The impact of biomass, geothermal and hydroelectric energy consumption on industrial production: A threshold cointegration model with regime shifts

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Abstract

This paper aims at estimating the impact of total renewable energy consumption and its components on industrial production. Paper launches the data of industrial production, total biomass energy consumption, hydroelectric energy consumption, geothermal energy consumption and total renewable energy consumption for US for the period January, 1974 - January, 2012. Paper, then, following the growth rate of the data, employs nonlinear cointegration vector and nonlinear vector error correction model (VECM) through regime shifts. In estimation algorithm, all coefficients, except cointegration vector, are allowed to shift from one regime to another. Finally paper reveals that (i) total biomass energy consumption and industrial production and (ii) geothermal energy consumption and industrial production are significantly cointegrated and, that, on the other hand, (iii) hydroelectric energy consumption and industrial production, (iv) total renewable energy consumption and industrial production do not follow cointegrating path, and (v) VECM's second regimes need larger adjustments in order for industrial growth to reach its long run equilibriums with growths of biomass and geothermal consumption.

Keywords: biomass energy consumption, geothermal energy consumption, hydroelectric energy consumption, industrial production, threshold cointegration and VECM

1. Introduction

In terms of today, global warming poses the greatest threat to humanity. EREC (2011) states that main source of Green House Gas (GHG) emissions is carbon dioxide (CO_2) emissions and that, hence, CO_2 is biggest contributor to global warming. Especially within last two decades, scientists underline the necessity of renewables to diminish the CO_2 emissions. Bilgili (2012), employing US data and following cointegration model with regime shifts, reveals that fossil fuel consumption increases CO_2 emissions while biomass consumption yields reverse effect on CO_2 emissions. EREC (2011) and Diakoulaki et al. (2006) explore as well that renewables have negative impact on GHG.

Related literature keeps the estimations of efficiency and impact of renewables on CO_2 as in Berglund and Börjesson (2006), Fischer et al. (2010), Acaroğlu and Aydoğan (2012), Khanna et al. (2011), and Reinhardt and Falkenstein (2011). Researches not only investigate the impact of renewables on CO_2, they estimate the influence of renewables on economic growth as well. This debate first can be seen in articles focusing on existence of correlation between total energy consumption and economic growth. Later, energy articles comprise also renewables consumption and economic growth nexus.

One may find some works through the literature on relationship between energy consumption and economic growth as in Aqeel and Butt (2001), Bowden and Payne (2009), Cheng and Andrews (1998), Masih and Masih (1997), Lee (2006), Erol and Yu (1987), Erbaykal (2008), Narayan and Prasad (2008), Narayan et al. (2008), Soytas and Sari (2003), Stern (1993), Stern and Cleveland (2004), Karanfil (2008), Ang (2008), Samouilidis and Mitropoulos (1984), He et al. (2008), Öztürk et al. (2010), Ouedraogo (2013), Esso (2010), Chiou-Wei et al. (2008), Fallahi (2011), Esteve and Tamarit (2012) Acaravci and Öztürk (2010), Kula et al. (2012) and Öztürk and Acaravci (2011). The successful detailed surveys on economic growth-energy consumption nexus can be found in Chiou-Wei et al. (2008) and Ozturk (2010).

One sees the papers yielding causality from economic growth to energy consumption as in Kraft and Kraft (1978), Cheng (1999), Abosedra and Baghestani (1989), Aqeel and Butt (2001) and Ang (2008). On the other hand, Yuan et al.(2007), Ramcharran (1990), Stern (1993), (2000), Soytas et al. (2001), Odhiambo (2009), Oh and Lee (2004), Wolde- Rufael (2004), Lee and Chang (2005), Ho and Siu (2007), Nazlioglu (2011) and Bowden and Payne (2009) reveal causality from energy consumption to economic growth. Glasure (2002), Hondroyiannis et al. (2002), Ghali and El-Sakka (2004), Erdal et al. (2008) and Belloumi (2009) find bi-directional causality between energy consumption and growth.

One monitors, as well, within literature, the papers concluding no causality between economic growth and energy consumption as in Yu and Jin (1992), Cheng (1995), Masih and Masih (1996), Fatai et al. (2002), Altinay and Karagol (2004), Halıcioglu (2009), Yu and Hwang (1984), Soytas and Sari (2009) and Gross (2012). Although some other papers have evidences of no causality, they reach also causality for the variables of energy consumption and economic growth, i.e., as in Karanfil (2008), Wolde- Rufael (2005), Soytas and Sari (2003) and Murray and Nan (1996).

Recently, energy and economic growth literature focuses on correlation between renewable consumption and economic growth as, i.e., in Lee (2005), Lee and Chang (2008), Al-Iriani (2006), Narayan and Smyth (2007), (2008), (2009), Narayan et al.(2007), Mahadevan and Asafu-Adjaye (2007), Sadorsky (2009), Apergis and Payne (2010a), (2010b), (2011),(2012), Hamit-Haggar (2012), Yildirim et al. (2012), Bildirici (2012), Menegaki (2011), Çoban and Yorgancılar (2011), Magnani and Vaona (2011) and Rafiq and Salim (2009).

Apergis and Payne (2012) launching data of 80 countries, Apergis and Payne (2011) employing for six Central American countries, Apergis and Payne (2010a) using data for 13 countries within Eurasia and Apergis and Payne (2010b) observing 20 OECD countries, follow heterogeneous panel cointegration and error correction models and find causality between renewable energy consumption and economic growth in both the short-run and long-run. Coban and Yorgancilar (2011), Magnani and Vaona (2011) and Rafiq and Salim (2009) find similar results claiming positive impact of renewables on economic growth. Some other studies show no effect of total renewables on GDP growth as is in Menegaki (2011) and Yildirim et al. (2012).

There are limited papers in the literature regarding the effect of subcomponents of total renewables on economic growth. Bildirici (2012), applying Autoregressive Distributed Lag Bounds Testing (ARDL) approach of cointegration and error correction models, reveals that in all 10 developing countries, except Paraguay, there is cointegration relation between biomass consumption and economic growth. Yildirim et al. (2012) launching Toda–Yamamoto procedure and bootstrap-corrected causality, find that biomass waste derived energy consumption influences real GDP in US. Aydın (2010), following some simulations, reaches that hydroelectric power has slightly positive effect on macro indicators of Turkish economy and Ziramba (2013), employing Toda-Yamamoto methodology, finds hydroelectricity has a significant positive impact in Egypt and South Africa but not in Algeria.

The motivation of this paper lies in three points. First, there are very few papers launching the data of biomass and hydroelectricity in the literature of energy-economic growth nexus. Secondly there is no paper considering the influence of geothermal energy consumption on economic growth estimated by statistical models. Thirdly there is no paper following nonlinear algorithm with structural changes in VECM through regime shifts in the related literature. To this end, this paper employs threshold cointegration model and vector error correction model (VECM) with two-regime shifts considering causality from biomass, geothermal, hydroelectric and total renewables consumption to economic growth. Therefore, this paper aims at observing, if available, significant evidence of long run and short run equilibrium between industrial production growth and subcomponents of renewables consumption growth through threshold cointegration and VECM allowing coefficients to shift from one regime to another regime.

Methodology and data section explains algorithm of threshold cointegration and VECM with two-regime shifts and introduces the data launched. The section of Estimation results yields estimation output of nonlinear threshold models given in the methodology section. Finally, Conclusions and policy proposals of this paper may provide policy makers with some considerable remarks on short run and long run estimations and offer some policy recommendations through analyses conducted in this paper.

2. Methodology and data

Assuming that X_t is $I(1)$ and m dimensional time series cointegrated with one m x 1 cointegrating vector, then, as is indicated in Hansen and Seo (2002), the linear form of VECM is given in Eq. (1).

$$\Delta X_t = \vartheta' X_{t-1}(B) + u_t \tag{1}$$

where

$$X_{t-1}(B) = \begin{pmatrix} 1 \\ z_{t-1}(B) \\ \Delta X_{t-1} \\ \Delta X_{t-2} \\ \vdots \\ \Delta X_{t-l} \end{pmatrix} \tag{2}$$

$X_{t-1}(B)$ is n x 1 and ϑ is n x m where $n = ml + 2$. The error term of u_t in Equation (1) is assumed to be a vector of martingale difference with finite covariance matrix of $\sum E(u_t u_t')$. The term z_{t-1} denotes error correction and $X_{t-1}(B)$ and $z_{t-1}(B)$ indicate that variables are considered at generic values of *B*.

One may extend linear model of (1) to a threshold cointegration model with regime shifts.

$$\Delta X_t \begin{Bmatrix} \vartheta_1{}' X_{t-1}(B) + u_t, & if\ z_{t-1}(B) \leq \gamma \\ \vartheta_2{}' X_{t-1}(B) + u_t, & if\ z_{t-1}(B) > \gamma \end{Bmatrix} \tag{3}$$

Or, cointegration equation (3) can be rewritten equivalently as is given in (4)

$$\Delta x_t = \vartheta_1' X_{t-1}(B) d_{1t}(B, \gamma) + \vartheta_2' X_{t-1}(B) d_{2t}(B, \gamma) + n_t \tag{4}$$

where

$$d_{1t}(B, \gamma) = 1(z_{t-1}(B) \leq \gamma) \tag{5a}$$

$$d_{2t}(B, \gamma) = 1(z_{t-1}(B) > \gamma) \tag{5b}$$

$$0 < \mathrm{P}\ (z_{t-1} \leq \gamma) < 1 \tag{6}$$

and where ϑ_1 and ϑ_2 are the dynamic coefficient matrices shifting from one regime to another regime and γ is threshold parameter. Hence, all coefficient matrices, except cointegrating vector *B*, are allowed to switch between regimes. The right hand side of Equations (5a) and (5b) are indicator functions. The threshold cointegration model in (3) or in (4) is valid if probability given in (6) is met. Otherwise, threshold cointegration model would be linear cointegration model as given in (1). Therefore, this paper, employing Equations 3 to 6 with residuals following white Gaussian pseudo-random process as explained in Hansen and Seo (2002), Peres (2013) and Matsumoto and Shirai (2013), seeks to estimate (i) parameters of nonlinear cointegrating vector between industrial growth and renewables growth and (ii) parameters of nonlinear vector error correction model. The estimation section yields the estimations from (i) and (ii).

This paper launches monthly data of Industrial Production Index, Total Biomass Energy Consumption (Trillion Btu), Hydroelectric Power Consumption (Trillion Btu), Geothermal Energy Consumption (Trillion Btu) and Total Renewable Energy Consumption (Trillion Btu) for US for the period 1973:1-2012:1. The source of Industrial Production Index is Board of Governors of the Federal Reserve System (FRS). Total Biomass Energy Consumption, Hydroelectric Power Consumption, Geothermal Energy Consumption and Total Renewable Energy Consumption are extracted from U.S. Energy Information Administration (EIA). The renewables, later, are transformed into quadrillion btu. Paper, following the growth rates of the variables, reaches initially Table 1 and Figures 1 to 4 to provide one with visual inspection of data. The growth of Industrial Production Index is taken as proxy for economic growth throughout observations and estimations of this paper.

Table 1 gives descriptive statistics of growths of Industrial Production (IP), Total Renewable Consumption (TRenewables), Total Biomass Energy Consumption (Biomass), Hydroelectric Power Consumption (Hydroelectric) and Geothermal Energy Consumption (Geothermal), respectively. One may follow these descriptive statistics to observe the first and second moments of the variables.

Table 1: Descriptive Statistics for Renewable Consumption Growth and IP Growth 1974:1-2012:1

Descriptive Statistics	IP	TRenewables (Quadrillion Btu)	Biomass (Quadrillion Btu)	Hydroelectric (Quadrillion Btu)	Geothermal (Quadrillion Btu)
Mean	2.068109	2.329026	3.132587	1.411333	8.295295
Standard Dev.	4.747305	8.928048	7.986891	15.65966	20.17662
Minimum	-15.5418	-25.1432	-28.136	-37.6823	-42.4862
Maximum	12.21305	33.32932	28.98699	65.62609	88.49738
Observation	457	457	457	457	457

The 457 monthly observations for US variables reveal that means of IP and TRenewables are close to each other and differ from the means of Biomass, Hydroelectric and Geothermal. The mean of geothermal growth is the highest among those of other variables. The statistics yields also that IP and Geothermal data comprise the smallest and highest standard deviations, respectively, and that standard deviation of Biomass approximates that of TRenewables as the standard deviations of other variables disperse prominently from each other.

One may also need to monitor the graphs of variables to compare to each other. Figures 1 to 4 provide one with preliminary observation to inspect if IP growth tends to have co-movements with the growth of other variables. In Figure 1, the trend of IP is represented by bold dashed line with polynomial equation of [$y= 2E-15x^4 - 2E-10x^3 + 1E-0.5x^2 - 0.2403x + 1955.5$] and trend of TRenewables is given by regular line with polynomial equation of [$y= 1E-15x^4 - 1E-10x^3 + 4E-06x^2 - 0.073x + 436.27$].

Figures 2 to 4, trends of Biomass, Hydroelectric and Geothermal are depicted by polynomial equations of [$y= -1E-14x^4 + 1E-09x^3 - 7E-05x^2 + 1.5754x - 13224$], [$y= 1E-14x^4 - 1E-09x^3 + 7E-0.5x^2 - 1.6375x + 13448$] and [$y= 6E-15x^4 - 7E-10x^3 + 3E-05x^2 - 0.7396x + 5962.7$], respectively. Considering movements of the series, one may examine from Figure 1 that IP and TRenewables disperse from each other during whole sample period, except some data points, and that IP and Hydroelectric series do not seem to move together, either, as is seen in Figure 3. Considering Figure 2, one may claim that IP and Biomass might converge through the end of period and tracing Figure 4, one might state that IP and Geothermal have some co-movements. All figures provide researchers with some visual inspections and some preliminary estimations regarding potential convergence or divergence of the series. This paper will launch, then, further econometrical analysis to comprehend whether or not the growth of total renewable consumption, its components and economic growth are cointegrated in next section.

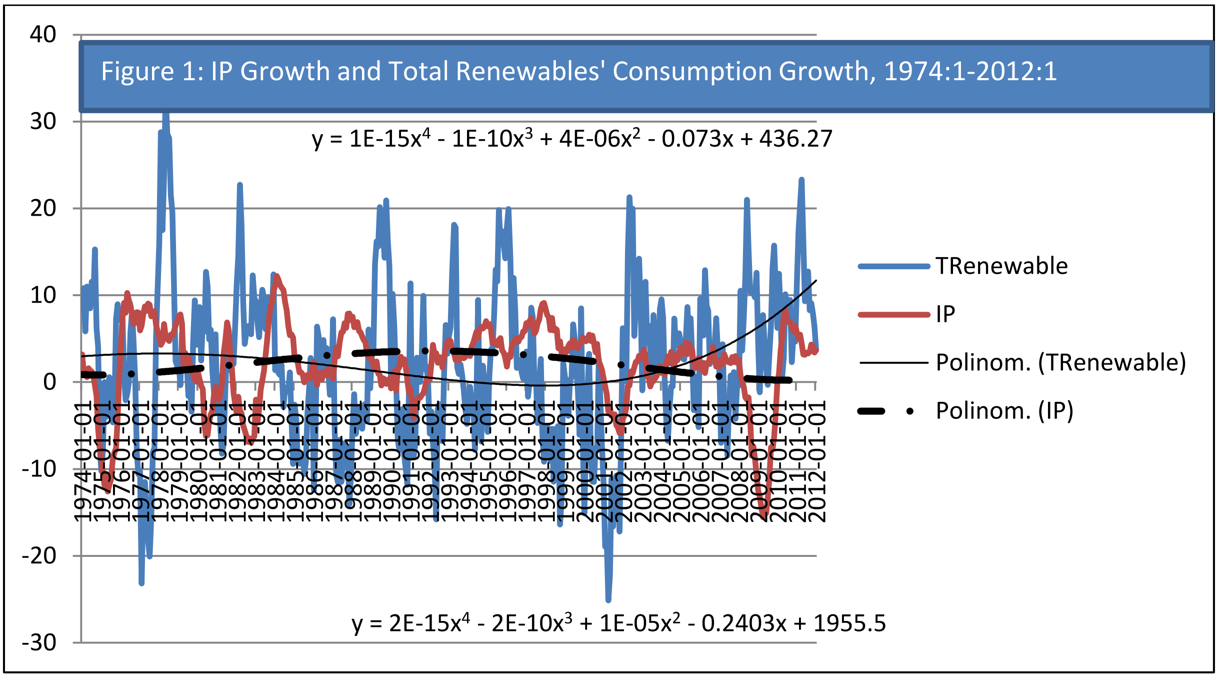

Figure 1: IP Growth and Total Renewables' Consumption Growth, 1974:1-2012:1

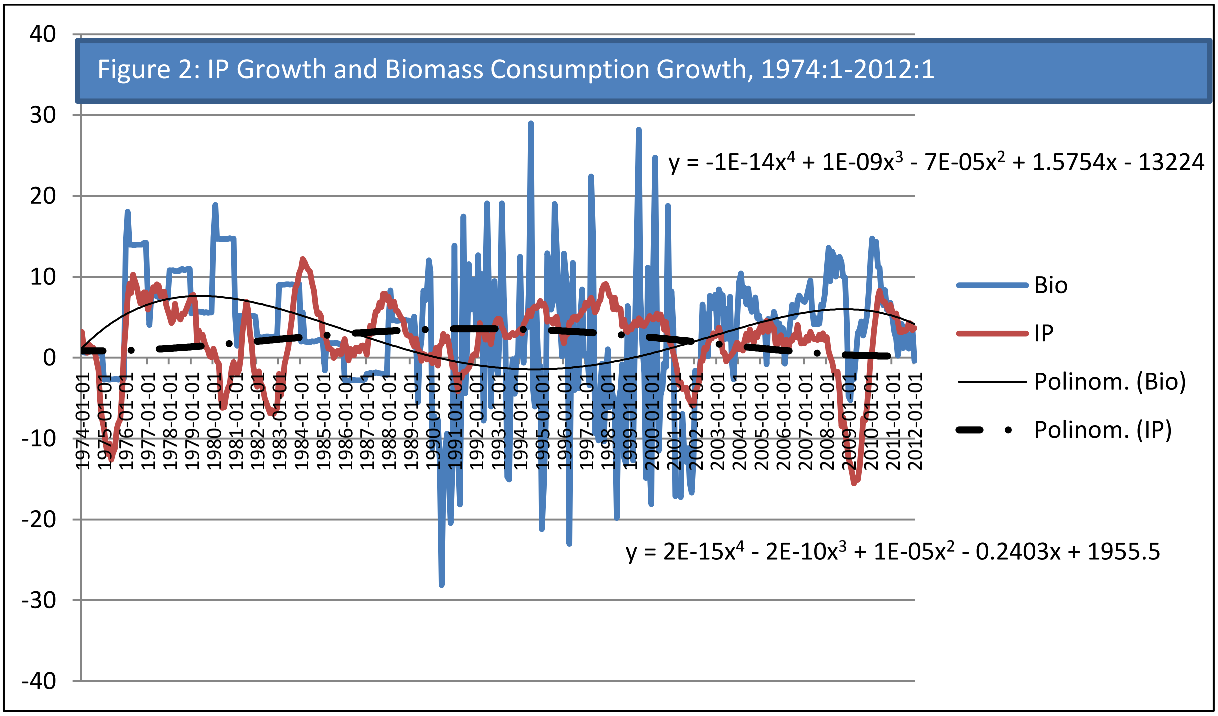

Figure 2: IP Growth and Biomass Consumption Growth, 1974:1-2012:1

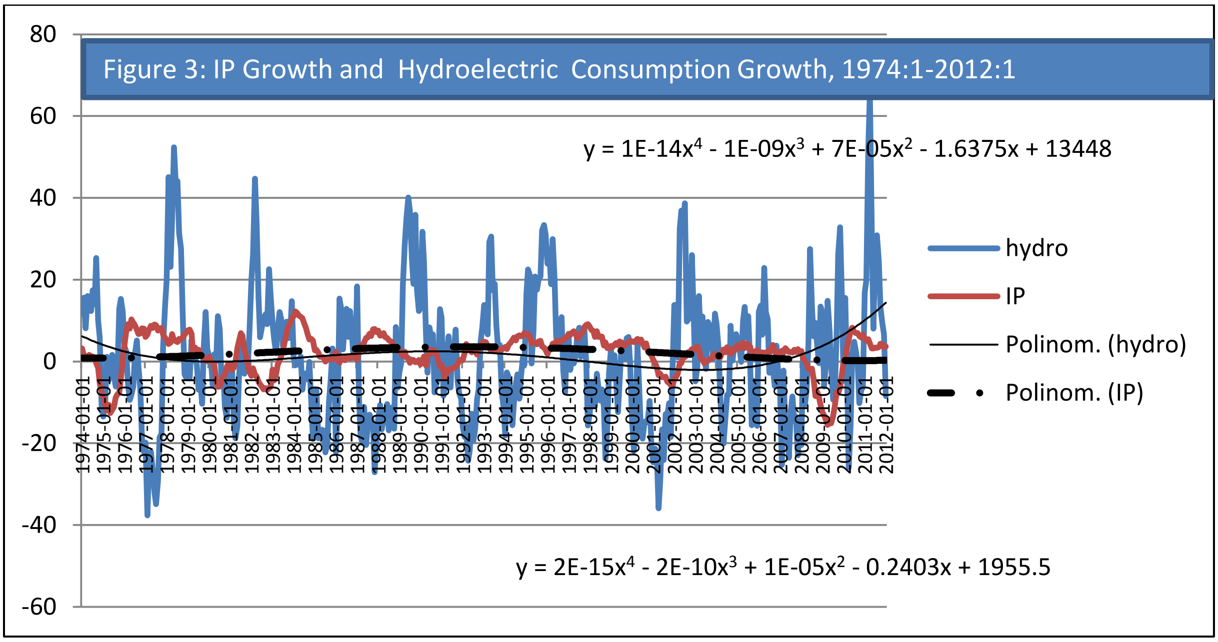

Figure 3: IP Growth and Hydroelectric Consumption Growth, 1974:1-2012:1

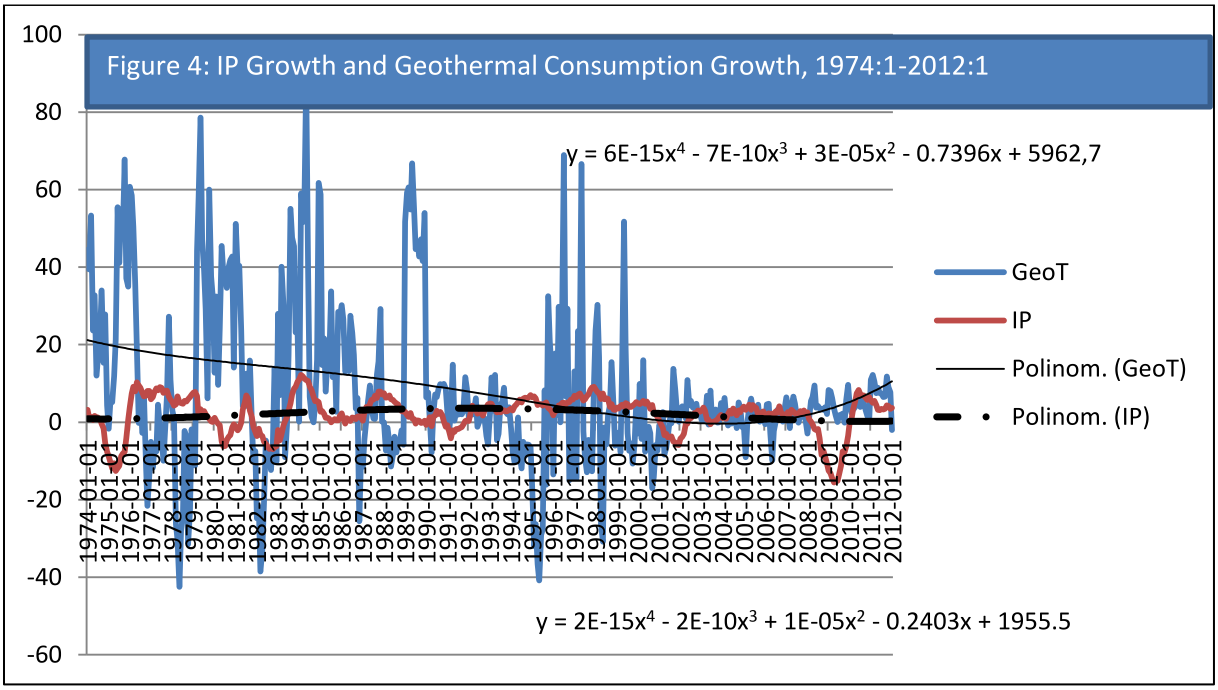

Figure 4: IP Growth and Geothermal Consumption Growth, 1974:1-2012:1

3. Estimation results

As is explained in Methodology section, this paper, following Hansen and Seo (2002), employs two-regime threshold cointegration model. The first estimation considers if there is an evidence of significant cointegration vector between IP and renewable energy consumption. Table 2 provides the *p*-values of threshold cointegration tests through 5000 Monte-Carlo simulations. The *p* values indicate that there are significant cointegrating vectors between IP growth and Biomass growth and for the variables of IP growth and Geothermal growth for the period 1974:1-2012:1. Table 2 indicates, as well, that hydroelectric consumption growth does not follow cointegrating path with industrial production growth. Hence total renewable consumption does not have long run relationship with industrial production either. This final result from threshold cointegration analysis through 5000 simulation replications disconfirms the majority of energy literature finding positive causality from total renewables to economic growth. The 5000 simulation replications employing US data do not verify also available few papers in the literature yielding positive impact of hydroelectricity on economic growth in Egypt, South Africa and Turkey.

Table 2: Threshold Cointegration Tests with 5000 Simulation Replications

Tests for Threshold Cointegration	*p*-values
H_0: There is no cointegration between IP and Biomass	0.00800
H_0: There is no cointegration between IP and Hydroelectric	0.60400
H_0: There is no cointegration between IP and Geothermal	0.07200
H_0: There is no cointegration between IP and Total Renewables	0.53600

Table 3: Threshold Cointegration Parameters with 5000 Simulation Replications

	Beta	Gamma
IP-Biomass	0.70465	11.50668
IP-Geothermal	0.24346	10.43383

Upon the results of Table 2, Table 3 yields the estimates of long run parameter (Beta) and threshold parameter (Gamma) for the pairs of IP-Biomass and IP-Geothermal. The cointegration equation for IP and Biomass growths is [IP growth = 0.70465 Biomass growth + z_t] and estimated threshold value is 11.50668. This equation depicts that growth in biomass energy consumption has a positive long run impact on industrial production growth. As biomass consumption growth increases by one unit, industrial production growth will rise by 0.70465 units. Estimated threshold value indicates that IP growth rate is more than 11 units above biomass consumption growth rate. The Beta and Gamma estimates also indicate that Regime-1 appears when [IP growth $\leq$ (0.70465 Biomass growth + 11.50668)] and Regime-2 occurs when [IP growth $>$ (0.70465 Biomass growth + 11.50668)]. The estimated threshold vector auto regression (VAR) is given below in 1*a* and 1*b* where Δ and z_{t-1} denote difference operator and deviation from log run equilibrium at time t-1, respectively. The first and third rows in VAR represent Regime-1 and Regime-2 estimations, respectively. Eicker-White standard errors are in parentheses. Regime-1 consists of 94.7% of the total observations whereas Regime-2 has 5.3% of the total observations. Therefore, one may consider, as Hansen and Seo (2002) do, Regime-1 and Regime-2 are typical and extreme, respectively. Equation 1a reveals short term behavior of industrial production growth in USA for the period 1975:1-2012:1 and yields vector error correction term and short term impact values of bio mass consumption on industrial production. The estimated coefficient value -0.02077 of zt-1 denotes the speed of adjustment in order for IP to reach its long run equilibrium at time t. Due to deviation at time t-1, industrial production growth will change by -0.02077zt-1 units to restore its long run equilibrium at time t. The short term influence of biomass energy consumption on industrial production is insignificant at typical regime while it is significant with the value of -0.02164 at non-typical (extreme) regime. Equation 1b gives short run fluctuations of biomass energy consumption in USA and reveals that, in the short term, industrial production growth has no impact on biomass energy consumption growth during both typical regime and extreme regime. And Equation 1b reveals, as well, that, upon deviations from lung run occurred at time t-1, biomass energy consumption growth will change by 0.23122 zt-1 units to restore its long run equilibrium at time t during Regime-1 and will change by 1.49107 zt-1 units to keep its long run equilibrium at time t during Regime-2.

$$\Delta \mathrm{IP} = \left\{ \begin{array}{lllll} -0.00517 & -0.02077\,\mathrm{z}_{\mathrm{t}-1} & +0.22560\,\Delta\mathrm{IP}_{\mathrm{t}-1} & +0.00829\,\Delta\mathrm{Bio}_{\mathrm{t}-1} & \\ (0.05445) & (0.01093) & (0.06798) & (0.00725) & u_{1t},\quad z_{t-1} \leq 11.50668 \\ -1.83384 & +0.09005\,\mathrm{z}_{\mathrm{t}-1} & -0.02792\,\Delta\mathrm{IP}_{\mathrm{t}-1} & -0.02164\,\Delta\mathrm{Bio}_{\mathrm{t}-1} & \\ (0.60689) & (0.03705) & (0.15716) & (0.01081) & u_{1t},\quad z_{t-1} > 11.50668 \end{array} \right\} 1a$$

$$\Delta \mathrm{Bio} = \left\{ \begin{array}{lllll} -0.18725 & +0.23122\,\mathrm{z}_{\mathrm{t}-1} & +0.35678\,\Delta\mathrm{IP}_{\mathrm{t}-1} & -0.10875\Delta\mathrm{Bio}_{\mathrm{t}-1} & \\ (0.29826) & (0.05749) & (0.22494\ ) & (0.08815) & u_{2t},\quad z_{t-1} \leq 11.50668 \\ -12.34810 & +1.49107\,\mathrm{z}_{\mathrm{t}-1} & -1.63445\,\Delta\mathrm{IP}_{\mathrm{t}-1} & +0.15757\Delta\mathrm{Bio}_{\mathrm{t}-1} & \\ (9.56565) & (0.61285) & (2.26334) & (0.18371) & u_{2t},\quad z_{t-1} > 11.50668 \end{array} \right\} 1b$$

The estimations of long term parameter Beta and threshold value Gamma are 0.24346 and 10.43383, respectively. The cointegration equation for IP and Geothermal growths is, then, [IP growth = 0.24346 Geothermal growth + z_t] and estimated threshold value indicates that IP growth rate is more than 10 units above geothermal consumption growth rate and then Regime-1 occurs when [IP ≤ (0.24346 Geot + 10.43383)] and Regime-2 happens when [IP growth > (0.24346 Geothermal growth + 10.43383)]. The estimated threshold VAR is given below in 2*a* and 2*b*. Regime-1 and Regime-2 correspond to 95% and 5% of total observations, respectively. Eicker-White standard errors are in parentheses.

Equation 2*a* yields short term impact of geothermal energy consumption growth on industrial production growth and Equation 2*b* shows short term effect of industrial prediction growth on geothermal energy consumption growth. Equation 2*a* indicates that there is negative causality in the short run from geothermal energy consumption to industrial production at two regimes although geothermal consumption has significant and positive effect on industrial production in the long run. On the other hand, Equation 2*b* claims that industrial production is found ineffective for geothermal consumption in the short run.

$$\Delta \mathrm{IP} = \left\{ \begin{array}{lllll} -0.00177 & -0.02703\,\mathrm{z}_{\mathrm{t}-1} & +0.24914\,\Delta\mathrm{IP}_{\mathrm{t}-1} & -0.01401\,\Delta\mathrm{Geot}_{\mathrm{t}-1} & \\ (0.05331\ ) & (0.00944) & (0.06529) & (0.00467) & u_{2t},\quad z_{t-1} \leq 10.43383 \\ 2.75602 & -0.25065\,\mathrm{z}_{\mathrm{t}-1} & -0.13045\,\Delta\mathrm{IP}_{\mathrm{t}-1} & -0.04505\,\Delta\mathrm{Geot}_{\mathrm{t}-1} & \\ (1.09713) & (0.08336) & (0.10952) & (0.01073) & u_{1t},\quad z_{t-1} > 10.43383 \end{array} \right\} 2a$$

$$\Delta \mathrm{Geot} = \left\{ \begin{array}{lllll} -0.46811 & +0.30235\,\mathrm{z}_{\mathrm{t}-1} & -0.41852\,\Delta\mathrm{IP}_{\mathrm{t}-1} & -0.25303\,\Delta\mathrm{Geot}_{\mathrm{t}-1} & \\ (0.64330) & (0.10479) & (0.57128) & (0.06848) & u_{2t},\quad z_{t-1} \leq 10.43383 \\ 40.64821 & -2.39202\,\mathrm{z}_{\mathrm{t}-1} & 3.13789\,\Delta\mathrm{IP}_{\mathrm{t}-1} & -0.00757\,\Delta\mathrm{Geot}_{\mathrm{t}-1} & \\ (36.15040) & (2.85010) & (4.11534) & (0.27902) & u_{2t},\quad z_{t-1} > 10.43383 \end{array} \right\} 2b$$

Throughout Equations 1*a*, 1*b*, 2*a* and 2*b*, one notices that the error correction terms of $\mathrm{z}_{\mathrm{t-1}}$ have greater magnitudes in extreme regimes (Regime 2) than those of typical regimes (Regime 1). From this output, one states that each Regime 2 of 1*a*, 1*b*, 2*a* and 2*b* needs stronger error correction. The strongest error-correction appears in 2*b* with the value of -2.39202 and second strongest error-correction happens in 1*b* with the value of 1.49107. All eight error-correction terms of 1*a*, 1*b*, 2*a* and 2*b* have significant *t* statistics except $\mathrm{z}_{\mathrm{t-1}}$ value of Δ Geot, standing for Δ Geothermal energy consumption growth, in 2*b* during Regime-2.

One may conclude through nonlinear threshold cointegration estimations with two regime VECMs that (i) biomass energy consumption and geothermal energy consumption have significant and positive impact on industrial production in the long run, (ii) hydroelectric data and total renewable energy consumption data do not affect industrial production data in the long run, (iii) there exist short term causalities from biomass and geothermal energy consumption to industrial production.

4. Conclusion and policy proposals

This paper considers nonlinear cointegration model and Vector Error Correction Model (VECM) with two regime shifts and reaches evidence for strong threshold effect for some variables. Data employed in estimations covers Industrial Production (IP), Total Renewable Consumption (TRenewables), Total Biomass Consumption (Biomass), Hydroelectric power consumption (Hydroelectric) and Geothermal Consumption (Geothermal), respectively, for US and ranges from January-1973 to January-2012. Following growth rates of the variables, findings of this paper reveal that one rejects the null hypotheses of no cointegration (i) between IP growth and biomass consumption growth variables and (ii) between the variables of IP growth and geothermal consumption growth. On the other hand, threshold simulation replications provide one with no evidence of long run equilibrium for IP growth and hydroelectric growth. Hence, there is no evidence of cointegration vector for IP growth and total renewables growth either. VECMs yield negative influence of biomass and geothermal consumption on industrial production in the short term though they affect industrial production positively in the long run. VECMs from (i) and (ii) indicate, as well, that the error correction terms have greater magnitudes in Regime-2s than those of Regime-1s to reach their long run equilibrium.

Eventually this paper states that biomass consumption and geothermal consumption have significant positive impacts on economic growth in the long run. A plausible policy recommendation of this paper is to stimulate production and consumption of biomass and geothermal. Considering output of this paper and Bilgili (2012), one may state that the consumption of biomass, for instance, not only contributes to economic growth, but it also mitigates CO_2 emissions. Therefore, some subsidies for renewables should be implemented. Such incentive policies, as one may suggest, should not only consider biomass, but they should also comprise geothermal energy supply and demand. These incentives might be tax subsidies directly for renewables and/or subsidies for low emitting energy sources and/or subsidies for research and development in production of renewables. Tax incentive policies, such as Energy Policy Act (EPACT) of 1992, 1999 and 2001 in US might be administered effectively today and in the future (EIA, 2013). Galinato and Yoder (2010) consider subsidies for low-emitting energy sources through revenues from taxes on high-emitting energy sources. Fischer and Newell (2007) propose subsidies for renewables production and R&D for renewables. Jacobsson et al. (2009) suggest developing capital goods industry employing renewable energy sources. Haas et al. (2004) and Reiche and Bechberger (2004) recommend long-term stability of support mechanism and fair and easy access to the electricity from renewable sources. Meyer (2003) recommends policy makers to follow feed-in system as is in Denmark, Germany and Spain and Kalkuhl et al. (2013) consider, as well, the feed-in tariff and the carbon trust policy to promote the production, and, hence, consumption of renewables.

It appears that there needs an optimal combination of short term/midterm plans via tax policies to stimulate biomass/geothermal production and consumption and long term implementations to increase investments in these renewables' production via feed-in tariff policies through long run commitments offered by governments to biomass/geothermal energy sectors, as industries which, most likely, might be able to yield higher welfare for societies with quality environment.

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