IMPACTS OF MARKET-ORIENTED ELECTRICITY REFORM ON ECONOMIC GROWTH: A CASE STUDY FOR 19 OECD COUNTRIES AND 7 AUSTRALIAN STATES

Reza Fathollahzadeh Aghdam[a*]; Deepak Sharma[b]; Mohsen Al-Hajji[a]; Talat Ulussever[a]
[a] King Fahd University of Petroleum and Minerals
[b] University of Technology, Sydney

**Corresponding Author: PO Box 257, KFUPM, Dhahran 31261, Saudi Arabia; Phone: +966-3-860-7525; Email: rezafa@kfupm.edu.sa or reza_f_a@yahoo.com*

ABSTRACT

This paper examines the impacts of market-oriented electricity reform on macroeconomic variables – real GDP growth, in particular. It develops an ad hoc econometric model for this purpose, using a panel data of 19 OECD countries plus 7 Australian States for the period of 1970–2008. Significance of the impacts are firstly tested against three distinct institutional features of electricity reform, namely: (i) Organisational Restructuring (i.e. Functional Unbundling of traditionally Vertically Integrated industry); (ii) Market Restructuring (introduction of mandatory bid-based spot market); and (iii) Privatization. The extents of the impacts are, then, quantified in terms of relative contribution of such institutional changes to real GDP growth in short-, medium- and long-run. The results reveal that only Functional Unbundling has made significant contribution to real GDP growth, whereas Market Restructuring and Privatization have not. The results, further, specify that Functional Unbundling has made, on average, an additional 0.06, and 2.7 percent contribution to real GDP growth rate in medium- and long-run, respectively. Such impacts, the results of this paper suggest, are presumably induced by the productivity gains that seem to be achieved as a result of lower electricity prices and more price-elastic electricity demands in economies, where electricity industry is organisationally restructured (i.e., Functional Unbundled).

1. Introduction

Since the 1990s, the Australian electricity supply industry, alongside many other countries, has been undergoing a significant reform (Sioshansi and Pfaffenberger, 2006). Such a global reform even though differs from country to country in terms of its country-specific features, it mostly follows a common reform-model as an institutional change. This reform-model is often called the market reform attributable to its underlying free market philosophy, emphasizing on promotion of competition through a bid-based market structure (see also, Quiggin, 2001; Sharma, 2003).

The reform has changed almost all institutional facet of the industry including: organisational structure, market structure, regulatory framework and ownership arrangement. The traditionally vertically integrated organisation of the industry has been functionally unbundled. The market structure of the industry has been drastically moved away from the traditional order-of-merit mechanism to a mandatory bid-based system. Nation-wide regulatory frameworks have been introduced for overseeing and harmonizing activities of state-based or regional regulatory bodies. In addition, considerable parts of the industry have been privatised.

Key aspects of such changes in terms of industry's organisational structure, market structure and ownership arrangement are summarized in Table 1 for a set of 19 OECD countries. Regarding the case of Australia, the data is decomposed by 7 Australian states as well. Following Hattori and Tsutsui (2004), in preparation of this table, the effect of functional unbundling is realized, when the transmission system operator has become an independent entity. In this definition, accounting separation is not regarded as functional unbundling. The existence of a wholesale market (power pool) is captured, when hourly or half-hourly spot prices are determined through a bidding process. There are some sorts of 'tight power pool' in some countries even prior to the market reform, but such power pools are not considered in this definition. Finally, the extents of privatization are captured by the share of private ownership, essentially in the generation segment, whether the share has gone above 25%, 50% or 75%, respectively. For example, in the state of Victoria (Australia), such a share was far below 25% up until 1994. In 1995, this exceeded above 50% and, since 1996, this has increased to more than 75%.

Table 1: Electricity Reform Timing and Economic Growth in Selected Countries

	functionally unbundeled	wholesale market	share of privatization exceeded 25%	50%	75%	real GDP in 2008 b US$	average annual growth 1970-1990 %	1990-2008 %
NSW	1994	1996	na***	na	na	171.7	-****	2.8
VIC	1993	1995	na	1995	1996	140.4	-	3.4
QLD	1995	1998	na	na	na	101.3	-	4.8
SA	1997	1998	na	na	2000	36.6	-	2.7
WA	2003	2006	na	na	na	60.7	-	4.6
TAS	1998	2006	na	na	na	10.3	-	2.9
NT	na	na	na	na	na	6.7	-	3.8
AUS	1993*	1998**	1995	na	na	527.6	2.9	3.5
BEL	1987	na	na	na	1970	269.8	2.7	2.0
CAN	1996	1996	na	na	na	873.3	3.4	2.6
DNK	1998	1999	1970	na	na	176.6	2.1	2.0
FIN	1997	1996	1970	1998	na	152.1	3.3	2.3
FRA	na	na	na	na	na	1517.5	3.0	1.8
DEU	na	na	na	1970	na	2092.1	2.6	1.7
GRC	na	na	na	na	na	175.2	2.6	3.1
IRL	na	na	1999	na	na	139.4	4.1	5.8
ITA	1999	na	na	na	1970	1179.4	3.1	1.3
JPN	na	na	na	na	na	5164.6	4.1	1.3
NLD	1998	1999	1990	na	na	448.6	2.6	2.6
NZL	1994	1996	1999	na	na	66.0	1.8	2.8
NOR	1992	1991	na	na	na	202.1	3.5	3.0
PRT	1994	na	1997	1998	na	121.5	3.9	2.0
ESP	1987	1998	na	1970	na	742.8	3.2	2.9
SWE	1992	1998	1970	na	na	297.1	2.1	2.2
GBR	1990	1990	na	na	1991	1777.6	2.3	2.4
USA	1998	1998	na	na	1970	11596.2	3.2	2.8

States/Countries are as follow: New South Wales (NSW), Victoria (VIC), Queensland (QLD), South Australia (SA), Western Australia (WA), Tasmania (TAS), Northern Territory (NT), Australia (AUS), Belgium (BEL), Canada (CAN), Denmark (DNK), Finland (FIN), France (FRA), Germany (DEU), Ireland (IRL), Italy (ITA), Japan (JPN), Netherlands (NLD), New Zealand (NZL), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), United Kingdom (GBR), and United States (USA).
* This is the time when first unbundling (Victorian) was experienced.
** This is when National Electricity Market among major in-land states (i.e., NSW, VIC, QLD and SA) was established.
*** "na" is "not applicable".
**** "-" means that data is not available and, hence, figures are "not calculable".

In addition, Table 1 indicates real GDP of these countries in 2008. It also shows average annual growth rate of real GDP for the periods of 1970-1990 and 1990-2008, which approximately reflect periods of before and after the market reform, respectively. On the basis of these figures, one can make no straightforward comment on whether there is any relationship between economic growth and implication of the market reform.

Nevertheless, the principle rational behind the market reform has been that this reform would improve the productivity of the industry, lowering electricity price, and ultimately enhance social well-being of people by contributing to economic growth at large.

Several studies have been conducted to substantiate such rationales. Most previous studies are focused on assessing the microeconomic impacts of electricity reform (i.e., analyzing reform's impacts on productivity of the industry). These studies mostly assume, implicitly, that sectoral productivity gains, if there are any, would unquestionably pass on a positive impact on real GDP growth. This logic might be true to a certain extent, but, in order to capture the true extents of macroeconomic impacts, one still need to undertake empirical analysis at macro level, using appropriate approach. The reason for this is that while sectoral productivity gains are necessary conditions towards gains at macroeconomic level, they cannot surely be sufficient conditions towards that end.

Against this background, the main objective of this paper is to examine the impacts of the market reform on macroeconomic variables – real GDP growth, in particular. The paper is organised as follow. Section 2 is devoted to literature review. Section 3 describes the model specification. Section 4 provides empirical results. Section 5 presents the conclusions.

2. Literature review

As noted, several studies have been conducted to substantiate the above-described rationales behind the market reform, both at national and international contexts. Analysis of such studies can be divided into two groups: (i) analyses of the impacts of electricity reform on productivity of the electricity industry; (ii) analyses – relying largely on the results of the first set of studies (either exogenously given or carried out independently) – of the impacts of electricity reform on economic performance of the wider economy that is essentially expressed in terms of real GDP growth (see also, Aghdam, 2011). In the context of this paper, the first group of analyses is called *micro-impact studies*, while the second group is called *macro-impact studies*. In turn, the impacts measured on the basis of the former are called *micro-impacts*, while the impacts measured on the basis of the latter are called *macro-impacts*. Methodologies used among micro- and macro-impact studies are distinct, too. In this section, the literature of this topic is briefly reviewed, with a view to identify a research gap, which ultimately is going to be addressed by this paper.

2.1. Micro-impact studies

With regards to micro-impact studies, at international context, the most important breakthroughs are made in the works of Pollitt (1995), Steiner (2000) and Hattori and Tsutsui (2004). Pollitt (1995) pioneers in international benchmarking and international surveys on this topic. Common methodology of micro-impact studies is a mix of a productivity analysis and some parametric and non-parametric hypothesis-testing (based on χ^2-, F-, or t-stat). Such a mix methodology was already well developed by several works, at country-specific contexts, that had assessed the impacts of privatization on productivity measures of the electric utilities. For instance, one can refer to seminal works of Färe et al. (1985) and Atkinson and Halvorsen (1986), in the context of the USA. Contributions of Steiner (2000) and Hattori and Tsutsui (2004) are significant, too. They introduce a set of well-defined binary or discrete variables (dummy variables) for capturing the reform-driven institutional changes. Further, they employ a parametric (regression) approach for hypothesis-testing (based on F- and t-stat). For example, Hattori and Tsutsui (2004) focuses on whether various institutional changes of the reform (captured by certain dummy variables) have truly affected electricity price, which is considered as the most important constituent of productivity gains. Micro-impact studies, at country-specific contexts, have a vast literature (see, Pollitt, 1997). For example, only in the context of Australia, one can cite a long set of studies, including: Lawrence et al (1990); London Economics (1993); Bureau of Industry Economics (BIE, 1994); Industry Commission (IC, 1991, 1995); Quiggin (1997); Short et al.(2001); Abbott (2006) and Aghdam (2011). The latter provides a concise summary about these studies.

2.2 Macro-impact studies

As mentioned above, marco-impact studies largely rely on the results of micro-impact studies, either exogenously given or carried out independently. They essentially aim to assess the impacts of electricity reform on real GDP growth and some other aggregate variables. Review of the literature reveals that macro-impact analysis has received lesser attention than micro-impacts, particularly at international context. Even at national levels, it has been more controversial than micro-impact studies. In the context of Australia, for instance, one can cite the following macro-impact studies: Industry Commission (IC, 1991, 1995); Quiggin (1997); Whiteman (1999); and Productivity Commission (PC, 1999). As their main methodology, these studies mainly employ Computable General Equilibrium (CGE) model together with scenario analyses to evaluate macroeconomic benefits of the market reform.

It is argued that scenario analyses of these studies suffer from a methodological weakness in assessing the impacts of electricity reform. SAIIR (2002), for instance, points out that 'the most common approach to estimate benefits of reform has been to estimate a best practise outcome for the electricity sector, and then assume that reform will achieve that outcome'. This implies that impacts of electricity reform have been assessed by the gap between two scenarios, namely no-reform and reform. The no-reform scenario consists of the continuation of the pre-reform trends of productivities, whereas the reform scenario assumes that these productivities will be improved to the best- practise benchmark. CGE model is, then, used to simulate and project the reform-induced macro-impacts, driven by assumed productivity gains. Productivity gains at sectoral level obviously cause unemployment rate raise in the short run. In CGE models, it is essentially assumed that the uemployed labour will quickly find employment elsewhere in the economy. This is a very strong assumption. According to Quiggin (1997), this is a critical methodological weakness. Quggin also argues that these studies are unable to specify 'what changes in practice need to take place, that reform will induce … *the electricity industry* … to emulate the performance of the benchmarked enterprise' (Quiggin, 1997, italic added). In other words, scenario analysis assumes these gains as somewhat granted as a result of reform. Such assumptions involves 'substantial leap of faith' (Johnson and Rix, 1991; SAIIR, 2002).

Perhaps, application of CGE model with scenario analysis, using counterfactuals, is known as inevitable for assessing micro- or macro-impacts of the reform, prior to, or in the early stages of implementation of the reform. However, more than two decades after implementation of the market reform, with few exceptions, it has still been a dominant approach. A robust approach should indeed allow for testing hypotheses against a suitable panel dataset. Panel should include both reformed and no-reformed firms/industries. In this way, dataset would contain actual counterfactuals rather than those of which are developed on the basis of subjective scenario assumptions.

Having said that, there is certainly a research gap to be filled, and this paper is one such attempt.

3. Model specification

This papers essentially follows Hattori and Tsutsui (2004) approach towards the topic, but for the purpose of a macro-impact analysis. A set of dummy variables (very much like those developed by Hattori and Tsutsui (2004)) is used in the model, allowing for hypothesis-testing against significance of various elements of the reform in improving economic growth. Three distinct institutional facet of the market reform are taken into consideration, namely: (i) Organisational Restructuring (i.e. Functional Unbundling of traditionally Vertically Integrated industry); (ii) Market Restructuring (introduction of mandatory bid-based spot market); and (iii) Privatization (i.e., reflecting ownership arrangement in a sense that to what extent the arrangement has shifted from public to private ownership). Accordingly, three dummy variables are defined to capture such institutional facet:

(1) Organisational structure, **S**: the value is 1 if functionally unbundled, and 0 if vertically integrated;
(2) Market structure, **M**: the value is 1 if mandatory bid-base, and 0 if traditional order-of-merit;
(3) Ownership arrangements, **O**: the value is 3 if the share of private ownership (in electricity generation) is more than or equal to 75%; 2 if the share is more than or equal to 50% but less than 75%; 1 if the share is more than or equal to 25% but less than 50%; and 0 if the share is less than 25%.

The paper develops an ad hoc econometric model using a panel dataset of 19 OECD countries plus 7 Australian states for the period of 1970–2008. The ad hoc model of this paper consists of a system of simultaneous equations as a structural model that shows micro-to-macro links of electricity-economy nexus. In other words, the model is specified in a way to capture interrelationship between relevant micro- and macro-economic variables. This model basically aims to examine the relationship between electricity/energy demand and aggregate output. Demand and supply of money are also included in the model (in a separate equation) with a view to capture inflation phenomena, endogenously. The model is dynamic, using the partial adjustment method that was firstly developed by Moroney (1992) for elaborating energy-economy nexus. This method is a way of justifying the application of the Koyck (1954) transformation (see also, Fisher and Kaysen, 1962; Houthakker and Taylor, 1970; Moroney, 1992). In this method, the gap between the desired (or expected) level of a variable (e.g., electricity demand, aggregate output or price level) and its actual level is gradually adjusted over time. One of the main advantages of this model is that it allows measurement of short-, medium-, and long-term impacts of a policy change, which can be traced either by a change in an exogenous variables or by a reform-driven change in the parameters of the model. This becomes possible by derivation of the reduced- and final-forms of the model. Coefficients of structural form help to interpret the short-run impacts, whereas coefficients of reduced- and final-forms help to interpret medium- and long-run impacts, respectively.

It is worth noting that one of the main disadvantages of this model, which is also classified under "adaptive expectation" models, is the cretisim that is satated by Robert Lucas (1937-) and alike, arguing that partial adjustment assumption undermines one of the fundamental principles of economics, which assumes human being is rational.

The structural form of the model (without insertion of any reform-related dummy variables) is as follow:

$$\ln(e_{it}) = C(10) + C(11)\cdot\ln(y_{it}) + C(12)\cdot\ln(\frac{p_{it}}{\pi_{it}}) + C(13)\cdot\ln(e_{it-1}) + \varepsilon_{1it} \quad (1)$$

$$\ln(y_{it}) = C(20) + C(21)\cdot\ln(k_{it}) + C(22)\cdot\ln(l_{it}) + C(23)\cdot\ln(E_{it}) + C(24)\cdot\ln(y_{it-1}) + \varepsilon_{2it} \quad (2)$$

$$\ln(\pi_{it}) = C(30) + C(31)\cdot\ln(M1_{it}) + C(32)\cdot\ln(r_{it}) + C(33)\cdot\ln(Y_{it}) + C(34)\cdot\ln(\frac{M1_{it}}{\pi_{it}}) + \varepsilon_{3it} \quad (3)$$

Where: e (TWh) is electricity demand (consumption)
y (billion US$) in terms of fixed prices of 2000, using exchange rate
Y (national currencies) is nominal GDP
p (US$/kWh) is electricity price
k is capital stock index (2000=100)
l ('000 person) is employed labour force
E (Mtoe) is total primary energy supply (TPES)
π is overall price index indicator (2000=100)*
$M1$ is the narrow monetary index (2000=100)
r (% per annum) is short-run interest rate
i is cross-section (country) identifier
t is time
ε_s are normal disturbance term
C(.) indicate parametric coefficients of the model.

Equation (1) denotes electricity demand function, whereas equation (2) shows aggregate output function. Equation (3) reflects the behaviour of overall price level (inflation) that is driven on the basis of equilibrium in money market (i.e., balance between real demand and supply of money: $M1/\pi = L(r,Y)$ (see e.g., Krugman and Obstfeld, 2009)).

Variables e, Y (also y) and π are endogenous in this model. Other variables are predetermined. There are two identities that need to be explained in relation to the above structural form of economy. These are identities for: *(i)* energy balance; and *(ii)* real and nominal GDP.

On the basis of each country's energy balance, there is a one-to-one relationship between electricity demand (e) and total primary energy supply (E). That is to say that knowing the amount of one implies knowing the amount of the other, if the amount of all other energy-contents (e.g., oil, gas, etc.) are given. Energy balance is a very complex identity. In order to simply it for the purpose of this paper's model, the coefficient of the following equation is introduced as an approximation to energy balance identity.

$$\ln(E_{it}) = C(40) + C(41)\cdot\ln(e_{it}) + C(42)\cdot\ln(E_{it-1}) + C_i(43) + \varepsilon_{4it} \quad (4)$$

Where, $C_i(.)$s are fixed- or random-effect (country-specific) intercepts. Once all coefficients and the values of disturbance term (ε_{4it}) are estimated for equation (4), one could specify the energy balances identity as follow:

$$\ln(E_{it}) \equiv \hat{C}(40) + \hat{C}(41)\cdot\ln(e_{it}) + \hat{C}(42)\cdot\ln(E_{it-1}) + \hat{C}_i(43) + \hat{\varepsilon}_{4it} \quad (5)$$

Equation (5), in turn, can be inserted in the right-hand-side of equation (2) for $\ln(E_{it})$.

In addition, the identity for real and nominal GDP is as follows:

* This is measured by GDP deflator, but also used as consumer price index (CPI)

$$y_{it} \equiv \frac{Y_{it}}{\pi_{it} \cdot \chi_{i0}} \tag{6}$$

Where χ_{i0} shows exchange rate in the base year (2000).

After insertion of these two identities in the structural form, it is clear that the model surely consists of a system of simultaneous equation and its coefficients should be estimated, according to relevant econometric approaches.

A vital modelling question is still remaining: where the dummy variables should be inserted in the model? Following the ideas behind Hattori and Tsutsui (2004) and alike, this model also assumes that micro-impacts of the reform should be realized firstly through electricity prices as the most important constituent of productivity gains. As a result, electricity demand function will be affected. Consequently, the ramification of changes in electricity demand will eventually be realized in other macroeconomic variables (e.g., output growth). Therefore, this logic justifies that the reform-related dummy variables must be inserted in equation (1). This implicitely implies that there is no short-run macroeconomic gains from electricity reform, which sounds plausible. Such gains are always medium- and long-run impacts.

One can imagine that two types of price-impacts on electricity demand is likely: (a) sudden impact, when electricity prices creates an impulsive change in electricity demand – a change in intercept; (b) gradual or ongoing impacts, when demand curves become more/less responsive to price change – a change in the slope (price-elasticity).

The following system is the transformed version of the above-described structural equations, after inserting all possible dummy-variable-terms (intercepts and slopes) in the demand curve and, also, after substituting the above-defined identities (equations (5) and (6)).

$$\begin{cases} \ln(e_{it}) = C(10) + C(11)\cdot\ln(\frac{Y_{it}}{\pi_{it}\cdot\chi_{it}}) + C(12)\cdot\ln(\frac{p_{it}}{\pi_{it}}) + C(13)\cdot\ln(e_{it-1}) + C(101)\cdot S_{it} + C(102)\cdot M_{it} \\ \quad + C(103)\cdot O_{it} + C(121)\cdot S_{it}\cdot\ln(p_{it}) + C(122)\cdot M_{it}\cdot\ln(p_{it}) + C(122)\cdot O_{it}\cdot\ln(p_{it}) + \varepsilon_{1it} \\ \ln(\frac{Y_{it}}{\pi_{it}\cdot\chi_{it}}) = C(20) + C(21)\cdot\ln(k_{it}) + C(22)\cdot\ln(l_{it}) + C(23)\cdot[\hat{C}(40) + \hat{C}(41)\cdot\ln(e_{it}) \\ \quad + \hat{C}(42)\cdot\ln(E_{it-1}) + \hat{C}_i(43) + \hat{\varepsilon}_{4it}] + C(24)\cdot\ln(y_{it-1}) + \varepsilon_{2it} \\ \ln(\pi_{it}) = C(30) + C(31)\cdot\ln(M1_{it}) + C(32)\cdot\ln(r_{it}) + C(33)\cdot\ln(Y_{it}) + C(34)\cdot\ln(\frac{M1_{it}}{\pi_{it}}) + \varepsilon_{3it} \end{cases} \tag{7}$$

It will be useful to re-write the system (7) in matrix algebra, as follows:

$$\mathrm{B}\widetilde{y}_{it} = \Gamma X_{it} + u_{it} \tag{8a}$$

where B is 3×3 matrix of the coefficients of endogenous variables (i.e., e, Y and π), $\widetilde{y}_{it}$ is the 3×1 vector of endogenous variables, Γ is the 3×14 matrix of coefficients of the predetermined variables, and u_{it} is the 3×1 vector of disturbance terms. With suitable partitions one can yet re-write (8a) as follows:

$$\mathrm{B}\widetilde{y}_{it} = [\Gamma_1 \vdots \Gamma_2]\cdot\begin{bmatrix} x_{it} \\ \cdots \\ \widetilde{y}_{it-1} \end{bmatrix} + u_{it} \tag{8b}$$

Where predetermined variables (and their corresponding coefficients) are separated into exogenous (x_{it}) and lagged-endogenous variables ($\tilde{y}_{it-1}$). In order to drive the reduced form of the model, one should algebraically solve the system (8b) with regards to predetermined variables. That is:

$$\tilde{y}_{it} = \Pi X_{it} + \nu_{it} \tag{9}$$

Where $\Pi = [\Pi_1 \vdots \Pi_2]$, $\Pi_1 = \mathrm{B}^{-1}\Gamma_1$, $\Pi_2 = \mathrm{B}^{-1}\Gamma_2$ $\nu_{it} = \mathrm{B}^{-1}u_{it}$.

In the long run, desired variables will equate actual ones. That is when $\tilde{y}_{it} = \tilde{y}_{it-1}$. In matrix language, that is to write:

$$\tilde{y}_{it} = \Xi X_{it} + \iota_{it} \tag{10}$$

Where $\Xi = (1-\Pi_2)^{-1}\Pi_1$ and $\iota_{it} = (1-\Pi_2)^{-1}\nu_{it} = (1-\Pi_2)^{-1}\mathrm{B}^{-1}u_{it}$.

Eviews7 software package is used to run the model and estimate its parametric coefficients. Further, Microsoft Excel is used to calculate coefficients of reduced- and final-forms. Eviews7 allows application of both single-equation and system methods, in two distinct ways of pool- and panel-data techniques. Authors have firstly employed single equation method with pool-data technique. At this stage, dummy variables are not inserted (equations 1, 2, 3 and 4). Two-Stage Least Square estimation method is used for this, and Hausman test is applied to choose between fixed- or random-effect. This allows us to investigate the soundness of the model specification for capturing electricity-economy nexus..

Then, panel-data technique is employed to estimate parameters of the system model (7). At this stage, for the sake of simplifying the model, common coefficient are considered for the system (no fixed or random effect are assumed). This allows to capture an overall (global) macro-impacts of the model over the sample countries/states.

4. Empirical results

Table 2 summarizes the results of estimations, using single equation approach. This refers to equations 1, 2, 3 and 4. Two Stage Least Square (2-SLS) method is applied. Likelihood Ratio is used to test redundancy of Fixed effect. Further, selection of Random vs. Fixed effect is made by Hausman test. One can note that the signs of all coefficients are consistent with economic theories. Further, coefficients are generally statistically significant (using t-stat). R-square and F-stats, too, confirm soundness of the model. These results generally validate the specification of the structural equations of the model.

One should note that the results of single equation estimations may lead to biased and inconsistent estimators, ignoring the relationships between disturbance terms. For this reason, this paper also applies system approach (e.g., Three Stage Least Square (TSLS) or Generalized Method of Moments (GMM)) under panel-data technique. However, one of the most important outputs of single equation estimation is the results of equation 4. This gives a simple approximation for country-specific energy balance identities (Eq. 5), which is needed for estimating parameters of System 7.

Table 2 Estimation results, using single equation approach

Eq.	1		2		3		4
Variable	Coef		Coef		Coef		Coef
Dependent	***ln(e)***		***ln(y)***		***ln(π)***		***ln(E)***
C	-0.504	C	-0.094	C	-0.451	C	0.150
	(-6.838)		(-1.287)		(-4.998)		(8.898)
ln(y)	0.193	ln(y)	0.975	ln(r)	-0.047	ln(e)	0.034
	(8.428)		(89.858)		(-10.186)		(4.951)
ln(p/π)	-0.063	ln(k)	-0.017	ln(Y)	0.042	ln(E(-1)	0.926
	(-7.597)		(-6.071)		(6.1867)		(87.238)
ln(e(-1))	0.788	ln(l)	0.028	ln(M1(-1)/ π(-1))	0.897		
	(32.990)		(2.667)		(82.77)		
		ln(E)	0.017				
			(2.806)				
		t	0.001				
			(3.686)				
Country-specific intercepts							
F/R effect	R		F		F		F
NSW--C	-0.008		0.012		0.055		-0.017
VIC--C	-0.049		0.023		0.081		-0.017
QLD--C	0.016		0.036		0.090		-0.011
SA--C	-0.060		0.028		0.130		-0.021
WA--C	-0.083		0.063		0.103		-0.084
TAS--C	0.111		0.064		0.186		-0.163
NT--C	-0.083		0.088		0.200		-0.106
AUS--C	0.015		-0.007		-0.017		0.039
BEL--C	-0.007		0.001		-		0.011
CAN--C	0.108		-0.026		-0.024		0.062
DNK--C	-0.088		0.017		-0.023		-0.044
FIN--C	0.082		0.015		-		-0.022
FRA--C	0.006		-0.030		-		0.070
DEU--C	0.009		-0.041		-		0.077
GRC--C	-0.004		0.010		-		-0.010
IRL--C	-0.081		0.050		-		-0.044
ITA--C	-0.026		-0.028		-		0.049
JPN--C	-0.055		-0.035		-0.364		0.091
NLD--C	-0.051		-0.005		-		0.028
NZL--C	0.048		0.013		0.079		-0.052
NOR--C	0.100		0.031		-0.025		-0.055
PRT--C	0.000		-0.001		-		-0.021
ESP--C	0.021		-0.018		-		0.047
SWE--C	0.074		0.000		-0.040		-0.018
GBR--C	-0.050		-0.032		0.014		0.056
USA--C	0.054		-0.064		-0.119		0.156
R-squared	0.9951		0.9999		0.9900		0.9996
Adjusted R-squared	0.9951		0.9998		0.9895		0.9996
F-statistic	97743		182051		1910		88921
Prob(F-statistic)	0.000		0.000		0.000		0.000

t-Values in brackets

Table 3 shows the results of estimation for System 7. Concentrating on t-Stat as our hypothesis-testing approach, one can realize that only coefficients of organisational restructuring are statistically acceptable with high confidence. That implies that only functional unbundling (as one of the institutional facet of the market reform) has truly affected electricity demand, both in terms of changes in intercept and change in slope (price-elasticity).

Table 3 Estimation results, using system approach

System: REZAFA01
Estimation Method: Generalized Method of Moments
Date: 06/04/11 Time: 23:51
Sample: 1971 2008
Included observations: 855
Total system (unbalanced) observations 1935
White Covariance
Linear estimation after one-step weighting matrix

	Coefficient	Std. Error	t-Statistic	Prob.
C(10)	-0.054617	0.011972	-4.562271	0.0000
C(11)	0.026940	0.003648	7.385597	0.0000
C(12)	-0.028132	0.003388	-8.304126	0.0000
C(13)	0.970373	0.003552	273.1964	0.0000
C(101)	0.036355	0.010440	3.482257	0.0005
C(102)	-0.017695	0.012468	-1.419152	0.1560
C(103)	0.006021	0.004552	1.322811	0.1861
C(121)	0.014621	0.004626	3.160874	0.0016
C(122)	-0.005609	0.005531	-1.014148	0.3106
C(123)	0.002552	0.002013	1.268016	0.2049
C(20)	-1.703647	0.095009	-17.93146	0.0000
C(21)	0.151339	0.007782	19.44709	0.0000
C(22)	0.407821	0.017782	22.93458	0.0000
C(23)	0.541181	0.016818	32.17825	0.0000
C(24)	0.103926	0.003249	31.98472	0.0000
C(30)	-0.386852	0.158232	-2.444842	0.0146
C(31)	0.911071	0.018163	50.15965	0.0000
C(32)	0.108004	0.015210	7.100815	0.0000
C(33)	0.044908	0.007502	5.986277	0.0000
C(34)	-0.791074	0.033761	-23.43174	0.0000
Determinant residual covariance		1.54E-07		
J-statistic		0.208599		

Therefore, the other two dummy variables (i.e., M and O, corresponding to market structure and ownership arrangement) are excludable from the model. Modified model (after exclusion of M and O variables) is again rerun. The results are used in matrix form (Eq 8a or 8b) as the selected structural form. On this basis, coefficients of reduced- and final forms (Eq 9 and 10) are calculated.

Table 4 is a summary of the results. It shows estimated coefficients of structural-, reduced- and final-forms of the model. With respect to exogenous variables, Table 4 selectively includes only a few of coefficients that are helpful in interpreting key impacts of the market reform on endogenous variables of this model, namely electricity demand, real GDP and price level (inflation).

The results in Table 4 reveal that in the short-run, when no behavioural adjustment is taken place between variables (*ceteris paribus*), the reform has no impacts on real GDP and inflation. In the short-run, electricity demand is the only variable which shows indications of changes as a result of the market reform. The results suggest that organisational restructuring of the electricity industry (i.e., functional unbundling) has caused a significant decline in electricity price, causing considerable boost in electricity demand. The model further suggests that such a boost has occurred in two distinct ways: (i) sudden boost (change in the intercept); and (ii) gradual increase (flatter slope, i.e., more elastic or price-sensitive demand function). As can be noted from Table 4, on average over entire sample, electricity demand is increased nearly 3% more growth in countries that have implemented functional unbundling reform process. Further, average price elasticity of electricity demand is -0.0256 among countries that their electricity industries hold a vertically integrated structure. This figure is dropped to -0.013 (-0.256+0.0126) among countries that have implemented functional unbundling. This implies that that the demand curve is more elastic, and hence more price sensitive among that group of countries. This result is consistent with Steiner (2000) and Aghdam (2011), but inconsistent with Hattori and Tsutsui (2004).

Table 4 Overall Short-, Medium- and Long-run Impacts of the market-Oriented Electricity Reform

		endogenous variables			Some exogenous variables			
		electricity demand	real GDP	Price Level	F.U. Intercept	F.U. Price slope	Electricity price	M1
electricity demand (E)	Short-run	1.0000	0.0262	-0.0262	0.0294	0.0126	-0.0256	0.0000
	Medium-run	1.0000	0.0000	0.0000	0.0294	0.0128	-0.0257	0.0000
	long-run	1.0000	0.0000	0.0000	1.0360	0.4493	-0.9033	0.0000
real GDP (Y/PI)	Short-run	0.0182	1.0000	0.0000	**0.0000**	0.0000	0.0000	0.0000
	Medium-run	0.0000	1.0000	-0.0005	**0.0006**	0.0002	-0.0005	0.9552
	long-run	0.0000	1.0000	-0.0235	**0.0269**	0.0117	-0.0235	5.6716
Price level (PI)	Short-run	0.0000	0.0447	1.0000	0.0000	0.0000	0.0000	0.9125
	Medium-run	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.9552
	long-run	0.0000	0.0000	1.0000	0.0059	0.0025	-0.0051	5.6716

In this empirical analysis, what seems to be very contrasting against general expectations is that one cannot validate the idea that such productivity (price) improvements could possibly be made as a result of wholesale markets or privatization. This implies that efficiency of electricity markets has remained unchanged under both market structures: traditional order-of merit mechanism, which is a command-and-control market structure; and bid-based spot market. The traditional pricing mechanism seems to be working, if not worst, as efficient as modern spot markets, overall. This is plausible because such mechanism uses information on marginal costs which used to be transparent to system operators. Modern bid-based market structure is good, too. What this study implicitly reveals is that the two market structures are almost at the same level of overall efficiency. Similar conclusions can be made about ownership change from public to private sector.

In the medium-rum, when behavioural adjustments are taken place between variables, the results are still very close to short-run impacts. However, minor changes are passed on real GDP. For example, the short run productivity (price) gains cause a 0.06% increase in real GDP growth. In the medium run, despite adjustments between variables, people's expectations are not fully fulfilled yet. Such fulfilments will only happen when desired (expected) variables equate actual ones (i.e., $\tilde{y}_{it} = \tilde{y}_{it-1}$) in the long run.

In the long-run, electricity demand is drastically boosted by functional unbundling. As can be noted from the Table 4, electricity demand is shown to be more than double (104% boost) in countries that have functionally unbundled their industries. Electricity demand price elasticity, too, is significantly fallen from -0.9033 among countries with traditionally vertically integrated industry to -0.454 among countries with functionally unbundled industry. Real GDP growth and inflation are significantly affected in the long-run. The results show that, on average, real GDP growth has shown 2.7% additional growth and 0.6% more inflation.

5. Conclusions

The results reveal that only Functional Unbundling has made significant contribution to real GDP growth, whereas Market Restructuring and Privatization have not. The results, further, specify that Functional Unbundling has made, on average, an additional 0.06, and 2.7 percent contribution to real GDP growth rate in medium- and long-run, respectively. Such impacts, the results of this paper suggest, are presumably induced by the productivity gains that seem to be achieved as a result of lower electricity prices and more price-elastic electricity demands in economies, where electricity industry is organisationally restructured (i.e., Functional

Unbundled). As can be seen from the Table 1, price elasticity of electricity demand for the sample is estimated as -0.0256, -0.0257 and -0.9033 for Short-, Medium-, and Long-run, respectively. Such elasticity is reduced to the levels of -0.0128, -0.0129 and -0.4540, respectively, as a result of Functional Unbundling.

Acknowledgment

The authors would like to acknowledge the support provided by Deanship of Scientific Research (DSR) at King Fahd University of Petroleum and Minerals (KFUPM) for funding this work through project No. IN100004. Sincere thanks goes to University of Technology, Sydney (UTS) for providing two-month research fellowship to the first author of this paper over June-August 2010. This provided valuable inputs into this work. Authors also would like to extend their thanks to Dr Hattori and Tsutsui of Central Research Institute of Electric Power Industry (CRIEPI), Japan, for generously sharing their data regarding reform-related dummy variables. The authors are, of course, responsible for the contents.

References

Abbott M. The productivity and efficiency of the Australian electricity supply industry. Energy Economics 2006;28; 444-454.

Aghdam RF. Dynamics of productivity change in the Australian electricity industry: Assessing the impacts of electricity reform. Energy Policy 2011;doi: 10.1016/j.enpol.2011.03.019.

Atkinson SE, Halvorsen R. The Relative Efficiency of Public and Private Firms in Regulated Environment: The case of U.S. Electric Utilities. Journal of Public Economics 1986; 281-294.

BIE. International performance indicators : electricity update 1994. Australia Bureau of Industry Economics (BIE), Australian Govt. Pub. Service: Canberra; 1994.

Färe R, Grosskopf S, Logan J. The Relative Performance of Publictly Owned and Privately Owned Electric Utilities. Journal of Public Economics 1985; 89-106.

Fisher FM, Kaysen C. A study in econometrics : the demand for electricity in the United States. North-Holland: Amsterdam; 1962.

Hattori T, Tsutsui M. Economic impact of regulatory reforms in the electricity supply industry: a panel data analysis for OECD countries. Energy Policy 2004;32; 823-832.

Houthakker HS, Taylor LD. Consumer demand in the united states : analyses and projections, 2d ed. Harvard University Press: Cambridge, Mass.; 1970.

IC. Energy generation and distribution. Industry Commission (IC), Australian Govt. Pub. Service: Canberra; 1991.

IC. The Growth and Revenue Implications of Hilmer and Related Reforms. A report by Industry Commission (IC) to Council of Australian Government (CoAG), Canberra: Canberra; 1995.

Johnson M, Rix S. Powering the Future: The electricity industry and Australia's energy future. Pluto Press; 1991.

Koyck LM. Distributed Lags and Investment Analysis. North-Holland Publishing Company: Amsterdam; 1954.

Krugman PR, Obstfeld M. International Economics: Theory and Policy. Pearson; 2009.

Lawrence D, Swan PL, Zeitsch J. The comparative efficiency of state electricity authorities. University of New South Wales Australian Graduate School of Management: Kensington, N.S.W; 1990.

London Economics, 1993. Measuring the efficiency of the Australian Electricity Supply Industry. Submitted to Electricity Supply Association of Australia (ESAA).

Moroney JR. Energy, growth and the environment. JAI Press: Greenwich, CT.; 1992.

PC, 1999. Impact of Competition Policy Reforms on Rural and Regional Australia. Productivity Commission (PC), Commonwealth of Australia, Canberra.

Pollitt MG. Ownership and performance in electric utilities : the international evidence on privatization and efficiency. Oxford University Press: Oxford; 1995.

Pollitt MG. The impact of liberalization on the performance in the electricity supply industry: an international survey. Journal of Energy Literature 1997; 3-31.

Quiggin J. Estimating the Benefits of Hilmer and Related Reforms. The Australian Economic Review 1997;30; 256-272.

Quiggin J. Market-oriented reform in the Australian electricity industry. Economic and Labour Relations Review 2001;12; 126-150.

SAIIR, 2002. Estimating the Benefits of Electricity Reform. South Australian Independent Industry Regulator (SAIIR), Information Paper No. 8, prepared by the SA Centre for Economic Studies, Adelaide.

Sharma D. The Multidimensionality of Electricity Reform: An Australian Perspective. Energy Policy 2003;31; 1093-1102.

Short C, Swan A, Graham B, Mackay-Smith W, 2001. Electricity Reform: The benefits and costs to Australia, Outlook 2001 Conference. Australian Bureau of Agriculture and Resource Economics (ABARE), Canberra.
Sioshansi FP, Pfaffenberger W, 2006. Electricity Market Reform: An International Perspective. ELSEVIER.
Steiner F, 2000. Regulation, Industry Structure and Performance in The Electricity Supply Industry. OECD, Economic Department Working paper ECO/WKP 11.
Whiteman J. The Potential Benefits of Hilmer and Related Reforms: Electricity Supply. Australian Economic Review 1999;32; 17-30.