{it}\Big) \qquad (12) \\
\%NatgasSteamCap_{it} &= f^2\Big(D_i^{i=j}, P^g_{it}, P^g_{it} D_i^{i=j}, P^{coal}_{it}\ , P^{oil}_{it}, Peak/AvgDemand_{it}, \\
&\quad \{Reg_1, ..., Reg_{12}\}, \varepsilon^2_{it}\Big)
\end{aligned}
$$

5.2.3 Functional Form

I estimate the equations under the assumption of two functional forms. The first is a linear model, the second a log-linear model. However, under the log-linear model the logarithm of the variables

[12] These regional variables will also capture other variables that vary by region, e.g. weather conditions, and are not included on the right hand side.

Table 4: Summary Statistics

Variable		Mean	Std Dev	Min	Max
$AvgRev$ for $Elec\,(\$/MWH)$	Entire Sample	4.924	1.481	2.373	10.34
	Dual-Product	5.112	1.585	3.035	10.34
$\%NatGas\,of\,SteamCapacity$	Entire Sample	15.02	26.17	0	100
	Dual-Product	15.16	26.43	0	100
$D_i^{i=j}$		.3905	.4882	0	1
P_{it}^g		1.588	.2254	1.086	2.326
$\%Gas_{it} \times P_{it}^g$		29.93	53.82	0	279.90
P_{it}^{coal}		5.981	64.02	.0664	9999[1]
$\%Coal_{it} \times P_{it}^{coal}$		26.02	397.1	0	764.3
P_{it}^{oil}		2.357	.4699	1.302	3.412
$\%Oil_{it} \times P_{it}^{oil}$		20.87	42.31	0	232.25
$\%Hydro_{it}$		5.841	10.92	0	63.13
$\%Nuke_{it}$		11.22	13.71	0	51.88
$Peak/AvgDemand_{it}$		1.541	.2495	1.003	2.246
$PeakStdDev_{it}$		462.1	627.84	5.589	8642
$\%Res_{it}$		.3330	.0681	.0917	.5328
$\%Ind_{it}$		.3377	.1367	0	.8123
$Income_{it}(1989\$1000s)$		18.22	2.162	13.12	25.91

[1]Because of environmental regulations, California firms are not able to burn coal. To capture this, the price is reported as $9999.

in percentage terms are not taken for two reasons. First because these variables can take on the value of zero, causes numerical problems when the logarithm is taken. Second, one of the appeals of the log-linear form is that the parameter estimates are elasticities. However, the elasticity of price with respect to a variable measured in percentage terms makes little sense. Therefore, the logarithm of the prices (electricity, natural gas, coal and oil), the ratio of peak to average demand and income levels are taken.

In addition, ε^1 and ε^2 are allowed to be correlated since unobserved variables that impact the pricing structure of one market may also impact the investment decisions of the same market, and vice versa.

5.3 Results

The results from the levels and log-linear specifications are reported in Table 5.

Price Equation: The results for levels specification suggest that dual-product firms have rates that are \$.28 per megawatt hour more than the rates of single-product electricity firms. Evaluated

Table 5: The Impact of Market Structure on Prices and Generation Choice

Variable	Levels Specification		Log-Linear Specification	
	Dependent Variable			
	P^e_{it}	$\%Natgas_{it}$	$\log P^e_{it}$	$\%Natgas_{it}$
$Constant$	5.326***	35.71***	1.814***	42.58***
	(.6227)	(8.479)	(.2192)	(8.350)
$D_i^{i=j}$	.2841***	7.814**	.0482***	7.354***
	(.0961)	(4.592)	(.0142)	(3.136)
$\%Gas_{it} \times P^g_{it}$	.0051***		.0011***	
	(.0012)		(.0005)	
$\%Gas_{it} \times P^g_{it} D_i^{i=j}$	$.5663 \times 10^{-3}$		$.9600 \times 10^{-4}$	
	$(.5107 \times 10^{-3})$		$(.4582 \times 10^{-3})$	
$\%Coal_{it} \times P^{coal}_{it}$	.0018		$.5673 \times 10^{-3}$***	
	(.0023)		$(.5077 \times 10^{-4})$	
$\%Oil_{it} \times P^{oil}_{it}$	.0073***		$.1185 \times 10^{-2}$*	
	(.0011)		$(.7359 \times 10^{-3})$	
P^g_{it}		–2.883*		–4.741*
		(1.802)		(3.012)
$P^g_{it} \times D_i^{i=j}$		–4.172		–7.573**
		(3.637)		(3.966)
P^{coal}_{it}		.3447		.2618
		(.3757)		(.3071)
P^{oil}_{it}		1.178		2.363
		(1.786)		(2.055)
$Peak/AvgDemand_{it}$	.0112	1.875***	.1003	1.900***
	(.0145)	(.2365)	(.2623)	(.2389)
$PeakStdDev_{it}$	$.2297 \times 10^{-3}$***	.0014	.0025***	.8465
	$(.5789 \times 10^{-4})$	(.0010)	(.0006)	(.5976)
$\%Hydro_{it}$	–.0079**		–.0055***	
	(.0039)		(.0008)	
$\%Nuke_{it}$	.0251***		.0042***	
	(.0023)		(.0006)	
$\%Res_{it}$	1.568**		.2160**	
	(.6147)		(.1099)	
$\%Ind_{it}$	–1.744***		–.3019***	
	(.3125)		(.0567)	
$Income_{it}$	.0244		–.0368	
	(.0197)		(.0639)	

N=717. *** significant at the .01 level, ** significant at the .05 level,
* significant at the .10 level. Heteroskedastic-consistent errors in parantheses.
Regional effects not shown.

at the mean price this implies that the rates of dual-product firms are 5.8 percent more than their single-product counterparts. Similarly, the log-linear specification suggests that rates are 4.8 percent higher when serviced by a dual-product firm. These estimates imply that while the integration of electricity and gas firms may lead to cost savings, the net effect on price of integration is positive.

This result is suggestive that, although these firms are regulated, regulation is imperfect in the sense that the relative incentives of single and dual-product electricity firms are still reflected in the rates they are allowed to charge. After controlling for demand and cost conditions, if regulators were not responsive to the incentives of firms, the rates of single and dual-product firms would not systematically differ.

The parameter estimates with respect to the control variables are largely consistent with economic intuition. The estimates with respect to $\%Gas_{it} \times P^g_{it}$ imply that increases in the price of natural gas lead to increases in the price of electricity. For the levels specification, the parameter estimates imply that a 10 percent increase in the price of delivered natural has implies that a single-product firms at the mean level of natural gas generation (13.0%), is associated with a 1.1 percent increase in the price of electricity.[13] This result is robust to changes in the functional form. For the log-linear specification, a 10 percent increase in the price of delivered natural gas for single-product firms at the mean level of natural gas generation share is associated with a 1.4 percent increase in the price of electricity.

Surprisingly, the estimates with respect to $\%Gas_{it} \times P^g_{it} D^{i=j}_i$ suggests that increases in the price of natural gas do not impact dual-product firms differently from single-product firms. We would expect increases in the price of natural gas to impact dual-product firms less than single produce firms, since some of this price increase will be absorbed by the firm as a result of increases in the retail rate of natural gas.

While the parameter estimates with respect to the price of coal is not significant, the estimates imply that increases in the price of oil are associated with increases in the price of electricity. In particular, the levels specification implies that a ten percent increase in the price of oil is associated with a 1.5 percent increase in electricity prices for firms at the mean level of oil generation share, while for the log-linear specification this estimate is 1.0 percent.

The parameter estimate with respect to the percentage of electricity produced via hydroelectric

[13] Recall that the variables $\%Gas_{it}$, $\%Coal_{it}$, and $\%Oil_{it}$ measure the percentage of all generation capacity (e.g. including hydroelectric resources) devoted to their respective technologies. The mean and standard deviation of $\%Gas$ are 12.99 and 23.01, respectively, for $\%Coal_{it}$ 48.80 and 31.15, respectively, and for $\%Oil_{it}$ 8.06 and 16.22.

resources suggest that greater hydroelectric resources is associated with reductions in rates. The levels specification suggests that a one standard deviation increase in the hydroelectric capabilities results in a 1.8 percent decrease in the price of electricity. The log-linear specification implies that a one standard deviation increase results in a price decrease of 3.8 percent decrease in the price of electricity.

The results also confirm our expectations that, although the marginal cost of nuclear units is very low, their high sunk costs lead to higher rates. Specifically, the results suggest that a one standard deviation increase in the percentage of capacity devoted to nuclear fuel is associated with a 7.0 percent increase in rates, in the levels specification, and a 3.6 percent increase in the log-linear specification.

The results with respect to the variability of demand variables suggest that the greater the variability of demand, the greater the average price. Although, the estimates with respect to the ratio of the peak demand period to the average demand are not significant, the results suggest that a 10 percent increase in the standard deviation of monthly peaks results in a .22 percent increase in electricity rates. In the log-linear specification, the results imply that 10 percent increase in the standard deviation of monthly peaks translates to an increase in the price of electricity of .25 percent.

The results also suggest that higher levels of demand from residential consumers, relative to commercial consumers, are associated with higher electricity rates, while higher levels of industrial consumers are associated with lower rates. These results are consistent with the observation that industrial demand is both more elastic and cheaper to service than that of other consumers, while residential demand is more inelastic relative to commercial demand and the cost of servicing residential consumers is greater.

Natural Gas Generation Equation: The results with respect to the investment equation suggest that dual-product firms rely more on natural gas generation than do single-product firms. This result suggests that despite regulation, single-product natural gas firms likely possess market power. In the absence of market power the price for natural gas would equal its marginal cost and both the single and dual-product electricity firms would face the same price for natural gas, and would therefore make the same investment decisions. However, if regulation is imperfect, single-product natural gas firms would price above marginal cost providing a relatively stronger incentive for dual-product firms to utilize natural gas generation for electricity.

In the levels specification, the parameter estimates suggest that the percentage of steam generation that utilized natural gas is 7.81 percent higher for dual-product firms. Taken at the mean percentage level of natural gas generation to that of all steam generation, this point estimate implies that dual-product firms utilize 52 percent more natural gas generation than single-product firms. This estimate is reduced in the log-linear specification, though still statistically significant. The log-linear specification suggests that the percentage of steam generation from natural gas generators in a dual-product setting is 7.354 percent higher, implying a 49 percent increase.

As one might expect, the estimates imply that as the price of natural gas increases, firms utilize less natural gas generation. Although generation decisions are made in the long run, and these prices are short run prices, they are likely to be positively correlated with the long run costs of natural gas, as well as previous prices. Specifically, the results imply that a 10 percent increase in the price of natural gas reduces natural gas steam generation share by 3 percent for the levels specification, and 1.5 percent in the log-linear specification.

The result with respect to the variable $P_{it}^{g}D_{i}^{i=j}$ suggest that dual-product firms substitute away from natural gas generation at greater levels than single-product firm. In particular, under the dual-product setting, a ten percent increase in the price of natural gas reduces the natural gas steam share by 7.5 percent and 3.8 percent in the levels and log linear specifications, respectively.

This result is consistent with profit maximizing behavior of the dual-product firm. If the demand for natural gas rises, *ceteris paribus,* a dual-product firm has an incentive to substitute natural gas generation with other technologies as a means of increase its sales of natural gas. This is the case because the increase sales of natural gas has a first order effect on profits while the substitution away from natural gas generation has only a second order impact on costs.

Once again, the parameter estimate associated with the variable $P_{it}^{g}D_{i}^{i=j}$ also suggests that natural gas regulation is imperfect. If under regulation prices equaled that of marginal cost then the integration of electricity and natural gas firms would not alter the relative costs of different steam generation. However, if prices under regulation differed from marginal cost, then integration would lower the relative cost of natural gas generation, implying dual-product firms would rely more heavily on natural gas generation.

Surprisingly, this same intuition for the price of coal and oil is not borne out in the data. Although positive, the estimates are not statistically significant. One potential reason for this is that increases in the price of coal would imply that the firm should substitute away from coal and into another technology. This other technology *may* be natural gas, but could also be oil, nuclear, etc. Therefore, while an increase in the price of natural gas is would definitely impact the use of natural gas generation, the opposite does not necessarily hold for increases in the price of other input fuels.

The results also suggest that greater demand variability is associated with an increase reliance on natural gas generation. This is consistent with the fact that the marginal cost of natural gas units is, on average, more expensive than that of coal units, however the fixed costs are, on average, lower relative to coal generators. Therefore, natural gas units are more suitable for peak load time periods, and optimal peak load investment would imply a greater reliance on natural gas plants. Specifically, the results suggest that a 10 percent increase in the ratio of peak to the average demand level results in a 1.9 percent increase in the natural gas share for the levels specification, and a 3.4 percent increase in the log-linear specification.

Taken as a whole, the results suggest that the combination of electricity and natural gas firms have higher electricity rates, relative to their single-product counterparts, and rely more heavily on natural gas generation. The increase in prices due to integration would imply a welfare loss to consumers from integration. However, the results also suggest that because the price for natural gas charged by single-product firms is above its true marginal cost, dual-product firms are able to produce more efficiently since they observe the true marginal cost of natural gas. Because electricity firms have a choice of generation technologies, implying their demand for natural gas is not perfectly inelastic, observing the true marginal cost is not likely to simply result in transfers from the natural gas firm to the electricity firm. Therefore, the net effect on social welfare from integration is ambiguous.

6 Conclusions

In this paper, I analyze relative equilibrium prices and investment decisions of single and dual-product electricity firms. The interesting relationship between these two products, namely that natural gas is both a substitute in consumption and an input in production of electricity, implies that left unregulated pricing and investment decisions would differ among the market structures. However, one could argue that because these firms are regulated entities, if regulation was perfect, these differing incentives would not be acted upon. The empirical evidence put forth in this paper suggests this is not the case.

The results have a wide array of policy implications. For one, the results of the pricing equation suggest that consumer welfare is reduced by integration, as integration leads to higher electricity prices. Therefore, while integration may lead to greater cost efficiency the increase in market power mitigates this social gain. Secondly, the results of the investment equation are suggestive that single-product natural gas firms also are pricing above marginal cost. The net impact on welfare as a result of integration, however, is ambiguous. While the pricing equation suggests that integration leads to higher prices, the investment equation suggests that the marginal cost of electricity generation is reduced as a result of integration. Therefore, while integration appears to be a loss to consumers, social welfare may be increased. In addition, because the demand for electricity is rather inelastic, the welfare loss due to an increase in price is likely minimal. Therefore, it can be viewed as equally likely that integration is a welfare gain, rather than a welfare loss. With that said, the results do suggest that there are imperfections in the regulation of electricity and natural gas firms.

The policy implications in a restructured electricity market may be different. If market power exists in a restructured electricity market, it may be exacerbated by integration for two reasons. First, because of the substitution effect, in a restructured electricity market dual-product firms will have a heightened incentive to bid higher in electricity generation auctions, because of the impact higher electricity prices have on the demand for natural gas. Secondly, in a restructured electricity market the dual-product firm will potentially be selling natural gas to entrants with power plants in their jurisdiction. Therefore, the incentives to "raise your rivals costs" will exist for both single *and* dual-product natural gas firms.

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A Data Sources

Data on the average revenue of electricity, the market structure the firm operates in, the relative electricity use by consumer class, and the ratio of peak demand load to average demand load was collected from the FERC Form 1 data source on US investor owned utility. A dual-product firm is defined as an IOU having natural gas sales of over $100,000 in a given year. This is to control for firms that have relatively inconsequential sales of natural gas. Defining the variable as having any sales at all did not change the results. Data on the capacity levels of the different technologies was collected from the Energy Information Administration's *Uniform Statistical Report.* Data on the percentage of electricity produced via hydroelectric resources was collected from the FERC Form 412 data. Data on the average price of delivered natural gas, coal and oil was collected Gas Research Institute's *Baseline Projection Data Book* published annually. These data report regional average prices of delivered inputs for all firms within a given region. In particular, the US is partitioned into 12 regions. Finally, data on the state's average personal income and the consumer price index was collected from the Bureau of Labor Statistics website. The base year of the consumer price index is 1989.