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Article

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Electricity Consumption and Green Mortgage: New Insights into the Threshold Cointegration Relationship

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ABSTRACT

This paper examines threshold dynamics of electricity consumption (EC) and green mortgage. Industrial and individual EC are considered respectively. We apply a threshold vector error correction model (TVECM) with a threshold endogenously model. An unusual regime is above a threshold, whereas below a threshold for a usual regime. Our results show threshold effects for total (or industrial) EC and green mortgage, suggesting structure changes with different asymmetric error-correction effects in the usual and unusual regimes. Specifically, in the unusual regime, the stronger effect in the total EC case for green mortgage causing EC than the opposite direction is found but the smaller effect in the industrial EC case. It implies that efficiency improvement will be proposed for a new plant and upgrades of existing plant. Therefore, our results should highlight the critical importance of using TVECM in empirical studies on threshold dynamics of EC and green mortgage.

Keywords: Electricity Consumption, Green Mortgage, Threshold Cointegration, Nonlinear Dynamics
JEL Classifications: C32, Q40, G12

1. INTRODUCTION

Electricity serves an important role in both the production and consumption of goods and services within an economy, particularly in emerging countries. Pollutant emission through electricity consumption (EC), like CO_2, is tied to environmental issues (Vlachou et al., 1996).[1] The EC and CO_2 emission of Japan, Korea, UK, Germany, the Netherlands, and Taiwan were further compared. Lu (2008) finds that the EC and CO_2 emission in Japan were much higher than the other countries over the period. Regarding the requirement of electricity and CO_2 emission in South Korea and Taiwan, they both increased substantially. The CO_2 emission in UK, Germany, and Netherlands had a negative growth, which implied that the CO_2 emission in these countries had improved in the recent years.

In order to reduce the effects of this environmental problem, governments must develop and implement energy conservation policies. However, energy efficiency improvement is a key choice for a new plant and upgrades of existing plant on reducing pollutant emission, as was demonstrated by Sari and Soytas (2007), Lee and Chang (2008), Lee and Chien (2010), and Shahbaz et al. (2012), and thus capital stock and energy tend to be complements (Berndt and Wood, 1979; Solow, 1987; Apostolakis, 1990; Raj and Veall, 1998), suggesting that a unidirectional causal relation is found from capital use to EC. Thus, the creation of any energy conservation policy could lead to a saving in EC. Chang and Carballo (2011) show that energy efficiency was found in Latin American and Caribbean countries, especially in the countries which have both cointegration and short-term equilibrium. On contrary, a unidirectional causal relation from EC to capital use indicates that energy use explains more of the variation of capital while capital explains less of the variation of energy use. It suggests that capital stock and energy tend to be substituted (Chang, 1994; Grepperud and Rasmussen, 2004; Koetse et al., 2008; Lee and Chien, 2010). Kim and Heob (2013) argue that the substitution of energy for capital has dominated the substitution of capital for energy because capital costs are much greater than energy costs in most countries.

1 Pollutant emission is such as CO_2 emissions, as shown by Vlachou et al. (1996).

Taiwan is insufficient in natural resources, and constrained by limited environment carrying capacity. Green mortgage in nation, banks and other agencies is important for solutions of reducing pollutant emission and increasing efficiency improvement. Moreover, green mortgage programs are qualified for bigger loans by folding in the additional cost of making improvements for new plant and upgrades of existing plant.[2] The green mortgage market for energy efficiency improvements in the sectors has seen significant government support over the past few years. According to annual statistics of Bureau of Energy in Taiwan in 2014, the CO_2 emission from the EC accounted for 52.2% of total CO_2 emission in 2013 and for 55.9% in 2005 although Taiwan suffered effects of the environmental problem for the past of 25 years. Hence, understanding the dynamics of EC and green mortgage is important in the design and effectiveness of electricity saving and green mortgage for policymakers and related organizations.

This study follows Hansen and Seo (2002) to investigate nonlinear dynamics of EC and green mortgage (GNM) by using threshold vector error correction model (TVECM) with a threshold endogenously model. An unusual regime is above a threshold, whereas below a threshold for a usual regime. However, traditional cointegration analyses fail to account for possible structural breaks.[3] Existing studies ignore green capital as a mobile input factor in EC. A further important difference is that the green capital may be beneficial for efficiency improvement. For green capital, we focus on Taiwan green mortgage in nation, banks and other agencies, mainly sponsored by the government, where green mortgage programs are designed for private enterprises with low-interest loans for pollution control equipment and concessional loans for the purchase and installation of energy-saving equipment.[4] On the other hand, besides of total EC, we further consider industrial and individual EC respectively.

Conducting threshold effect tests in above three cases on GNM and EC, our findings except for individual EC and GNM identify two regimes, suggesting the existence of threshold effects. We examine the casual relation between EC and GNM. Significant feedbacks in both two regimes are obtained, suggesting that creation of any energy conservation policy could lead to a saving in EC. However, asymmetric substitutability between energy and capital is obtained in the unusual regime in the industrial EC case, implying the substitution of energy for capital has dominated the substitution of capital for energy. Thus, government provides more strong incentives on making improvements for new plant and upgrades of existing plant. Finally, our results for total EC and GNM as well as industrial EC and GNM have also show asymmetric error-correction effects respectively, with strong asymmetries in the speed of adjustment to the long-run equilibrium in both two regimes. It implies that GNM has a critical and predominant role on increasing efficiency improvement and reducing pollutant emission. Therefore, our results should highlight the critical importance of using TVECM in empirical studies on threshold cointegration and dynamics of EC and green mortgage.

The organization of the rest of the paper is as follows. The next section reviews methods developed by Hansen and Seo (2002) and explains the data used, and section 3 summarizes the estimated results. Finally, section 4 concludes the article.

2. METHODOLOGY AND DATA

Balke and Forby (1997) first allow the combination of non-linearity and traditional cointegration, but they don't allow for non-linear adjustment to the long-run equilibrium. However, Hansen and Seo (2002) consider a VECM with one cointegrating vector and a threshold effect based on the error-correction term to develop in the framework of two-regime threshold cointegration models.

We follow Hansen and Seo (2002) to model a TVECM of order l+1 of EC and green mortgage (GNM). The two regime threshold model where the γ is the threshold parameter takes the following form,

$$\begin{aligned}\Delta EC_t &= \alpha_{10}^2 + \lambda_1^2\omega_{t-1} + \sum_{i=1}^{1}\alpha_{1i}^2\Delta EC_{t-i} + \sum_{i=1}^{1}{}^{2}\,{}_{1i}^{2}\Delta GNM_{t-i} \\ &+ u_{1t}^2 \Delta GNM_t = \alpha_{20}^2 + \lambda_2^2\omega_{t-1} + \sum_{i=1}^{1}\alpha_{2i}^2\Delta EC_{t-i} \\ &+ \sum_{i=1}^{1}\beta_{2i}^2\Delta GNM_{t-i} + u_{2t}^2,\ \omega_{t-1} \le \gamma\end{aligned} \quad (1a)$$

$$\begin{aligned}\Delta EC_t &= \alpha_{10}^2 + \lambda_1^2\omega_{t-1} + \sum_{i=1}^{1}\alpha_{1i}^2\Delta EC_{t-i} + \sum_{i=1}^{1}\beta_{1i}^2\Delta GNM_{t-i} \\ &+ u_{1t}^2 \Delta GNM_t = \alpha_{20}^2 + \lambda_2^2\omega_{t-1} + \sum_{i=1}^{1}\alpha_{2i}^2\Delta EC_{t-i} \\ &+ \sum_{i=1}^{1}{}^{2}\,{}_{2i}^{2}\Delta GNM_{t-i} + u_{2t}^2,\ \omega_{t-1} > \gamma\end{aligned} \quad (1b)$$

Where,

$\omega_{t-1} = EC_{t-1}\text{-}\alpha\text{-}\beta\times GNM_{t-1}$

2 As shown by Taiwan's Executive Yuan National Development Fund, maximum terms are 10 years for low-interest loans and 7 years for concessional loans, with interest rate of postal savings 2-year time deposit plus 2.175% and 2.45% respectively. Amount of low-interest loans and concessional loans are provided with an upper limit of NT\$1 billion and of NT\$400 million respectively. Loan financing programs may allow 3-year grace period for principal. Because mortgage interest payments are tax-deductible, an energy-efficient mortgage can be a more cost-effective way to finance equipment upgrades for energy improvements.

3 For the Indian context, Tiwari (2011) tests for cointegration in presence and absence of structural breaks and finds conflicting results in both approaches. While testing for cointegration in the absence of structural breaks he finds the presence of cointegration, in presence of structural breaks he finds absence of cointegration.

4 If green mortgage are not available, emissions taxes are inefficient for two reasons. First, in setting the emissions tax rate each government takes into account the environmental damage in its own country, but not the environmental damage in the other countries. Second, from the point of view of the individual country the emissions tax distorts the investment decision of the dirty sector since it increases the user costs of capital in this sector and thereby leads to a capital outflow to other sectors and, in particular, to other countries.

Let x_t be a 2-dimensional vector of time series of EC and green mortgage (GNM) respectively with t observations. The threshold model with two regimes (1) is rewritten as follow.

$$\Delta x_t = \begin{cases} A_1' X_{t-1}(\beta) + u_t & \text{if} \quad \omega_{t-1}(\beta) \le \gamma \\ A_2' X_{t-1}(\beta) + u_t & \text{if} \quad \omega_{t-1}(\beta) > \gamma \end{cases} \tag{2}$$

Where

$X_{t-1}(\beta) = (1, \omega_{t-1}(\beta), \Delta x_{t-1}, \Delta x_{t-2}, \ldots, \Delta x_{t-l})'$, $\omega_{t-1}(\beta)$ denotes the I(0) error-correction term, the γ is the threshold parameter, $X_{t-1}(\beta)$ is $k\times 1$ regresssor, and A is $k\times 2$ where $k = 2l+2$. In particular, the estimated coefficients of ω_{t-1} of each regime denote the different adjustment speeds of the series towards equilibrium. This may be rewritten as

$$\Delta x_t = A_1' X_{t-1}(\beta) \Delta d_{1t}(\beta, \gamma) + A_2' X_{t-1}(\beta) \Delta d_{2t}(\beta, \gamma) + u_t \tag{3}$$

Where $d_{1t}(\beta, \gamma) = 1(\omega_{t-1}) \le \gamma)$ and $d_{2t}(\beta, \gamma) = 1(\omega_{t-1}(\beta) > \gamma)$, and $1(.)$ denotes the indicator function.

As described in Hansen and Seo (2002), the threshold effect only has content if $0 < P(\omega_{t-1} \le \gamma) < 1$, otherwise the model simplifies to linear cointegration. We impose this constraint by assuming that $\pi_0 \le P(\omega_{t-1} \le \gamma) \le 1-\pi_0$ where π_0 is a trimming parameter. For the empirical application, we set $\pi_0 = 0.05$. Estimations of model (3) are proposed by maximum likelihood under the assumption that the errors are iid Gaussian (Hansen and Seo, 2002).

For tests for threshold effects, a test for the null of no cointegration in the context of the threshold cointegration model is conducted. As shown by Hansen and Seo (2002), the LM statistic with testing for the presence of the threshold cointegration is employed. Hansen and Seo (2002) develop two tests the SupLM^0 and the SupLM tests for a given or estimated using a parametric bootstrap method to calculate asymptotic critical values with the respective P-values. The first test is denoted as $\text{supLM}^0 = \sup_{\gamma_L \le \gamma \le \gamma_U} LM(\beta_0, \gamma)$ and would be used when the true cointegrating vector β is known a priori. The second test is used when the true cointegrating vector $\tilde{\beta}$ is unknown and they denote this test statistic as $\text{supLM} = \sup_{\gamma_L \le \gamma \le \gamma_U} LM(\hat{\beta}, \gamma)$ where $\tilde{\beta}$ is the null estimate of the cointegrating vector. In these tests, the search region $[\gamma_L, \gamma_U]$ is set so that γ_L is the π_0 percentile of $\tilde{\omega}_{t-1}$ [where: $\tilde{\omega}_{t-1} = \omega_{t-1}(\tilde{\beta})$], and γ_U is the $(1-\pi_0)$ percentile. Thus, the asymptotic distribution depends on the covariance structure of the data, precluding tabulation. Hansen and Seo (2002) suggest using either the fixed regressor bootstrap of Hansen (1996, 2000), or alternatively a parametric residual bootstrap algorithm, to approximate the sampling distribution where the tests were done using a parametric bootstrap method with 1,000 replications.

To conduct Granger causality test for dynamics of EC and green mortgage (GNM) in the TVECM, we follow Granger (1969), Fung and Patterson (1999), and Granger et al. (2000). We first define following procedures.

First, a time series EC causing another time series GNM in the Granger sense (denoted as EC $\rightarrow$ GNM) is that energy use explains more of the variation of capital, suggesting that capital stock and energy tend to be substituted (Grepperud and Rasmussen, 2004; Lee and Chien, 2010). On the other hand, the substitution of energy for capital has dominated the substitution of capital for energy because capital costs are much greater than energy costs (Kim and Heob, 2013).

Additionally, if the reverse is true, then we say GNM Granger-causes EC (or GNM $\rightarrow$ EC). It implies that capital stock and energy tend to be complements, suggesting that a unidirectional causal relation is found from capital use to EC. Thus, creation of any energy conservation policy could lead to a saving in EC.

However, when both relationships are true, a feedback effect is said to exist between EC and GNM. It implies that EC explains more (less) of the variation of green mortgage, while green mortgage explains less (more) of the variation of EC.

We apply above procedures to provide expected findings and implications with the existence of threshold effects in two regimes. In the usual regime, we expect the evidence of EC leading green mortgage (GNM), suggesting less pollutant emission through EC. On the other hand, in the unusual regime, mixed evidence of EC following GNM is expected to be found, even for bi-directional feedbacks, suggesting more pollutant emission through EC. Energy improvement will be proposed to reduce pollutant emission through EC, even formulating the plan of time-of-use electricity rates to restrain the power load during the peak time. Thus, Efficiency improvement is a key choice for a new plant and upgrades of existing plant on reducing pollutant emission.

2.1. Data

This study employs monthly data spanning the period from January 1998 to April 2013. EC and green mortgage (GNM) in Taiwan are obtained by Taiwan Economy Journal (TEJ) databases. Also, we obtained EC for individuals and industries from TEJ. So the time series of 184 sampling points are obtained.

Green mortgages (GNM) at the banks are the main source of Taiwan's Executive Yuan National Development Fund, in compliance with Executive Yuan policies. Loan financing programs under green mortgages for pollution prevented policy include low-interest loans to private enterprises for pollution control equipment and concessional loans for the purchase and installation of energy-saving equipment respectively. Loan financing programs should also be in accordance with regulations of the banks.[5] Moreover, pollutant emission through EC is tied to environmental issues. Individuals and businesses are benefits

5 For instance, as shown by Taiwan's Executive Yuan National Development Fund, maximum terms are 10 years for low-interest loans and 7 years for concessional loans, with interest rate of postal savings 2-year time deposit plus 2.175% and 2.45% respectively. Amount of low-interest loans and concessional loans are provided with an upper limit of NT$1 billion and of NT$400 million respectively. Loan financing programs may allow 3-year grace period for principal. Thus, we use amounts of green mortgages at the banks to capture the improvement of pollutant emission through electricity consumption.

from green mortgages. Hence, we use amounts of green mortgages at the banks to capture the improvement of pollutant emission through EC.

3. RESULTS

Table 1 reports summary statistics for monthly green mortgage (GNM) and monthly degrees of EC, including total EC, individual EC, and industrial EC. All variables are transformed as natural logarithm function. The preliminary statistics includes the mean, median, maximum, minimum, standard deviation, skewness, and kurtosis. Note that the units of EC are 1000° and the unit in GNM is 1 million Taiwan dollars. Table 1 shows the average values are total EC of 16.442, industrial EC of 15.805, people EC of 15.683 and green mortgage of 10.143, respectively. The standard deviation is total EC of 0.182, industrial EC of 0.192, individual EC of 0.203, and GNM of 0.388 respectively.

Table 2 reports results of the ADF tests. We use the augmented Dickey-Fuller test (ADF test) to construct a parametric correction for higher-order correlation and examine the null hypothesis of unit roots by the ADF test (Dickey Fuller, 1981). This table shows that the levels in EC and GNM series are not stationary. However, after one difference, the null hypothesis of unit root would be significantly rejected at the 1% level.

Table 3 report estimated results of the Engle-Granger cointegration test for EC and GNM. We employ the Engle and Granger (1987) cointegration test to examine the long-term relationship between EC and GNM. This test can be described as $\omega_t = EC_t\text{-}\alpha\text{-}\beta GNM_t$ where w_t is the error correction term at time t, α is the coefficient for the intercept term, and β is a cointegration value. In addition to considering total EC and GNM, we further discuss the cointegration test for GNM and industrial (individual) EC.

Table 3 shows that the ECs are cointegrated with the GNM in total EC, industrial EC, and individual EC cases because the estimated coefficients of b1are significant in the two of three cases where b1 is the estimated coefficient of the error term in the ADF test. It implies that the long-term equilibrium relationships between EC and GNM in total EC and industrial EC cases. This table presents significant coefficients of the intercept of α, suggesting more other variables included. The cointegration values are positive and significant, reflecting positive relationship between EC and GNM in the three cases. These findings may be used in the design and effectiveness of electricity and environmental policies. The government would monitor and control pollutant emission through EC.

To understand the cross-correlations (C_{ij}) between EC and GNM, we follow Kantar and Keskin (2013) to compute correlation functions, as following.[6]

6 We compute correlations between EC and GNM and find the correlations of 0.64 in the total EC cases and 0.69 in the industrial EC cases during our sample period.

Table 1: Summary statistics of green mortgage (GNM) and EC

Statistics	EC			GNM
	Total	Industrial	Individual	
Mean	16.442	15.805	15.683	10.143
Median	16.454	15.813	15.674	10.068
Maximum	16.777	16.162	16.071	10.810
Minimum	15.950	15.265	15.161	9.494
SD	0.182	0.192	0.203	0.388
Skewness	−0.399	−0.250	−0.177	0.066
Kurtosis	2.477	2.274	2.381	1.625

Industrial and individual ECs are also considered. All variables for EC and GNM are transformed as natural logarithm function. The units of EC are 1000 degrees and the unit of GNM is one million Taiwan dollars. The monthly period data is from January 1998 to April 2013, with total observations of 184. EC: Electricity consumption, SD: Standard deviation

Table 2: Results of the ADF test (Dickey and Fuller, 1981)

EC	Level	Difference
Total	−2.038	−3.365**
Industrial	−1.436	−3.818***
Individual	−2.328	−13.447***
GNM	−1.600	−15.036***

***, ** and *Denote significance at the 1%, 5%, and 10% level. Critical values at the 1%, 5%, and 10% level are - 3.469, −2.879, and−2.576 respectively. ADF: Augmented Dickey–Fuller, EC: Electricity consumption

Table 3: Estimated results of the Engle-Granger cointegration test for EC and GNM

Variables	Total EC	Industrial EC	Individual EC
α	13.392***	12.303***	13.166***
β	0.301***	0.345***	0.248***
b1	−3.003**	−3.133**	−2.398
F-value	15.993***	12.133***	23.019***
AIC	−2.372	−1.643	−2.291

The equation ECt = α+β GNMt+wt is tested by Engle–Granger cointegration test. α is the constant coefficient in the regression and β is the cointegrated coefficient. b1 is the estimated coefficient of the error term in the ADF test. *P* values are in parentheses. ***, ** and * denote significance at the 1%, 5%, and 10% level, EC: Electricity consumption

$$C_{ij} = \left(R_i R_j - R_i R_i\right) / \sqrt{\left(R_i^2 - R_i^2\right)\left(R_j^2 - R_j^2\right)} \quad (5)$$

Where i and j are the numerical labels to EC and GNM and the notation <…> means an average over time. $R_{i,t}$ is defined as $R_{i,t} = \ln (P_{i,t+\tau}/P_{i,t})$ where P_t is the series of EC (GNM) level at the time τ. All cross-correlations range from −1 to 1, where −1 and +1 mean that two series i and j are completely anti-correlated and correlated, respectively. In the case of $C_{ij} = 0$ the series i and j are uncorrelated.

Next, the correlation coefficient between two series can be transformed to a distance between them by using an appropriate function as:

$$d_{ij} = \sqrt{2\left(1 - C_{ij}\right)} \quad (6)$$

Where a distance d_{ij} for series i and series j can lie in $0 \le d_{ij} \le 2$, while correlations run from −1 to +1. High correlations correspond to small values of d_{ij}.

Figure 1 plots the series of d between EC and GNM in the total and industrial EC cases separately, with moving window of 12 months.

Table 4: The results of the threshold effect tests

Statistics	EC vs. GNM	
	Total EC	Industrial EC
Value of SupLM	39.634**	35.496**
Fixed regressor (asymptotic) 5% critical value	35.029	32.617
Fixed regressor (asymptotic) *P* value	0.020	0.020
Bootstrap 5% critical value	31.651	29.511
Bootstrap *P* value	0.010	0.000
Threshold value	13.184	11.580
Percentage of sample number in Regime 1	0.184	0.101

The critical value of SupLM is obtained by the asymptotic and bootstrapping methods. Regime 1 means the data point is less than the threshold value. Other definitions can be found in Table 3. **Denotes significance at the 5% level

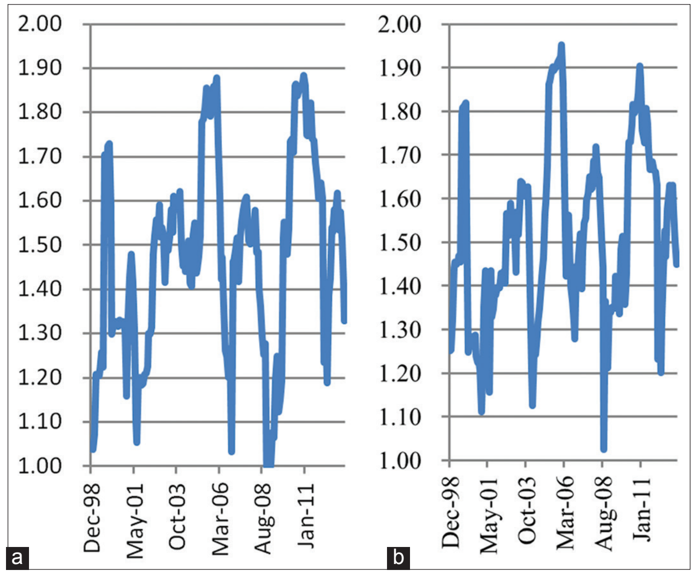
This figure shows the extreme high and low correlations may induce structure change and the asymmetric adjustment behaviors in the long term cointegration between EC and GNM. However, high correlation does not necessarily imply causalities.

Table 4 shows results of threshold effect tests. Due to possible structure change and the asymmetric adjustment behaviors as shown in Figure 1, we employ TVECM model suggested by Hansen and Seo (2002) to uncover cointegration relationships and causalities of their behaviors as well as structural change. We use a parametric bootstrap method with 1000 replications, with lag length of 4 based on the Schwartz information criterion.

Our results in the Table 4 show that the Sup LM values exceed the asymptotic and bootstrap 5% critical values respectively. Corresponding threshold levels are 13.184 in the total EC case and 11.580 in the industrial EC case. Note that Regime 1 is defined as that the error term is less than the threshold level while Regime 2 is defined as that the error term is larger than the threshold level. We also define which regime is the common economic situation. In empirical studies, the expected value of error term is always assumed to be a zero value. If the threshold level is positive (negative), we infer that Regime 1 (Regime 2) is more common economic situation. Our results present that Regime 1 are the common economic situation in both two cases because of positive threshold level.

Table 5 reports the estimated coefficients for the traditional and TVECM and Eicker–White standard errors are reported. Regime 1 represents the usual regime whereas Regime 2 represents the unusual regime. From Panel A, in the total EC case, the estimated coefficients of w_{t-1} of each regime denote the different adjustment speeds of two series towards equilibrium. We find the error-correction effects of EC in the unusual regime are lower than in the usual regime but opposite in direction on GNM variable. It implies that there is significantly larger adjustment speed of EC and GNM towards equilibrium in the usual regime is found. In the unusual regime, there is only significant adjustment speed of EC towards equilibrium. On the other hand, similar results are found when considering nonlinear dynamics in the industrial EC case. There is only significantly different adjustment speed of EC towards equilibrium in the usual and unusual regimes, with larger adjustment speed in

Figure 1: Plots of series of d between electricity consumption and GNM in the total and industrial EC cases, (a) total electricity consumption case, (b) industrial electricity consumption case



the usual regime. Thus, although EC and GNM variables show maximal error-correction effects in the usual regime, one finding in the total EC case of great interest is that the estimated error-correction effects of GNM are positive in the usual regime but negative in the unusual regime.

In Figure 2, we plot the error-correction effect—the estimated regression functions of EC_t and GNM_t as a function of w_{t-1}, holding the other variables constant.

In Figure 2(a), you can see the negative error-correction effect on the right size of the threshold, and on the left of the threshold, the sharp positive relationships for the GNM equation and negative relationships for the EC equation. On the other hand, Figure 2(b) shows the negative error-correction effect on the left size of the threshold, and on the right of the threshold, the negative relationships for the EC equation and the flat near-zero error-correction effect for the GNM equation. Finally, the transitory effects expressed by the differenced terms highlight significant or moderate autoregressive behavior for GNM, whereas the same is more accentuated for the EC.

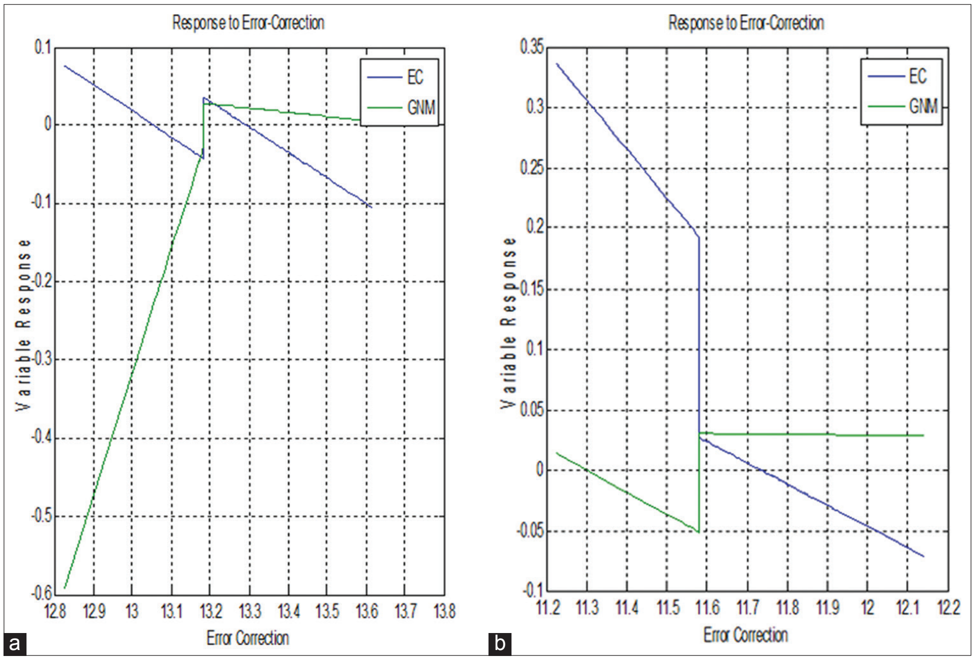
We also tested the causality of the two time series for EC and GNM variables using a Granger causality Wald test (Granger, 1969; Granger et al., 2000), which tests the null hypothesis of no causal relationship between the two time series.[7] Results in the traditional VECM and TVECM are presented in Table 6.

It is to note that the variable response is at the vertical line and error correction is at the horizontal line. The green line is represented as green mortgage (GNM) while blue line is represented as EC.

Table 6 documents results of Granger causality test in the traditional VECM and TVECM. From Table 6, the existence of

7 This approach is also used by Fung and Patterson (1999) and Hsueh et al. (2008), etc.

Figure 2: Plots of response to error-correction in the threshold vector error correction model, (a) in the total electricity consumption case, (b) in the industrial electricity consumption case



bidirectional relations between EC and GNM in the traditional VECM is found in the total and industrial EC cases, with larger magnitude on the causality from EC to GNM. On the other hand, in the TVECM, feedbacks for EC and GNM are found in both two regimes in the total case with the stronger effect in the unusual regime. It is to note that GNM Granger causes EC in the unusual regime in the total EC regime. It implies that, as EC is higher than threshold level, GNM significantly Granger causes EC although EC also Granger causes GNM. In the industrial EC case, the unidirectional causality from EC to GNM is only found in the usual regime but feedbacks are found in the unusual regime. It is also to note smaller dynamics of GNM than EC in the unusual regime in the industrial EC case.

Therefore, EC following green mortgage (GNM), even as feedbacks, suggests that the government would formulate the plan of time-of-use electricity rates to restrain the power load during the peak time, especially for more pollutant emission through EC. On the other hand, the firms should replace equipment to avoid more pollutant emission through EC through loan financing programs in the banks, including low-interest loans to private enterprises for pollution control equipment and concessional loans for the purchase and installation of energy-saving equipment respectively.

4. DISCUSSIONS

Due to asymmetric causalities in the Regime 2 in the industrial EC case from Table 6, energy use explains more of the variation of capital while capital explains less of the variation of energy use. It suggests capital stock and energy tend to be substituted. Our findings are consistent with Grepperud and Rasmussen (2004), Lee and Chien (2010), and Kim and Heob (2013). Possible reasons are the substitution of energy for capital has dominated the substitution of capital for energy because capital costs are much greater than energy costs (Kim and Heob, 2013). However, in general, asymmetric causalities in the Regime 2 in the EC case from Table 6, energy use explains less of the variation of capital while capital explains more of the variation of energy use. It indicates that creation of any energy conservation policy could lead to a saving in EC. Our findings on energy efficiency are consistent with Chang and Carballo (2011).

In order to reduce potential environmental problems, governments must further develop and implement energy conservation policies. Some studies show that the green subsidy relocates capital from the dirty sector in the dirty country to the green sector in the green country and thus reduces global emissions (Markusen et al., 1995; Hoel, 1997; Ulph and Valentini, 2001; Eichner and Runkel, 2014). On the other hand, a significant proportion of energy efficiency derives from higher energy prices (Jones, 1995; Gately and Huntington, 2002; Griffin and Schulman, 2005). Therefore, examinations of dynamics of EC and green capital should shed alternative and valuable insights on effects of structural changes across levels of economic development and growth as well as efficiency improvement.

5. CONCLUSIONS AND POLICY IMPLICATIONS

This paper examines threshold cointegration and dynamics of EC and green mortgage (GNM) in Taiwan by applying a TVECM. Industrial and individual EC are also analyzed respectively.

Our findings first show threshold effects for EC and GM in the total and industrial EC cases. For causalities between EC and GNM, feedbacks in total EC case and EC causing GNM in the industrial EC case are obtained in the usual regime respectively, suggesting

Table 5: Results on traditional and TVECM

Dependent variable	Traditional VECM		Threshold VECM			
			Regime 1		Regime 2	
	ΔEC	ΔGNM	ΔEC	ΔGNM	ΔEC	ΔGNM
Panel A	**In the total EC case**					
w_{t-1}	−0.344***	0.353***	−0.335**	1.579***	−0.326***	−0.053
C	4.459***	−4.554***	4.370**	−20.838***	4.329***	0.725
ΔEC (−1)	0.033	−0.084	−0.553***	−0.999**	0.196***	0.260*
ΔEC (−2)	0.492***	−0.175***	0.237**	−0.092	0.555***	−0.064
ΔEC (−3)	0.250***	−0.346***	0.236	−0.381	0.311***	−0.077
ΔEC (−4)	−0.107*	0.024	−1.194***	−0.987***	−0.027	0.339*
ΔGNM (−1)	−0.115***	−0.563***	−0.079***	−0.638***	−0.023	−0.006
ΔGNM (−2)	−0.064*	−0.337***	0.097***	−0.564***	−0.050	0.090
ΔGNM (−3)	−0.040	−0.194***	0.202***	−0.406**	−0.045	0.070
ΔGNM (−4)	−0.003	−0.118***	0.204***	−0.247*	−0.017	−0.001
Panel B	**In the industrial EC case**					
w_{t-1}	−0.249***	0.377***	−0.403*	−0.182	−0.176**	−0.004
C	2.878***	−4.335***	4.857*	2.059	2.060**	0.080
ΔEC (−1)	−0.425***	−0.213***	−0.322*	0.133	−0.342***	0.054
ΔEC (−2)	−0.088	−0.167*	0.655**	0.032	−0.027	0.003
ΔEC (−3)	0.141*	−0.200**	1.208***	−0.497***	0.145**	−0.008
ΔEC (−4)	−0.037	−0.075	−0.276**	−0.013	−0.034	0.114
ΔGNM (−1)	−0.121***	−0.529***	−0.350***	−1.060***	−0.097*	−0.012
ΔGNM (−2)	−0.104**	−0.307***	−0.296	0.029	−0.096*	0.036
ΔGNM (−3)	−0.025	−0.163***	−0.416*	0.091	0.015	0.020
ΔGNM (−4)	0.029	−0.099**	−0.662**	0.001	0.062	−0.032

wt−1 denotes the error term obtained from the cointegration regression; ΔEC denotes the change in EC at time t; ΔGNM denotes the change in the bank deposits on pollution prevented at time t. Regime 2 means the datapoint is larger than the threshold value. Other definitions can be found in Table 3. ***, ** and *denote significance at the 1%, 5%, and 10% level

Table 6: Results of Granger causality test in the traditional VECM and TVECM

Alternative hypotheses	VECM	TVECM	
		Regime 1	Regime 2
In the total EC			
GNM→EC	2.8456**	2.2137*	4.8501**
EC→GNM	9.7102***	2.7419**	3.9995***
In the industrial EC			
GNM→EC	2.2303*	1.6596	2.9224*
EC→GNM	8.1480***	2.9656*	3.2027**

F-statistics are reported. Regime 1 represents the usual regime whereas Regime 2 represents the unusual regime. ***, ** and * denote significance at the 1%, 5%, and 10% level, EC: Electricity consumption, VECM: Vector error correction model, TVECM: Threshold VECM

that energy use explains more of the variation of capital while capital explains less of the variation of energy use. It suggests capital stock and energy tend to be substituted but efficiency improvement will be proposed. On the other hand, feedbacks in the unusual regime also detected in the total and industrial EC cases, with asymmetric substitutability between EC and GNM. It implies that the substitution of energy for capital has dominated the substitution of capital for energy in the industrial EC case but a reverse relation in the total EC case. In order to reduce the effects of the potential environmental problem, energy efficiency improvement will be strongly proposed for a new plant and upgrades of existing plant on reducing pollutant emission. Thus, creation of any energy conservation policy could lead to a saving in EC.

Finally, we further find statistically different error-correction coefficients for EC and GNM in two regimes, with a substantially larger impact in the usual regimes. Our finding of great interest is different estimated error-correction effects of EC and GNM and strong asymmetries in the speed of adjustment to the long-run equilibrium in both two regimes. Thus, GNM has a critical and predominant role on increasing efficiency improvement and reducing pollutant emission.

Several important policy implications emerge from our empirical results of EC and green mortgage. Stronger effects on EC following GNM in unusual regime than EC causing GNM suggest that government strongly support and propose future efficiency improvement to reduce the effects of potential environmental problems. For instance, power generating options are proposed, with including coal-fired rankine cycle steam plants with advanced steam parameters, natural gas-fired gas turbine-steam, and coal gasification combined cycle plants. On the other hand, government improves and decreases current capital costs, lower than energy costs. Therefore, our results should highlight the critical importance of using TVECM in empirical studies on threshold cointegration and dynamics of EC and green mortgage.

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