The economic impact of electricity conservation policies: A case study of Ireland

Nyamdash, Batsaikhan and Denny, Eleanor

Trinity College Dublin, Department of Economics

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Batsaikhan Nyamdash[a,*], Eleanor Denny[a]

[a] *Department of Economics, Trinity College Dublin, Ireland*

Abstract

As electricity is an essential input in almost every production process, it is essential to quantify the impact of economic policies aimed at electricity conservation on the output. This research investigates the effect of unanticipated shocks in electricity consumption, technical efficiency, and electricity price on the value added in the heterogenous service and industrial sectors, under a demand side model. Ireland is utilized as a case study as it is pursuing ambitious **electricity conservation targets** while in the midst of a severe economic recession. Given the important role of electricity as an input in both the services and industrial sectors, it was feared that these energy conservation targets may adversely impact on these sectors and as a result worsen the national economic situation. Findings show that value added, electricity consumption, electricity price and technical efficiency are co-integrated for both the service and industrial sectors. However, impulse response functions show that positive technical efficiency and consumption shocks have persistent negative effects on the value added of both sectors. Therefore, a direct electricity conservation policy, that puts a constraint on electricity consumption, should not have an adverse effect on sector specific value added.

Key words: Electricity consumption, Value added, Granger Causality, Impulse response

1. Introduction

In recent decades, policy makers have been implementing ambitious policies to tackle climate change. At a global level, the Kyoto protocol sets binding emissions targets for participating countries amounting to an average of 5% against 1990 levels over the five-year period 2008 2012 (United Nations, 1998). The European Union (EU) has commitments to reduce greenhouse gas emissions to 20% below the 1990 level by 2020 (Commission of European Communities, 2007a), to increase the share of renewable energy in the energy mix to 20% by 2020 (Commission of European Communities, 2007b) and to increase energy efficiency by 20% by 2020 (Commission of European Communities, 2006). In other words, energy conservation has become a cornerstone for tackling global climate change.

Energy demand has steadily increased with the growth in world population and the increase in global output and as such, the design of targets to conserve energy, without affecting output have proved challenging (Kaufmann, 1992). Energy is an essential

*Corresponding author can be contacted at batsaikn@tcd.ie, tel: +353 1 8962325

part of the production process and hence economic activity (Stern, 1997; Chian-Lee and Chang, 2007; Sorrell, 2009; Marinescu et al., 2007). Therefore, it raises the question of whether the energy conservation policies could be implemented successfully at an individual country level without distorting output and international competitiveness.

This paper examines a case study of the impact of electricity conservation in Ireland. In the last two decades, Ireland experienced rapid economic growth and transformed from an agricultural to a service oriented economy. However, since 2007 Ireland has seen a dramatic reversal of fortunes fueled by the international banking crisis, a property crash and inflated public sector expenditure (Whelan, 2009). At the end of 2010, Ireland's sovereign bond spreads were the highest in Europe and resulted in a high profile rescue package from the European Union and the International Monetary Fund (Department of Finance, 2010b). Despite its economic challenges, Ireland remains committed to meeting its energy related obligations, in particular in the electricity sector (as it is relatively easier to achieve savings here rather than in the transport and heat sectors) (Department of Finance, 2010a,c). This paper investigates the relationship between electricity consumption, electricity price, technical efficiency and value added of service and industrial sectors in Ireland in order to ascertain if pursuing electricity conservation policies is likely to impact positively, negatively or neutrally on Ireland's current economic situation.

In 2008, the electricity sector was responsible for the 32% of total CO_2 emissions in Ireland (International Enegrgy Agency, 2010). Based on EU targets (Commission of European Communities, 2007a,b, 2006), Ireland has set an ambitious target of achieving 40% of electricity generation from renewable energy sources by 2020 (Statement by Minister for the Environment and Government, 2008). In addition to the promotion of renewable energy, the Irish Government are also pursuing measures to boost energy-efficient behaviour (Diffney et al., 2009) and a nationwide roll-out of smart meters with time of use electricity consumption and price information (Commission for Energy Regulation, 2009). It has been shown that targets aimed at energy efficiency, which is an indirect energy conservation policy, can result in a rebound effect (Grepperud and Rasmussen, 2004; Barker et al., 2009; Broadstock et al., 2007) which increases energy demand at later date. On the other hand, direct conservation policy, such as placing a constraint on energy consumption, may reduce the growth of energy demand and as a result reduce growth in the economy, in particular if the economy is energy intensive.

A large body of research has looked at the relationship between energy consumption and economic activity to study the impact of climate policies, *i.e.* energy conservation policy, for various countries. However, inconclusive results were produced due to the varying energy intensities of heterogenous production sectors in the different countries

(Mishra et al., 2009; Soytas and Sari, 2007).

While previous studies have examined the relationship between aggregate energy consumption and aggregate output, in order to contribute to the research, this paper studies the impacts of **different electricity conservation policies** on the economic performance of the Irish economy at a disaggregate level, *i.e.* industrial and service sectors[1]. Following the methodology in Stern (2004) and Hall et al. (2001), we employ a demand side time series model and examine the effects of unanticipated shocks in technical efficiency, electricity consumption and electricity price on the value added of both sectors and *vice versa*.

The structure of the paper is as follows: Section 2 reviews the existing literature, Section 3 describes the econometric methodology employed, Section 4 shows the empirical results, Section 5 gives a brief discussion and Section 6 concludes.

2. Literature review

The main body of research in this area has employed time series econometrics modela to investigate the direction of Granger causality between energy consumption and economic activity (Table 1). In general, forecasts of the energy consumption were improved when output was taken into account (multi-country cases). In other words, energy consumption was Granger caused by economic output, hence energy conservation policy would not affect economic output. But, this result does not hold at a country or at a disaggregate levels. For instance, in the Turkish economy, industrial value added Granger caused the industrial electricity consumption in the long run (Karanfil, 2008) while there was no-causality found at the aggregate level (Jobert and Karanfil, 2007). This is an appealing result because intuitively, some fraction of the current revenue is invested in the energy intensive capital in the industrial sector which is then utilized in the next period. But, for the US economy, uni-directional causalities, that run from output to the energy consumption in the industrial sector and from energy consumption to the value added in the service sector were found (Zachariadis, 2007; Thoma, 2004) while bi-directional causality was found at the aggregate level (Lee, 2006).

Mishra et al. (2009); Soytas and Sari (2007) emphasized the importance of studying this relationship at a disaggregate level rather than at an aggregate level (aggregate measures suffer from an aggregation bias) and Hall et al. (2001) found that the energy input is more important than the capital and labour inputs. Stern (2004) argued that omitting such variables would result in spurious regression results.

[1]In 2008, 32% of the total electricity consumption was consumed by the industrial consumers while 33% was consumed by commercial consumers (International Energy Agency, 2009)

Table 1: Overview of the selected studies.

Country		Model	Short run	Long run
Multi-country Studies:				
Asian 10	(Chen et al., 2007)	Bi-variate	Y→EC	Y→EC
Developed	(Chian-Lee and Chang, 2007)	Bi-variate	Y↔EC	-
Developing			Y→EC	-
G-7	(Narayan et al., 2008)	Bi-variate	Y↔EC	-
Pacific Islands	(Mishra et al., 2009)	Demand	Y↮EC	Y↔EC
Caribbean	(Francis et al., 2007)	Bi-variate	Y↔EC	-
Single country studies:				
USA	(Chiou-Wei et al., 2008)	Bi-variate	Y↮EC	-
	(Lee, 2006)	Bi-variate	Y↔EC	-
Korea	(Oh and Lee, 2004)	Supply	Y←EC	Y↔EC
	(Chiou-Wei et al., 2008)	Bi-variate	Y↮EC	-
China	(Shiu and Lam, 2004)	Bi-variate	Y↔EC	Y←EC
	(Yuan et al., 2007)	Bi-variate	Y←EC	Y←EC
Australia	(Narayan et al., 2008)	Bi-variate	Y←EC	-
	(Narayan and Smyth, 2005)	Supply	Y→EC	Y→EC
India	(Ghosh, 2002)	Bi-variate	Y→EC	-
	(Asafu-Adjaye, 2000)	Demand	Y←EC	Y→EC
Thailand	(Mashih and Masih, 1998)	Demand	Y↮EC	Y←EC
	(Asafu-Adjaye, 2000)	Demand	Y↔EC	Y↔EC
Turkey: GNP	(Jobert and Karanfil, 2007)	Bi-variate	Y↮EC	-
Studies at a disaggregate level				
USA:SVA	(Zachariadis, 2007)	Bi-variate	Y←EC	Y↮EC
IP	(Thoma, 2004)	Bi-variate	Y→EC	-
Turkey:IVA	(Jobert and Karanfil, 2007)	Bi-variate	Y↮EC	-
	(Karanfil, 2008)	Bi-variate	Y↮EC	Y→EC

- Direction of causalities are indicated by →, ← and ↔, and no causality by ↮.
- Output (GDP unless it is specified) by Y, and energy/electricity consumptions by EC. IP-Industrial Production. SVA-Service sector Value Added. IVA-Industrial sector Value Added.

3. Econometric methodology

In order to investigate the relationship between value added and electricity consumption for the industrial and service sectors, we employed the following standard time series econometric methodology, which was based on the stationarity and the co-integrating relationships across the variables considered.

Let y_t be a vector of m variables that satisfies the following process:

$$\phi(L)y_t = \delta + \epsilon_t \tag{1}$$

where $\phi(L)y_t = I_m - \sum_{i-1}^{p} \phi_i L^i$ and ϵ_t is white noise. In the case when the above Vector Autoregressive Regression (VAR) is stationary *i.e.* $det|\phi(L)| = 0$, we do not need further transformation. In the case when the above VAR is non-stationary, *i.e.* $det|\phi(L)| = 0$ is singular, y_t would be the vector of *I(1)*[2] variables and $\triangle y_t$[3] would be the vector of *I(0)* variables. Also, according to the representation theorem (Engle and Granger, 1987) the combination of *I(1)* variable can be *I(0)*, *i.e.* co-integrated and the (1) can be written in the following form:

$$\triangle y_t = \delta - \phi(1) y_{t-1} + \sum_{i-1}^{p-1} \psi_i \triangle y_{t-i} + \epsilon_t \tag{2}$$

If the rank of $\phi(1)$ is zero, which is the equivalent of $\phi(1)$=0, the model can be written in the form of *VAR*. If the rank of $\phi(1) = r < m$, with r being the number of co-integrating relationships among m variables in the y_t vector, there exists a B$[m \times r]$ matrix of rank r such that $\phi(1) = BA^T$, and the (2) follows the Vector Error Correction Model (VECM) representation.

$$\triangle y_t = \delta - BA^T[1, t, y_{t-1}] + \sum_{i-1}^{p-1} \psi_i \triangle y_{t-i} + \epsilon_t \tag{3}$$

where $A^T[1, t, y_{t-1}]$ is the *I(0)* error correction terms (ECT). The ECT may include a constant and/or deterministic trend. The deterministic trend is intended to capture the behavior of trend stationary variables *i.e.* variables that are stationary after detrending rather than first differencing (Johansen and Juselius, 1995).

Granger causality, which shows whether the particular variable improves the forecast of the dependent variable when included in the model, is tested according to the standard Granger or Engle-Granger approach (Engle and Granger, 1987) for the perceived VAR or VECM, respectively. When VAR was adopted, the joint significance of lagged independent variables in the model are tested. In the case of VECM, the Granger causality is distinguished into long and short run causalities and tested by the significance of error correction terms and the joint significance of lagged independent variables, respectively. Since, all variables in (1) and (2) are *I(0)*, simple t- and F-tests would be employed to investigate the direction of the Granger causality.

Based on the estimates of the VAR or VECM, (1) could be written in the moving average form. Then, the impulse response function can be calculated by the following (Enders, 2004):

$$\frac{\partial y_{i,t+s}}{\partial \epsilon_{j,t}} \tag{4}$$

[2] *I(d)* variable is a variable that becomes stationary after the difference is taken d times. *I(1)* variable would become stationary when the first difference is taken. *I(0)* variable is a stationary variable.

[3] $\triangle$ is the difference operator which takes the first difference of the variable.

where $i, j = \overline{1, m}$.

It describes the response of $y_{i,t+s}$ (s=0,1,2...) of y_t to a one-time impulse/shock in $y_{j,t}$ with all other variables dated t or an earlier held constant.

4. Results

4.1. Data and Hypothesis

Electricity consumption[4] for the industrial and the service sectors and non-residential electricity prices for the period of 1978-2007 for Ireland were obtained from the International Energy Agency (2009). Service and industrial sectors' value added for the same time period were obtained from the World Bank (2009).

Figure 1, 2 show that, in the Irish economy, electricity consumption is linearly related to the value added while it is nonlinearly related to the electricity price [5].

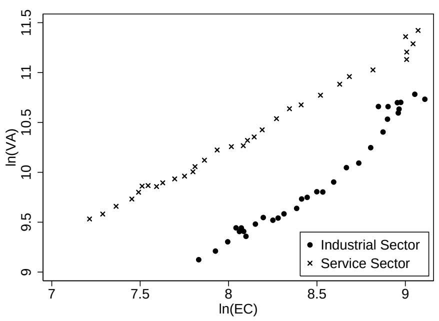


Figure 1: Electricity consumption and Value added

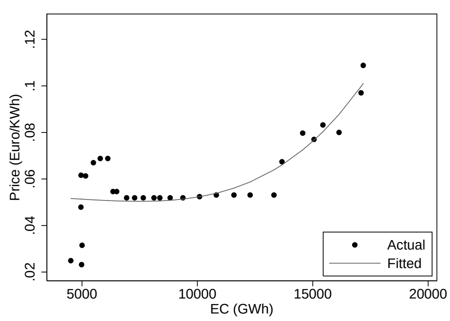


Figure 2: Electricity price and consumption

4.2. Identification

Electricity is an essential component of the production process with few substitutes.Thus, electricity consumption, technical efficiency and electricity price are used as policy instruments of energy conservation in the model to be estimated. Technical efficiency is proxied by the sector specific VA per GWh electricity consumed by the sector:

$$A_t^i = \frac{VA_t^i}{EC_t^i} \tag{5}$$

[4]Electricity consumption of the construction sector has been included in the industrial sector electricity consumption.

[5]Electricity is produced according to the economic dispatch of power plants with different fuel costs. In Ireland, the electricity price is then associated with the fuel cost of the marginal plant which is dispatched to balance demand and supply.

The reduced form time series model is almost theory free and gives an opportunity to analyse the effect of an unanticipated shock in the independent variable on the dependent variable and *vice versa* without being required to set up an explicit mechanism that explains the underlying process. The model deals with the endogeneity issue by using the past values of the dependent variable as an instrumental variable[6].

Stationarity and co-integration tests found that the variables considered in this research were found to be difference stationary[7] and value added, electricity consumption, electricity price and technical efficiency for industrial and service sectors were found to be co-integrated[8]. Therefore, we posit the following VECMs to test the directions of Granger causalities for service and industrial sectors, and the impacts of unanticipated shocks in the value added, electricity price, electricity consumption and technical efficiency on each other:

$$\triangle EC_t^i = A_0 + \kappa^{ec} e_{t-1}^i + [lagged\ \triangle VA^i;\ \triangle EC^i;\ \triangle P^i,\ \triangle A^i] + u_t^i \tag{6}$$

$$\triangle VA_t^i = A_0 + \kappa^{va} e_{t-1}^i + [lagged\ \triangle VA^i;\ \triangle EC^i;\ \triangle P^i,\ \triangle A^i] + u_t^i \tag{7}$$

$$\triangle P_t^i = A_0 + \kappa^{p} e_{t-1}^i + [lagged\ \triangle VA^i;\ \triangle EC^i;\ \ \triangle P^i,\ \triangle A^i] + u_t^i \tag{8}$$

$$\triangle A_t^i = A_0 + \kappa^{a} e_{t-1}^i + [lagged\ \triangle VA^i;\ \triangle EC^i;\ \triangle P^i,\ \triangle A^i] + u_t^i \tag{9}$$

where A_0 is the constant and e_{t-1}^i is the error correction term, κ^i is the coefficient to be estimated, A_i is the technical efficiency, VA_i is the value added, EC_i is the square of the electricity consumption, P_i is the electricity price and u_t^i is the error term (*i=service, industrial*). Since, the variables considered here found to be difference stationary, the co-integrating relation would not include the deterministic trend and the explicit definitions of ECTs would be as follows:

$$VA_t^i = a_0 + \pi_0^i EC_t^i + \pi_1^i P_t^i + \pi_2^i A_t^i + e_t^i \tag{10}$$

where a_0, $\pi_{0,1,2}$ are coefficients to be estimated and e_t^i is the error term *i.e.* ECTs.

[6]Inclusion of l more variables in the model would increase the size of the model as p lags of the included l variables have to be added and l new regressions have to be estimated.

[7]See Table 4 in the Appendix for the unit root test.

[8]See Table 5 in the Appendix for the co-integration tests.

4.3. Co-integrating relations

The co-integrating relationship of the value added, electricity price and electricity consumption showed that the electricity consumption was negatively related to the electricity price while it was positively related to the value added for both sectors (Table 2). This is the long run relationship of these variables and at least one of the ECTs should be significant in the VECM.

Table 2: Co-integrating relations

Variables	$e_{t-1}^{industrial}$	$e_{t-1}^{service}$
P	1	1
EC	1.100 (0.425)***	3.804 (0.972)***
VA	-1.377 (0.310)***	-3.52 (1.38)***
A	0.660 (.692)	5.090 (1.69)

Standard errors are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

4.4. Granger causality

Table 3 shows the short and long run Granger causality tests for models specified by (6) - (10). It was found that no Granger causalities exist in the relationship between electricity consumption and value added. Nevertheless, the error correction term was significant in the underlying process of the electricity price in both sectors which represents the long run Granger causality. Thus, any deviation from the long run trend was corrected in the short run for electricity price. This is in line with rules of the electricity market, *i.e.* electricity price strongly relates to the current generation of electricity.

It was found that technical efficiency Granger causes electricity consumption and electricity price while the value added causes only the electricity price in the service sector. There was no dynamic Granger causality found in the industrial sector.

4.5. Impulse response functions

In this section, we further investigated the impulse response functions (IRF) of the value added, electricity consumption, technical efficiency and electricity price. IRFs show the response of the dependent variable to an unexpected shock in one of the independent variables while holding everything else constant. Since, electricity is one of the main components of the production process, it is expected that decisions by firms regarding electricity consumption are made to maximise profits, *i.e.* electricity consuming equipment is allocated optimally. If electricity consumption is not an important factor of the production process or the daily activity of the service sector, it would be neutral in the

Table 3: Coefficients of VECMs

	Industrial				Service			
	$\triangle EC_t$	$\triangle VA_t$	$\triangle P$	$\triangle A$	$\triangle EC_t$	$\triangle VA_t$	$\triangle P$	$\triangle A$
Long run:								
e_{t-1}	0.05	0.001	-0.448***	-0.028	-0.036	-0.021	-0.293***	0.009
Short run:								
$\triangle EC_{t-1}$	-	-0.159	0.195	0.037	-	-0.144	-1.025**	0.487**
$\triangle VA_{t-1}$	0.003	-	-0.092	0.016	0.544	-	-1.471**	-0.325
$\triangle P_{t-1}$	-338***	-0.057	-	0.158**	-0.93	-0.071***	-	-0.093
$\triangle A_{t-1}$	0.439	-0.579	-0.617	-	-0.331	-0.331	2.83***	-

*** p<0.01, ** p<0.05, * p<0.1
- No autocorrelation found for the lag length of 2.
- Akaike Information Criterion (AIC), Schwarz Bayesian Information Criterion (SBIC) and Hannan-Quinn Information Criterion (HQIC) were used to select the lag length.

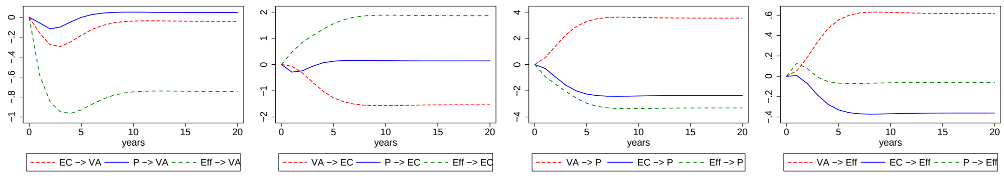
value added; neither changes in the growth of consumption nor an unanticipated increase in consumption would have an impact on the value added and *vice versa*.

Since the models we posit have stationary right-hand side variables, impulse response functions would yield consistent estimates (Enders, 2004) and reactions of the value added of industrial (Figure 3) and service (Figure 4) sectors would be sensible estimates.

Impulse responses of value added to unanticipated shocks in electricity consumption and technical efficiency showed that they were important factors for both sectors as they have persistent effects on the value added. A shock in the electricity price had a small transitory effect on both sectors (Figure 3(a), 4(a)). Hence, decisions regarding electricity consumption were made in order to increases the profit of the firm.

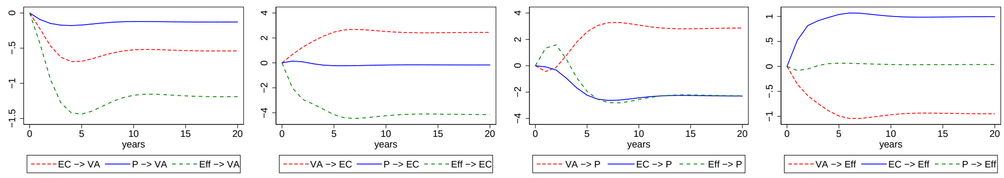
Figures 3(b), 4(b) showed the response of electricity consumption to various shocks. Electricity consumption was found to be more affected by a shock in the value added for both sectors, but in different ways. For the industrial sector, electricity consumption decreases when value added increases unexpectedly. A shock in value added has the opposite effect in the service sector. But, the effect of technical shocks had a positive permanent effect on industrial electricity consumption and a negative permanent effect on the service sector electricity consumption. This could be due to the rebound effect in the industrial sector. The effect of electricity price was small and transitory. It is in line with the price inelastic demand of electricity.

On the other hand, the response of the electricity price was in line with the supply schedule of the electricity market (Figure 3(c), 4(c)). It decreases in the long run due to the electricity demand shock because an increase in demand would increase the partici-



(a) Response: *VA* (b) Response: *EC* (c) Response: *P* (d) Response: *A*

Figure 3: Impulse response functions of the industrial sector



(a) Response: *VA* (b) Response: *EC* (c) Response: *P* (d) Response: *A*

Figure 4: Impulse response functions of the service sector

pation of cheap, base-load power plants. But, an unanticipated increase in value added of both sectors would result in increased electricity prices in the long run. A shock in technical efficiency (increase) had a short run small positive and a long run negative effect on the electricity price.

Finally, Figure 3(d), 4(d) shows that the technical efficiency responded positively to the value added in the industrial sector while the value added in the service sector had an opposite effect. It responded positively to the shock in electricity consumption in the service sector while it had an opposite reaction in the industrial sector. The impact of price was transitory and small for both sectors.

5. Discussion

In this paper, a reduced form time series model was adapted to empirically test the relationship between electricity consumption and value added for industrial and service sectors of the Irish economy. A Granger causality test did not find any causality between value added and the electricity consumption in both sectors. It found some causalities with the electricity price and technical efficiency. This indicates that electricity consumption (value added) is exogenous to the underlying process of value added (electricity consumption) for both sectors. However, this only shows the capability of one variable in forecasting the other and the Granger causality test cannot be used to describe the true causation *i.e.* the underlying mechanism that links those variables.

Nevertheless, the impulse response functions showed the impact of an exogenous shock in the independent variable on the dependent variable. It should be noted that it also does not explain the underlying mechanism that links electricity consumption and value added, but it gives an indication of what might happen if there was such an exogenous shock (Stock and Watson, 2001).

Energy or electricity conservation policies could be considered as a negative shock (that is a direct constraint on the electricity consumption rather than electricity saving through technological advancements) to electricity consumption and would have the opposite effect to what was shown by the IRFs previously. Thus, such a policy targeted at a specific sector would not have an adverse effect on its value added. The effect was smaller for the service sector compared to the industrial sector. Nevertheless, such a policy, through efficiency was explained by the exogenous shock in the technical efficiency as the positive shock would be an increase in the efficiency which would explicitly reduce the consumption of electricity.

From the perspective of the electricity system as a whole, the residential sector is a vital sector to be studied. But, from an economic perspective, the residential electricity consumption is more related to the household characteristics such as the number of people and the number of rooms in the house than any other aggregate measures such as household expenditure or the disposable income[9], and not related to the economic activity of the country.

6. Conclusion

In this paper, the relationship between the value added and electricity consumption was investigated for industrial and service sectors of the Irish economy controlling for electricity price and technical efficiency. Based on the unit root and co-integration tests, VECMs were employed. The Granger causality was tested and the results showed the non-existence of Granger causality between the value added and the electricity consumption for both sectors. Furthermore, IRFs showed that the electricity conservation policy would not have an adverse impact on the value added of both sectors if it is not implemented through improvements in technical efficiency.

[9]It was found that there is no co-integration and the Granger causality between aggregate household expenditure and the electricity consumption. Results are available from the author upon request.

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7. Appendix

7.1. Unit root test

The Dickey-Fuller (*DF*) test is applied to test whether a time series variable has a unit root and the Kwiatkowski, Phillips, Schmidt and Shin (*KPSS*) test is used to verify the results of the DF test (Soytas and Sari, 2007). The null hypothesis of the DF is H_o*: variable is non-stationary* while *KPSS* tests the null hypothesis of H_o*: variable is stationary.*

Table 4 shows that at level, none of the variables were stationary as DF tests failed to reject the H_o of the non-stationarity series with (τ_{ct}) and without (τ_c) trend. KPSS tests rejected the H_o of the stationarity of EC of both sectors and service sector A when there is no trend and accepts when there is a trend. But, the first difference of these variables were found to be stationary without trend under KPSS. As the first difference

Table 4: Unit root tests

	ADF			KPSS		
	τ_c	τ_{ct}	$\triangle^a$	K_c	K_{ct}	$\triangle^a$
Industrial sector						
EC_t	-1.027	-2.010	-4.054***	0.746***	0.848	0.118
VA_t	0.011	-1.176	-3.586**	0.723	0.136	0.103
A_t	-1.027	-2.904	-5.379***	0.758***	0.065	0.077
Service sector						
EC_t	0.391	-1.414	-4.26***	0.741***	0.187	0.132
VA_t	2.025	-0.318	-3.217**	0.738	0.158	0.377
A_t	0.031	-1.464	-4.324***	0.731	0.164	0.113
P_t	-1.279	-1.625	-3.205**	0.512**	0.099	0.136

*** p<0.01, ** p<0.05, * p<0.1.
[a] first difference, with constant and no trend.

of time series are stationary (integrated order of 1 - *I(1)*), the co-integration test can be applied in order to select the appropriate model.

7.2. Co-integration test

Johansen co-integration tests (λ_{max} and λ_{trace}) are employed (Johansen and Juselius, 1990; Johansen, 1991) to test the existence of co-integrating relations among the variables since the first difference of variables considered here were found to be stationary.

Table 5: Co-integration tests: Johansen Trance and Eigenvalue tests

		λ_{trace}			λ_{max}		
Ho	*Ha*	Statistics		Critical Value	Statistics		Critical Value
		industrial	*service*		*industrial*	*service*	
		VA-EC-P-A	*VA-EC-P-A*	Value	*VA-EC-P-A*	*VA-EC-P-A*	Value
r=0	r≥1	64.69	54.67	47.21	37.86	34.82	27.07
r=1	r≥2	26.82*	19.85*	29.68	15.45*	12.58*	20.97
r=2	r≥3	11.37	7.27	15.41	10.16	6.63	14.07
r=3	r≥4	1.21	0.63	3.76	1.21	0.63	3.76

- 5% critical values are reported in the table
* number of co-integrating relations.

The results of co-integration tests for the relationship between electricity consumption and value added, controlling for electricity price, for both sectors are summarized in Table 5. The underlying VAR model includes an intercept but no trend. It is shown that test statistics of λ_{max} and λ_{trace} tests are lower than their critical values for one co-integrating relationship for both sectors, *i.e.* there is one co-integrating (long run) relationship among electricity consumption, value added and electricity price. Hence it is appropriate to conduct further analysis under the VECM framework for both sectors.