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# The Relationship between Electricity and Gas Industries in Australia

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***Abstract –*** *Electricity and gas industries are major industries in the Australian economy. Significant reforms were initiated in these industries in the early 1990s, with a core objective of improving their efficiencies through recourse to market competition. Further, these reforms were being undertaken separately for each industry, in total disregard of the relationship that may exist between these two industries. Several studies have alluded to the need for examining the nature of this relationship as it may provide useful insights for developing more meaningful reform program for each of these industries. This paper is an attempt in that direction. This relationship is examined both through qualitative (historical) and quantitative analyses. The qualitative analysis is supported by cross price elasticities of demand between electricity and gas, at the national and state levels. These elasticities are estimated using simultaneous demand functions for electricity and gas. While this paper focuses on Australia, its findings should be relevant for other countries that are in the process of reforming their electricity and gas industries.*

***Keywords –*** Electricity and gas industries, qualitative and quantitative review, relationship.

## 1. INTRODUCTION

Electricity and gas industries are major industries in the Australian economy as their products are the inputs for all other industries. Both industries have been separately functioning since the late nineteenth century. A reform program has been introduced to both industries, in the early 1990s, with a core objective of improving efficiency through recourse to competition. These reforms are being undertaken separately for each industry, in total disregard of the relationship that may exist between these two industries. Several studies have alluded to the relationship between electricity and gas industries (for example [1], [2], and [3]). No comprehensive study has, however, been undertaken to establish the nature of such relationship. This paper focuses on establishing such relationship.

## 2. THE EVOLUTION

Electricity was introduced in Australia in the late nineteenth century. Natural gas was introduced on a commercial scale in the late 1960s, even though it was first discovered in 1899, in Roma, Queensland. Before the use of natural gas on a commercial scale, town gas was in use as energy source for lighting purposes. Figure 1 shows the relationship between these industries.

The evolution of electricity and gas industries in Australia, examined in this paper, is classified into five time periods, namely, the early days (1770-1900); industry segregation (1901-1950); industry growth (1951-1970); further expansion (1971-1989); industry re-segregation (1990-present). The classification of periods is guided by the considerable changes that have taken place in both industries.

### *The Early Days (1770-1910)*

Both industries started as rival providers of energy in the late 1880s. There was a fierce competition between these two industries in those years. This was due to the competing uses of electricity and gas for lighting purpose. In those days, the main input for generating electricity and gas was coal, except in Western Australia (WA), which used town gas to generate electricity. During this period, these industries clearly showed close interrelationship, both on demand and supply sides.

### *Industry Segregation (1901-1950)*

During this era, the demand for electricity and gas increased gradually, and with it their importance in the economy. A fierce competition remained visible in the early years of this period, as the consumers and the usage (i.e., lighting) of electricity and gas were the same. The later years witnessed a separation of interests between these two industries. Even though gas industry lost its customers to the electricity industry for lighting purposes, it gained new customers in heating, cooking, and other household applications. Hence, electricity and gas industries began to evolve as independent industries. Coal continued to be a key input for both electricity and gas production.

### *Industry Growth (1951-1970)*

After World War II, the Australian lifestyle changed significantly [4]. The demand for electricity and gas increased considerably during this period. This caused electricity and gas shortages across the country. The government engagement began to emerge in both industries, not only to solve this shortfall, but also in response to other factors including: belief in the role of electricity in development; trend towards bigger governments; perceptions about the responsibility of the government in promoting economic development, social

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welfare, employment, equity, justice and community interests; realization by the political parties of the electoral appeal of electricity; including the strategies to centralized and integrated operation supervised by the State Government [5]. For example, in New South Wales (NSW), both industries were unable to satisfy demand for energy. The state government, initially, had to make a decision whether to take over the control of electricity or gas companies. The government decided in favor of the former, as the government believed it had better potential than gas industry [6]. Hence, the Electricity Commission of New South Wales (ECNSW) was established to manage the entire industry, including the development of the State's power resources on an integrated basis [7]. In the same period, the Australian Gas & Light Limited (AGL), a key gas company in NSW, acquire other companies and established a numbers of subsidiary companies. The interesting feature is that even though electricity industry was taken over by the state government and gas industry was not, the strategy to overcome the energy shortfall was similar.

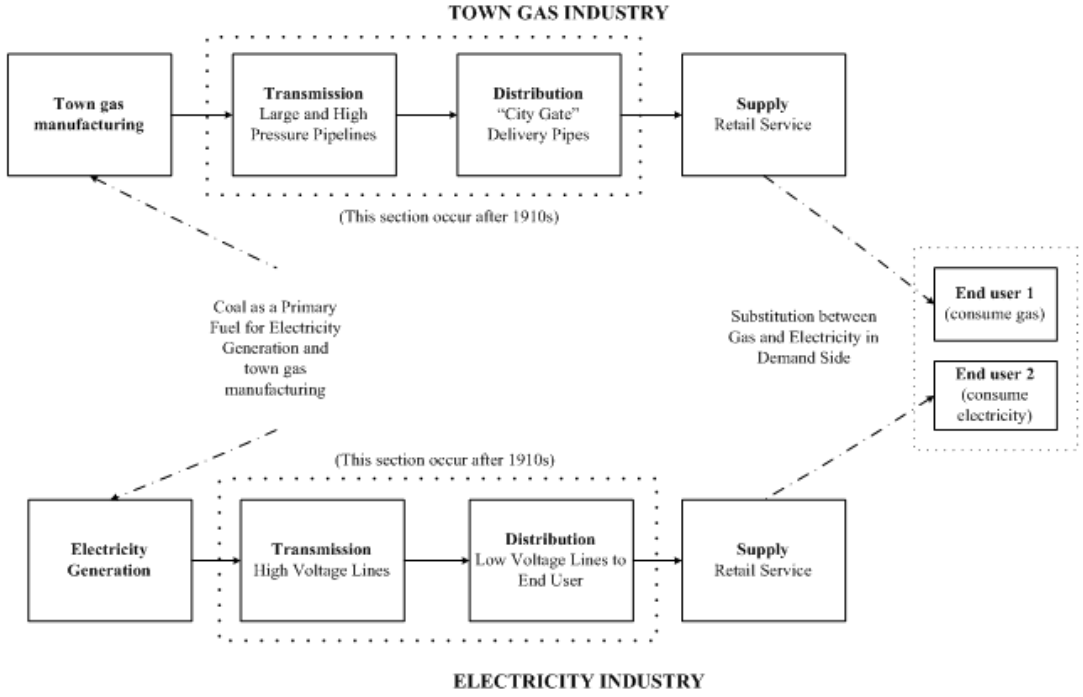


**Fig.1. Link Between town gas and electricity industries**

### *Further Expansion (1971-1989)*

This period witnessed the introduction of natural gas, which is more efficient, reliable, and cleaner than town gas. Natural gas therefore began to replace town gas. The relationship between electricity and gas became stronger and more noticeable, as natural gas became a preferred choice. The arrival of natural gas moreover affected the increase in gas demand across the country, including the states that did not have gas resources for example NSW.

Electricity industry, on the other hand, encountered problems of overcapacity and lack of efficiency. Significant investments were made in the electricity industry during the 1960s and 1970s, in anticipation of increase in electricity demand. This created a significant amount of debts for the industry owners (i.e., the governments) and lead to financial crisis. New technology, gas-fired power plant, was imported and replaced coal and oil-fired power plants in some states, such as WA and Northern Territory (NT).

Unlike the Australian electricity industry, private enterprises took predominantly control in the Australian natural gas industry especially in production sector. The state government had, however, authority to operate transmission and distribution sectors and responsibility in regulating tariff and industry as general. On the other hand, in electricity industry, the Federal and State governments had taken entirely control on the electricity industry during this period.

### *Industry Re-segregation (1990-present)*

Natural gas became one of the most important primary energy fuels for electricity generation not only in Australia but across the world. In Australia, coal has been the most important input for electricity generation process since 1900s. The share of coal consumption in electricity generation process has decreased after the advent of natural gas. This period, however, witnessed the dramatically increase in the share of natural gas as a primary energy fuel for electricity generation process which bring about the solid relationship between both industries in supply side. The relationship between electricity and gas occurred not only on the supply side, but also on the demand side. Natural gas, being cleaner and less damaging to the environment, began to replace electricity. The relationship between electricity and gas industry during this period can be briefly presented as in Figure 2.

Energy market reforms were introduced in the Australian electricity and gas industries in the early 1990s. These reforms had similarities, for example, they emphasized functional unbundling, legislated access to monopoly networks, and private ownership. This reinforces the argument about 'relationship' between these

two industries. However, there are also dissimilarities between electricity and gas industries reforms, for example, pool trading was introduced to electricity industry firstly in Victoria and currently applied for all state in the context of National Electricity Market (NEM), while gas prices rely heavily on long term contract especially for industrial and commercial sectors. Nevertheless, for residential sector, both industries introduced the full retail contestability in most of the state except in Western Australia (WA) which provide a right to customer to be able to select their supplier.

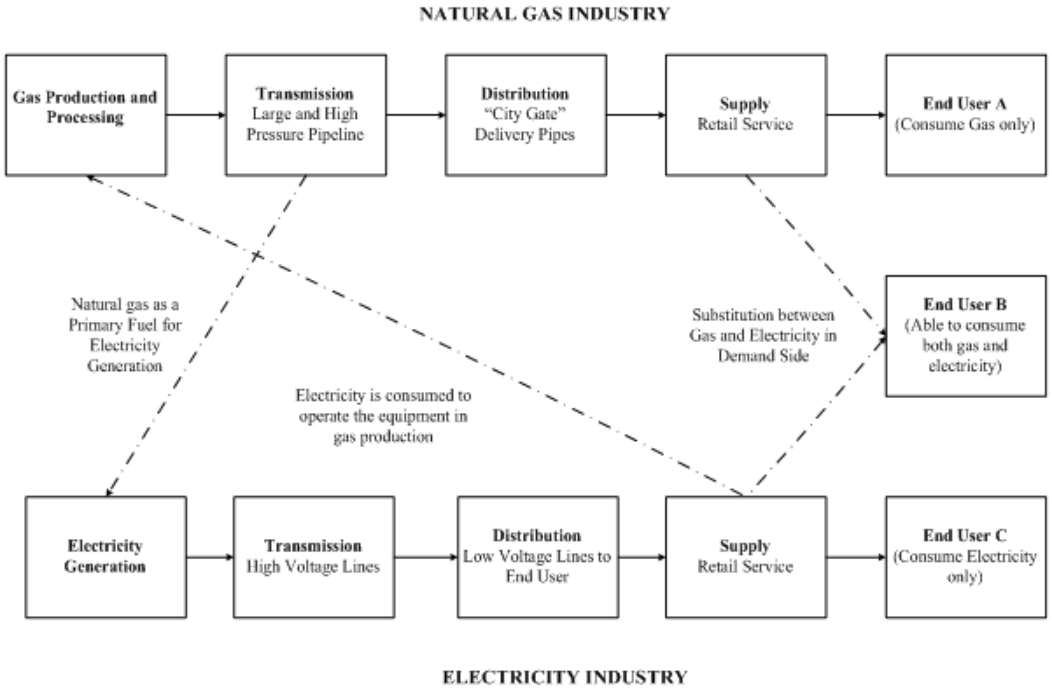


**Fig. 2. Link between natural gas and electricity industries**

## 3. MODEL SPECIFICATION

In this paper, a simultaneous equation approach was employed to model the relationship between electricity and gas industries in Australia. The model consists of three sets of equations, namely, aggregate production, electricity demand, and gas demand functions. A state-based energy balance identity is formulated. The partial adjustment method is adopted in this study in order to capture the dynamism of the interrelationship between macroeconomic variables. This model follows a transformation method suggested by Kyock [9] (see also [10]-[13]).

Further, own and cross price elasticities of demand that are estimated in this study represent immediate elasticities, as it is assumed that the desired level of variable is equal to the actual level. 'Fix effect' method is applied in order to distinguish a state-specific intercept in each equation. The state electricity and gas demand equations, which are used to estimate state-based own and cross price elasticities are, on the other hand, used as single equations.

### *Aggregate Production Function*

The GSP (Gross State Production) is represented in this study as a function of labor, capital, and primary energy:

$$y_{st} = f_1\left(L_{st}, K_{st}, PE_{st}\right) \tag{1}$$

where $y_{st}$ is the Gross State Production ($m); $L_{st}$ is the amount of labor ('000 persons); $K_{st}$ is the physical capital stock ($m); and $PE_{st}$ is the total primary energy supply (TJ); $s$ and $t$ represent states and times (years), respectively. This mathematical equation can be modified to a log-log functional form as:

$$\ln y_{st} = \gamma_0 + \gamma_1 \ln L_{st} + \gamma_2 \ln K_{st} + \gamma_3 \ln PE_{st} + \varepsilon_1 \tag{2}$$

where $\gamma_0$, $\gamma_1$, $\gamma_2$, $\gamma_3$ are unknown coefficients, which are restricted to values more than zero, as a higher state production is a result of higher values of $L$, $K$, and $PE$. As production level in a particular year is unlikely to be affected by changes in labor, capital stock, and primary energy in that year, Kyock transformation could be used to establish the dynamic link [9]. This dynamic relationship could be represented as:

$$\ln\left(y_{st}\right) - \ln\left(y_{st-1}\right) = \xi\left[\ln\left(y^{*}{}_{st}\right) - \ln\left(y_{st-1}\right)\right] \tag{3}$$

where $\xi$ is known as the coefficient of adjustment with a value of $0 < \xi < 1$, and $[\ln (y^*_{st}) - \ln (y_{st-1})]$ and $[\ln (y_{st}) - \ln (y_{st-1})]$ are the desired and actual changes, respectively. Substituting Equation 2 in 3 and solving for $\ln(y_{st})$, the production function can be written as:

$$\ln y_{st} = \lambda_0 + \lambda_1 \ln L_{st} + \lambda_2 \ln K_{st} + \lambda_3 \ln PE_{st} + \lambda_4 \ln y_{st-1} + \varepsilon_1 \tag{4}$$

where $\lambda_0 = \xi\gamma_0, \lambda_1 = \xi\gamma_1, \lambda_2 = \xi\gamma_2, \lambda_3 = \xi\gamma_3, \lambda_4 = (1-\xi)$.

### *State-Based Energy Balance Identity*

For modeling purposes, a set of state-based energy balance identities are interpreted as:

$$\ln(PE_{st}) \equiv A_i + B_i \ln(e_{st}) + C_i \ln(g_{st}) + R_{st} \quad (5)$$

where e is electricity demand (MWh) and g is natural gas demand (TJ). $A_{st}$, $B_{st}$, $C_{st}$, $R_{st}$ can be estimated by ordinary least-square (OLS) method. Initially, $R_{st}$ is considered as a disturbance term of the regression. After $A_{st}$, $B_{st}$, $C_{st}$ are estimated, $R_{st}$ can be measured in TJ units by substituting $A_{st}$, $B_{st}$, $C_{st}$ in Equation 5; it represents the reminder of the energy balance identity[1].

***Electricity Demand Function***

Electricity demand depends upon real electricity prices, real gas prices, and real state production. A general functional form of the electricity demand function for this study is written as:

$$e_{st} = f_2(y_{st}, p_{gst}, p_{est}) \quad (6)$$

where $P_{est}$ is real electricity price (¢/kWh); and $P_{gst}$ is real natural gas price (¢/kWh). In order to create a realistic model for electricity demand function, two dummy variables are introduced, namely, $d_{1st}$ and $d_{2st}$. $d_{1st}$ is a structural dummy variable for the electricity industry, which assumes values of 0, 1, and 2 depending on the type of industry structure, e.g., vertical integrated, ring-fenced, and functional unbundled, respectively. $d_{2st}$ is the ownership dummy variable for the electricity industry, which is equal to 0, 1, and 2 depending on the type of ownership, e.g., public, mixed, and private, respectively. With the introduction of time-lag effects, and following Kyock transformation method, Equation 6 can be written as:

$$\begin{aligned} lne_{st} &= \beta_0 + \beta_1 lny_{st} + \beta_2 lnp_{gst} \\ &+ \beta_3 lnp_{est} + \beta_4 ln(e_{st-1}) + \beta_5 d_{1st} \\ &+ \beta_6 d_{2st} + \varepsilon_2 \end{aligned} \quad (7)$$

***Gas Demand Function***

Gas demand, similar to electricity demand, depends upon real gas prices, real electricity prices, and real state production. A general functional form of the natural gas demand function can be written as:

$$g_{st} = f_3(y_{st}, p_{gst}, p_{est}) \quad (8)$$

where $P_{gst}$ is real natural gas price (¢/kWh); and $P_{est}$ is real electricity price (¢/kWh). In order to create a realistic model for gas demand function, two dummy variables are introduced, namely, $d_{3st}$ and $d_{4st}$. $d_{3st}$ is a structural dummy variable of the gas industry, which assumes values of 0, 1, and 2 depending on the type of industry structure, e.g., vertical integrated, ring-fenced, and functional unbundled, respectively. $d_{4st}$ is the ownership dummy variable of the gas industry, which is equal to 0, 1, and 2 depending on the type of ownership, e.g., public, mixed, and private, respectively. With the introduction of time-lag effects, and following Kyock transformation method, Equation 8 can be written as:

$$\begin{aligned} lng_{st} &= \alpha_0 + \alpha_1 lny_{st} + \alpha_2 lnp_{gst} \\ &+ \alpha_3 lnp_{est} + \alpha_4 ln(g_{st-1}) + \alpha_5 d_{3st} \\ &+ \alpha_6 d_{4st} + \varepsilon_3 \end{aligned} \quad (9)$$

[1] This state-based energy balance identity is a strategy to overcome the lack of state-based energy balance data in Australia.

Substituting the state-based energy balance identity, Equation 5 in Equation 4, creates a system of three simultaneous equations:

$$\begin{aligned} lny_{st} &= \lambda_0 + \lambda_1 lnL_{st} + \lambda_2 lnK_{st} \\ &+ \lambda_3 ln[A_i + B_i ln(e_{st}) + C_i ln(g_{st}) + R_{st}] \\ &+ \lambda_4 lny_{st-1} + \varepsilon_1 \end{aligned}$$

$$\begin{aligned} lne_{st} &= \beta_0 + \beta_1 lny_{st} + \beta_2 lnp_{gst} \\ &+ \beta_3 lnp_{est} + \beta_4 ln(e_{st-1}) + \beta_5 d_{1st} \\ &+ \beta_6 d_{2st} + \varepsilon_2 \end{aligned} \quad (10)$$

$$\begin{aligned} lng_{st} &= \alpha_0 + \alpha_1 lny_{st} + \alpha_2 lnp_{gst} \\ &+ \alpha_3 lnp_{est} + \alpha_4 ln(g_{st-1}) + \alpha_5 d_{3st} \\ &+ \alpha_6 d_{4st} + \varepsilon_3 \end{aligned}$$

Various own and cross price elasticities of demand can be presented as:

$$E_{GG} = \left( \frac{dg_{st}}{dp_{gst}} . \frac{p_{gst}}{g_{st}} \right) \quad (11)$$

$$E_{EE} = \left( \frac{de_{st}}{dp_{est}} . \frac{p_{est}}{e_{st}} \right) \quad (12)$$

$$E_{GE} = \left( \frac{dg_{st}}{dp_{est}} . \frac{p_{est}}{g_{st}} \right) \quad (13)$$

$$E_{EG} = \left( \frac{de_{st}}{dp_{gst}} . \frac{p_{gst}}{e_{st}} \right) \quad (14)$$

Where: $E_{GG}$ is own price elasticity of demand for gas; $E_{EE}$ is own price elasticity of demand for electricity; $E_{GE}$ is cross price elasticity of demand for gas; and $E_{EG}$ is cross price elasticity of demand for electricity. From Equations 7 and 9, elasticities of demand can be determined directly as coefficients $\alpha_2$, $\beta_3$, $\alpha_3$, and $\beta_2$, respectively [14].

## 4. DATA CONSIDERATIONS

The data employed in this research is a panel data for 7 states (NSW, VIC, QLD, SA, WA, and NT) from 1990 to 2004 and was collected from various sources including Australian Bureau of Statistics (ABS), Australian Bureau of Agricultural and Resource Economics (ABARE), Energy Supply Association of Australia (ESAA, former Electricity Supply Association of Australia), and the Australian Gas Association (AGA) [15]-[16].

*Aggregate production function* comprises gross state production (GSP), labor (L), capital (K), and primary energy consumption (PE). Gross state production (GSP) is a dollar term of the total production in each state, provided by the ABS yearly report. Labor is estimated by the total number of employee in each state. Capital stock for each state is estimated using the ratio of capital expenditure (investment) for each state. These sets of data were obtained from the data prepared yearly by ABS from 1990 to 2004. The data for primary energy consumption at state level is not publicly available. This shortfall is overcome by the introduction of the state-based energy balance identity (Equation 5).

*Electricity and gas demand equations* consists of four key parameters: electricity demand (e), gas demand (g), electricity price ($P_e$), and gas price ($P_g$). To identify demand in a particular year, consumption rate is used as a proxy for demand for that year. The annual electricity and gas consumption is obtained from ABARE. The price data for electricity and gas were calculated by using the average value of the residential and business electricity and gas prices published annually by ESAA and AGA, respectively.

## 5. EMPIRICAL RESULTS

Results obtained from the regression analysis of the simultaneous and single electricity and gas demand equations are presented in Table 1.

**Table 1. Own and cross price elasticities of demand for electricity and gas**

| | AUS | NSW | VIC | QLD | SA | WA | NT |
|---|---|---|---|---|---|---|---|
| $\varepsilon_{e,pel}$ | -0.05 | -0.15 | -0.05 | -0.29 | -0.23 | -0.55 | -0.39 |
| | *(0.0000)* | *(0.0483)* | *(0.0270)* | *(0.0270)* | *(0.0500)* | *(0.0048)* | *(0.0051)* |
| $\varepsilon_{e,pg}$ | n/a* | 0.38 | 0.07 | 0.35 | 0.39 | 0.53 | -0.39 |
| | *n/a* | *(0.0279)* | *(0.0378)* | *(0.0138)* | *(0.0276)* | *(0.0403)* | *(0.0001)* |
| $\varepsilon_{g,pg}$ | -0.11 | 0.27 | 0.03 | -2.59 | 0.83 | 2.05 | -0.59 |
| | *(0.0080)* | *(0.0400)* | *(0.0008)* | *(0.0050)* | *(0.0450)* | *(0.0003)* | *(0.0350)* |
| $\varepsilon_{g,pel}$ | -0.10 | -0.36 | -1.88 | 1.20 | -0.44 | -1.37 | -0.09 |
| | *(0.0000)* | *(0.0270)* | *(0.0270)* | *(0.0280)* | *(0.0190)* | *(0.0001)* | *(0.0070)* |

Note: numbers in the parentheses show the t-stat at 95% level of significance
* Not applicable because the coefficient is statistically rejected

The results and some reasons behind these results are discussed below:

***Nation-Based Results***

At the national level, there appears to be a weak (inelastic) relationship between electricity and gas. Further, gas demand is relatively more sensitive to own price variations as compared with electricity. This is largely due to the limitation in the appliance that has no alternative to electricity, for example, lighting; while there are alternatives in most of gas appliances. In the absence of a cross price elasticity of demand in electricity, it is not possible to develop reliable analysis at this level. Some preliminary estimates, based on state-based data and individual equations, are however developed in this study, and are analyzed in the next section. At the national level, it could be argued that electricity and gas are distinct commodities, with insignificant interrelationship. Each of them has its own customer base. Even though the choice is available for buyers to substitute between electricity and gas, customers appear to remain royalty to their products. As natural gas is generally traded through the long-term contract particularly in upstream level, the short-run elasticities might not be able to capture such relationship. However, in electricity generation sector, the possibility to switch the input from coal to natural gas or vice versa is relatively difficult. This has been largely due to the high capital cost of switching the power plant type and not only gas is traded through long term contract, but also coal is traded through long term contract.

***State-Based Results***

The results show that each state has its own specific energy consumption behavior.

- In contrast to the weak relationship (between electricity and gas) at the national level, such relationship at the state levels is varied. For example, NSW, Southern Australia (SA) and Northern Territory (NT) show weak relationship, while Victoria (VIC), Queensland (QLD) and WA show relatively strong relationship. Further, the relationships are stronger for the demand of gas (in response to changes in the price of electricity). This is likely due to the availability of natural gas in the states. For example, VIC, QLD, and WA have appreciable proven natural gas reserves, while NT and SA do not. Therefore, due to the incremental costs of gas transport, the possibility of substitution is lower.
- In VIC, demand for both electricity and gas are less sensitive to gas price variations, whereas, changes in electricity price effects only its own demand. On the other hand, when the electricity price decreases, demand for gas increases. Such increase in the demand for gas in respect to decrease in electricity price might be due to the increasing use of natural gas as a primary energy fuel to generate electricity. As a result, natural gas consumption rate for electricity generation purpose, in VIC, is continuingly increased.
- Electricity demand in WA is quite sensitive to the variations in the prices of electricity and gas. This is because the largest gas reserve in Australia is located in this state (Carnarvon Basin) [17]. After natural gas reticulation system was fully established in WA, natural gas became a significant energy resource and natural gas consumption rate increased continually. Further, the demand for gas remains high, even when the gas price increases. It can be concluded that natural gas is the main energy resource for end users as well as for electricity producers in WA as the percentage of natural gas consumption in WA is approximately 50 percent of the total energy consumption in 2005 [15].
- In Queensland (QLD), the variation in gas prices has

more effect on electricity and gas demand as compared with electricity price variations. This might be due to the efficiency of the QLD electricity industry [18] and also the lack of availability of natural gas resources in the state. In addition, most of natural gas customers are in the industrial sector who buys natural gas in bulk. Only 13% of natural gas sale is for the residential sector [19]. Therefore, as soon as gas price increases, customers immediately substitutes gas with electricity, which is cheaper.

- There is a similar pattern of energy consumption behavior in NSW and SA. The demand for gas in SA is, however, slightly more sensitive to price variations as compared to its demand in NSW.
- Another intriguing finding from the state-based result is that, in NSW, VIC, SA, and WA, the extent of own price elasticity of gas demand is positive. These results contradict with the nature of demand function which is an inverse relationship between price and quantities. This might be resulted from the proxy of observation data. Gas prices change constantly during the year, depending on weather and availability. The prices data in this study is, however, estimated on annual basis using the average prices of business and residential sectors during the year. This might cause some misspecification problem and lead to the positive value of the own price elasticity of gas demand. The long term contract of natural gas trading might, moreover, relate to this problem. As natural gas was introduced as commercial scale after 1980, a number of new natural gas customers have constantly increased every year. The important point is that gas prices are lower than electricity prices. Even in the year that gas prices increased, customers continue to consume and select natural gas rather than switch to electricity.

## 6. CONCLUSION AND FURTHER DISCUSSION

Electricity and gas industries are major industries in the Australian economy. Both industries were subjected to reform in the early 1990s, with a core objective of improving their efficiency through recourse to market competition. These reforms are being undertaken separately for each industry, in total disregard of the relationship that may exist between these two industries. Some people have alluded to the need for understanding the nature of this relationship as it may provide useful insights to developing more meaningful reform program for each of this industry. This paper is a preliminary attempt in that direction.

The relationship between electricity and gas industries are examined both through qualitative historical analysis, and quantitative analysis, supported by cross price elasticities of demand between electricity and gas. These elasticities are estimated using a simultaneous demand function for electricity and gas. Even though many studies have argued about the existence of the relationship between electricity and gas industries in Australia, the result from the model applied in this paper suggests that the relationship between electricity and gas industries (at the national level) is in fact very weak. It is further shown in the analysis at the state level that the relationship between these industries is varied with mix of strong and weak relationship. This study, therefore, argues that there is a weak relationship between these two industries, which has also been supported by the historical survey of this paper. The qualitative analysis of this paper, however, strongly suggests that there is a need to appreciate the institutional relationship between these industries, which will then enhance the economic prosperity and social wellbeing.

This research studies the historical relationship between electricity and gas industries in Australia in term of qualitative and quantitative perspective. The contradictive result between qualitative and quantitative analyses demonstrate that not only the limitation of econometric analyze is found, but also the relationship between both industries in mid-stream (i.e., transmission and distribution) is needed to take into the account of the design of the future reform program. The quantitative result, moreover, witnesses the failure attempt of improving the relationship between both industries especially in Australia, in general. This demonstrates the lack of collaboration between interstate energy regulators and policy makers. As the strong relationship is found in the qualitative analyses, it shows that the benefits of the reform program in both industries can be enhanced if one can take such relationship into the design of future reform program.

However, this econometric model has some weaknesses, as some of the coefficients are statistically rejected, such as the cross price elasticity in electricity demand, structure and ownership dummy variables (which is not presented in this paper). The result from regression analysis can be, moreover, improved if the more frequency and wider range of the observation data were used, for example monthly or quarterly price data. In addition, the research in upstream and downstream levels in electricity and gas industries would clarify the understanding of the relationship between both industries, as the core relationship between both industries occurred mainly in both upstream and downstream levels. Despite of this weakness, the model provides an insight result emphasis on the true relationship between electricity and gas industries. This model can also be able to apply with the other nexus, such as energy and water or electricity and oil. While this paper focuses on Australia, its findings should be relevant for other countries that are in the process of reforming their electricity and gas industries.

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