Residential electricity use effects of population in Kazakhstan

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Abstract: We studied impacts of population groups of 15–64 and 65–above on residential electricity use in Kazakhstan in the STIRPAT framework. Unlike earlier studies for Kazakhstan in the STIRPAT framework, we applied time series cointegration and error correction methods. Results from the autoregressive distributed lags bounds testing approach indicate a significant impact of the age group of 15–64 on the residential electricity use in long-run, however, the age group of 65–above has only short-run effects and affluence has no effect. Another finding is that, 21% of short-run disequilibrium can be corrected towards long-run equilibrium during a year. Policymakers should consider the trend of the population group of 15–64 in their decision about the long-run stance of the residential electricity consumption. The trend suggests an implementation of energy conservative policy and increasing efficiency of its usage. Another policy implication is that household's electricity consumption is not income dependent maybe due to cheap electricity prices subsidised by the government. In the short-run, policy makers should consider the age group of 65–above among other factors in their implementations. Moreover, they should be careful in making any policy shock to the residential electricity consumption system, because convergence towards long-run equilibrium path takes about six years.

Keywords: age groups; residential electricity consumption; STIRPAT; Kazakhstan; cointegration; error correction modelling; income; Commonwealth of Independent States; CIS.

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1 Introduction

Energy is an indispensable part of our society and economy. Understanding the role of economic growth and population on energy consumption is critical for policymaking and economic development. This topic has been analysed by a vast number of studies. One of the prominent questions in this field is relationship between energy use and socio-economic factors, which has gained special attention with the pioneering study of Kraft and Kraft (1978). One can find many different studies devoted to the divergent aspects of this relationship both in national and in cross-national levels. However, little attention has been paid to the oil-exporting economies of the Commonwealth of Independent States (CIS), including Kazakhstan. In this regard, as one of the fast growing economies of the Central Asia, it is valuable to investigate the topic in Kazakhstan.

The results of the research on the relationship between energy use and socio-economic factors are ambiguous. Therefore, there are four hypotheses in energy-growth literature (Bozoklu and Yilanci, 2013; Damette and Seghir, 2013; Ozturk, 2010; among others). The growth hypothesis implies that energy consumption is one of the drivers of economic growth while the conservative hypothesis argues for unidirectional causality from economic growth to energy consumption. The feedback hypothesis suggests a bi-directional causal relationship between energy consumption and economic growth. The last view is neutrality hypothesis, which claims that there is no causality between energy consumption and economic growth.

As Liddle (2013) expresses, many studies analysing energy use take it as a function of per capita GDP and price (Holtedahl and Joutz, 2004; Halicioglu, 2007; Dergiades and Tsoulfidis, 2008; Narayan et al., 2007). However, the impact of population age groups on energy was not considered by any of the above-mentioned studies. In his work, Liddle (2013) used panel data for 31 developed countries and 54 developing countries to analyse the effect of population and its age groups on residential energy consumption. Despite conducting a large panel analysis, Kazakhstan, the focus of this study, was not included in his analysis. Meanwhile, numerous valuable studies investigated the relationship of environmental effects of energy use and age structure of population. Two main directions draw attention in the energy studies: energy-affluence and energy-population relationships, which can/need to be combined by the unique model.

The STIRPAT model, developed by Dietz and Rosa (1994, 1997), allows for analysis of the impacts of population and economic factors on energy use (Liddle, 2014). Almost all of the energy studies based on the STIRPAT framework investigate the relationship of the variables of interest using panel or cross-national data for a group of developed and developing countries (York et al., 2003b; Poumanyvong et al., 2012; York, 2007; Liddle and Lung, 2010). Regarding Kazakhstan, only a few studies analysed impacts of economic growth and population or its age groups on energy use by employing STIRPAT and other modelling frameworks (Brizga et al., 2013). In addition, many of these studies employed cross-sectional or panel data (Shafiei, 2013; Scarrow, 2010; Fang et al., 2012; Nouri et al., 2012). By applying STIRPAT framework, Hasanov et al. (2016) examined the impact of population, age groups and GDP growth on energy use of Azerbaijan, Kazakhstan and Russia. However, their dependent variable was total energy use and they did not examine the effects on sectoral energy use, such as industrial or residential consumption. To our knowledge, this is the first Kazakhstan focused study that examines the effects of population and affluence on residential electricity consumption (REC) using the STIRPAT framework, time series cointegration, and error correction modelling.

This study aims to reveal long- and short-run relationships between the above-mentioned variables as well as convergence effects for Kazakhstan in the STIRPAT modelling framework. In the cointegration context, convergence effects, also known as speed of adjustment (SoA hereafter), provides useful information about the timeframe needed for the short-run deviation of the relationship to converge towards the long-run path. Therefore, it is of great importance for policymakers when they develop measures for managing the growth of electricity use.

We applied the time series cointegration and error correction modelling approach of the autoregressive distributed lags bound testing (ARDLBT hereafter) to the Kazakhstani data over the period of 1999–2012. We found a significant impact of the population age group 15–64 on the residential electricity use in long-run, however, the age group of 65–above has only short-run effects and affluence has no effect. Estimations also revealed out 21.3% of SoA in the relationship between Kazakhstan's residential electricity use and population.

We would expect this study to contribute to the literature as follows: it is the pioneer study dedicated to residential electricity effects of population and affluence for Kazakhstan in a time-series analysis. Panel studies have some weaknesses (Kasprzyk et al., 1989; Dietz and Rosa, 1994; Hsiao, 2003), and country specific features are more easily discovered in studies using time series analyses as they offer better representation of country specific features, thus enable more reliable policy recommendations.

Furthermore, as Liddle (2013) expresses, the non-stationarity properties of data were not considered in earlier STIRPAT-based studies, except for Poumanyvong and Kaneko (2010) and Liddle (2011). As Liddle (2014) puts it, earlier studies might possibly contain spurious regression results as economic and population data are commonly non-stationary.[1] By taking non-stationarity of data into account, Liddle (2011, 2013, 2014) and Poumanyvong and Kaneko (2010) applied unit root (UR) and cointegration tests and estimated long-run elasticities. However, they did not estimate error correction models and SoA coefficients. The review of existing literature reveals that only Shafiei (2013) employed panel error correction modelling and estimated SoA coefficient in the STIRPAT framework. Her study focuses on renewable and non-renewable energy use effects of population and affluence where she applied panel cointegration and ECM in the STIRPAT modelling framework for 29 OECD countries. As her focus is on OECD countries, Kazakhstan is not among the countries studied. Moreover, country specific aspects are overlooked which, is common for panel analysis, as mentioned before. In the light of the above-mentioned shortcomings, we accounted for the integration and cointegration properties of the data and estimated SoA coefficient.

Unlike previous studies on electricity use, we employed Pesaran's (2001) ARDLBT approach, to test for cointegration and then to estimate long-run and short-run elasticities as well as SoA coefficient in the STIRPAT framework. One of the advantages of the ARDLBT approach is that it works better with small sample sizes and brings about much more consistent and unbiased estimates (Pesaran et al., 2001; Sulaiman and Muhammad, 2010; Oteng-Abayie and Frimpong, 2006).

The findings of this study may offer useful insights for Kazakhstan's policymakers so they can make better electricity market forecasts, and develop adequate measures to manage the growth of REC. The policymakers should take into account future trend of the population group aged 15–64 in their decision on the long-run stance of residential energy consumption. They also should consider that REC in long-run is not income dependent, perhaps due to government subsidisation leading to cheap electricity prices. In the short-run, the policy makers should consider the population age group of 65–above among other factors in their REC related measures. Policy makers should also be careful to avoid creating a policy shock to the REC system, since complete convergence towards long-run equilibrium path will take about six years.[2]

The remaining sections of the paper are organised as follows. Section 2 briefly reviews the existing literature on the STIRPAT analyses of energy use in selected countries. Section 3 shortly introduces the STIRPAT modelling framework and Section 4 presents the data and describes the econometric method. Section 5 presents and discusses the results of the empirical analysis. Finally, the main concluding remarks and policy implications of the study are in Section 6.

2 Brief literature review

A great deal of literature is devoted to studying the energy consumption effects of population and economic growth by employing STIRPAT modelling framework. Thus, in this section, we will limit our review only to studies relevant to our research in terms of methodology used and country chosen.[3]

As previously noted, some earlier studies have examined this relationship in the oil-exporting economies of the CIS, including Kazakhstan. However, studies are either cross-sectional (York et al., 2003a; Knight, 2008; Kick and McKinney, 2014; Lamb et al., 2014; Mattos and Filippi, 2013), or panel studies (Fang and Miller, 2013; Martínez-Zarzoso, 2009; York and Rosa, 2012; Brizga et al., 2013; Jorgenson, 2011; Lankao et al., 2008; Grunewald and Martínez-Zarzoso, 2009a, 2009b, 2011; Prew, 2010; Iwata and Okada, 2014; Martínez-Zarzoso and Maruotti, 2011) that investigate environmental issues rather than energy use.[4] Only Scarrow (2010), Liddle (2011), Fang et al. (2012), Nouri et al. (2012), Shafiei (2013), Hasanov et al. (2016) studied the energy use impacts. Although these energy studies, except Hasanov et al. (2016) and Mikayilov and Hasanov (2015) are based on panel analysis and ignored country-specific features. We still review them below.

Shafiei (2013) applied the STIRPAT modelling framework to examine the determinants of renewable and non-renewable energy consumption for the panel of 29 OECD countries. She chose the period of 1980–2011 and used error correction and cointegration modelling. Her study found a long-run relationship between the two energy types and set of the variables: population, its density, GDP per capita, and the GDP share of service and industry. Coefficients of all regressors were statistically significant in the long-run elasticity estimations for the non-renewable energy use model. However, urbanisation and population density were insignificant for the renewable energy use model. The study results reveal that long-run elasticity with respect to population and affluence was 1.763 and 0.710 for non-renewable energy, and 0.537, 0.268 for renewable energy, respectively. Additionally, the estimated SoA coefficients were –0.91 and –0.92 for non-renewable and renewable energy use, which is an indication of rapid convergence to an equilibrium path.

Scarrow (2010) studied energy consumption effects of population and affluence, with other explanatory variables, over the period 1960–2007 for a panel of almost all countries of the world, including Kazakhstan. Results of the employed STIRPAT model showed that affluence has a statistically significant positive impact on total energy consumption and per capita energy consumption. The estimated affluence elasticities of total and per capita energy consumption varied from 0.03 to 0.2. Total population was found to have a positive impact (with the coefficients within the interval 0.4–0.8) on total energy use and negative effect (coefficient was around –0.1) on per capita energy use. However, the results of the study may suffer from spurious regression problem, because non-stationarity properties of the data were not taken into account.

Liddle (2011) also used STIRPAT modelling framework to example the environmental impacts of transport carbon emissions and REC by applying panel FMOLs to data for 22 OECD countries for the period of 1960–1970. The population variable was divided into four age groups: 20–34, 35–49, 50–69, and 70 and older. Although Kazakhstan is not included in this study, it is still relevant to our research since it conducted a cointegration analysis in the STIRPAT framework. Impacts of population age structure were statistically significant and different for the age groups. The study reveals a U-shaped impact of age structure for REC, which means the youngest and oldest groups have positive effects while middle groups have negative impact. REC elasticities with respect to population age groups 20–34, 35–49, 50–69 and 70 and above were 0.219, –0.418, –0.404 and 0.552, respectively.

Nouri et al. (2012) analysed demographic and economic determinants of energy use, measured in kiloton of oil equivalent for the Economic Cooperation Organization (ECO) countries, including Kazakhstan over the period of 1960–2012. Panel regression estimations showed that the driving factors of energy use in the ECO members are total population, urbanisation and affluence.

Using the STIRPAT framework, Hasanov et al. (2016) examined impacts of total population, its age groups and affluence on the use of energy in oil-exporting economies of the CIS: Azerbaijan, Kazakhstan and Russia over the period 1990–2011. An Autoregressive Distributed Lags Bounds Testing approach was employed in the study. The study found significant impact of population and its age groups as well as affluence on the energy use in selected countries. The long-run elasticities of energy use with respect to the population age group 15–64 in Azerbaijan, Kazakhstan and Russia were 1.92, 0.13 and 8.59, while for the age group of 65 and above the elasticities were 1.71, 0.14, and –1.23, respectively.

Mikayilov and Hasanov (2015) examined impacts of affluence and age groups on REC in Azerbaijan employing ARDL Bounds Testing approach in the STIRPAT framework for the period 2000–2012, and concluded that there are significant effects of population age groups and affluence. The elasticities of REC with respect to population age group of 15–64 and 65 and above were 10.46 and 2.33, respectively.

In sum, the review of existing literature for the CIS oil-exporting economies shows a significant gap in this research area. The studies of the economies are mainly panel studies, which neglect specific features of countries. With the exception of Shafiei (2013), Hasanov et al. (2016) and Mikayilov and Hasanov (2015), none of these studies applied cointegration and ECM, and thus have not estimated SoA in the STIRPAT framework. Finally, except the above mentioned three studies none of them applied the ARDLBT approach to the time series data of the countries considering that data for these countries spans for a short period. Hasanov et al. (2016) examined the impact of population and growth rate on total energy use, but not on residential or industrial energy use. As a result, their policy suggestions remain too general and do not address specific energy-type issues. Mikayilov and Hasanov (2015) studied the impacts only in the case of

Azerbaijan but not for Kazakhstan. Yet, Shafiei (2013) did not include Kazakhstan in her analysis.

Saleheen et al. (2012) studied the effect of per capita electricity consumption among capital, labour and trade openness on economic growth in the production function framework, applying ARDL BT approach in case of Kazakhstan. They found that 1% increase in per capita electricity consumption leads to 0.28% increase in per capita GDP. However, they did not find any casualty from economic growth to electricity consumption. Moreover, their main interest was economic growth rather than electricity consumption and therefore, STIRPAT modelling framework have not been applied.

In this study, we consider all of the above-mentioned aspects of the REC in the STIRPAT framework for Kazakhstan.

3 Framework of analysis: STIRPAT

This section briefly describes the STIRPAT modelling framework employed in our empirical analysis. STIRPAT is a popular and widely used approach developed by Dietz and Rosa (1994, 1997). It is based on IPAT, which was first offered by Ehrlich and Holdren (1971). IPAT assumes that environmental impacts (*I*) are multiplicative product of population (*P*), affluence (*A*) and technology (*T*):

$$I = PAT \tag{1}$$

Since IPAT is an accounting identity and therefore assumes proportionality, there is no space for hypothesis testing. However, the impacts of population, affluence and technology are certain to differ in magnitude. Primarily because energy use, environmental, demographic and economic characteristics of the countries differ from each other. Consequently, IPAT was not featured much in empirical studies. Dietz and Rosa (1994, 1997) added stochastic terms in equation (1) and thus, the STIRPAT was developed. The STIRPAT formula can be expressed as the following:

$$I = aP^b A^c T^d e \tag{2}$$

where a, b, c and d are the coefficients to be econometrically estimated, and e is a stochastic error term.

Equation (3), which is natural logarithmic expression of equation (2) can be estimated empirically as:

$$Ln(I) = q + b * Ln(P) + c * Ln(A) + d * Ln(T) + w \tag{3}$$

where *Ln* expresses the natural logarithm. q and w are natural logarithm of a and e.

4 Data

In line with the STIRPAT modelling framework, our dataset for Kazakhstan covers the following indicators:

- *REC:* The dependent variable in our analysis, measured as the total kilowatt-hours consumed by residential sector. The data was retrieved from the International Energy Association (IEA).

- *Gross domestic product (GDP):* The sum of gross value added by all resident producers in the Kazakhstani economy, plus any product taxes, and minus any subsidies not included in the value of the products (World Bank, 2015). It is measured in constant 2005 US$.

- *Population age group of 15–64 years old (POP_15_64):* It is calculated as the share of the population in the interval of 15–64 years old multiplied by total population, and measured in persons.

- *Population age group of 65 years and older (POP_65):* It is calculated as the population share of 65 years and older multiplied by total population, and measured in persons.

- *Affluence (GDPPC):* Measured as GDP per person in constant 2005 US$.

With the exception of REC, the data was retrieved from the World Bank Development Indicators Database and cover the period of 1999–2012.

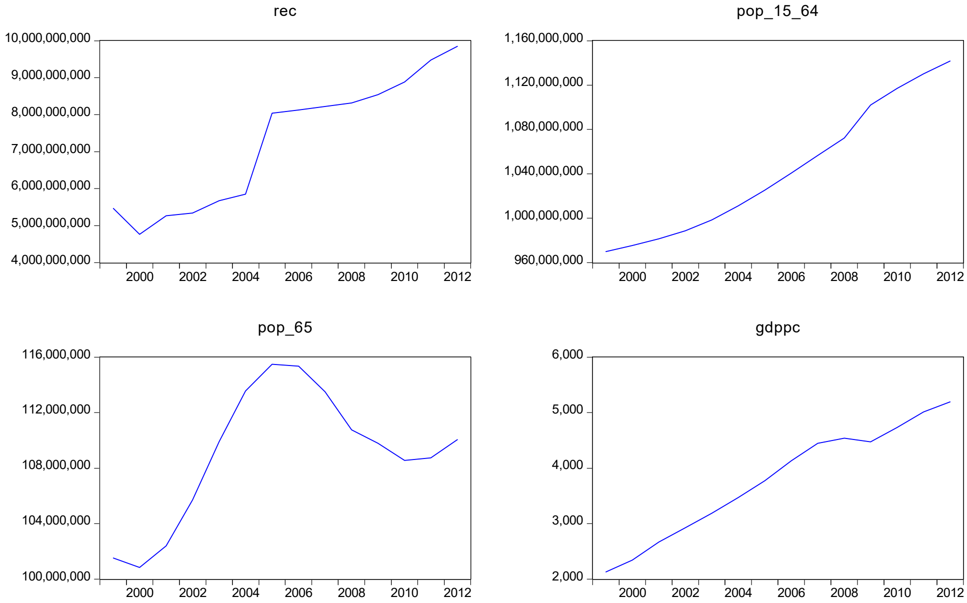
Figure 1 illustrates time profile of the variables over the period 1999–2012.

As illustrated in panel A of Figure 1 REC shows an upward trend over the 2000–2012 periods with a level shift in 2005. This level shift may be explained with the economic developments described below. Strong economic growth observed in Kazakhstan, due to the record export prices for its energy, minerals, and agricultural goods in 2005. Government's efforts to create a good investment environment, especially in the energy sector, through economic liberalisation and privatisation resulted cumulative 38.4 billion USD of foreign investment by September 2005. In February 2002, Kazakh Government established a national energy conglomerate, KazMunaiGaz, combining the national oil company with the national oil and gas transport company for the stated purpose of being able to compete with the international oil companies. In 2002, agreement was reached among Azerbaijan, Georgia, Turkey, Turkmenistan, and Kazakhstan on the route for the Baku-Tbilisi-Ceyhan (BTC) pipeline, and construction began in May 2003. The first stage of the pipeline was officially inaugurated in 2005. After re-election in 2005, President Nazarbaev announced his new economic reforms, which also contributed significantly to the economic development of the country. Moreover, the construction of the new energy pipeline between Kazakhstan and China started in 2005.

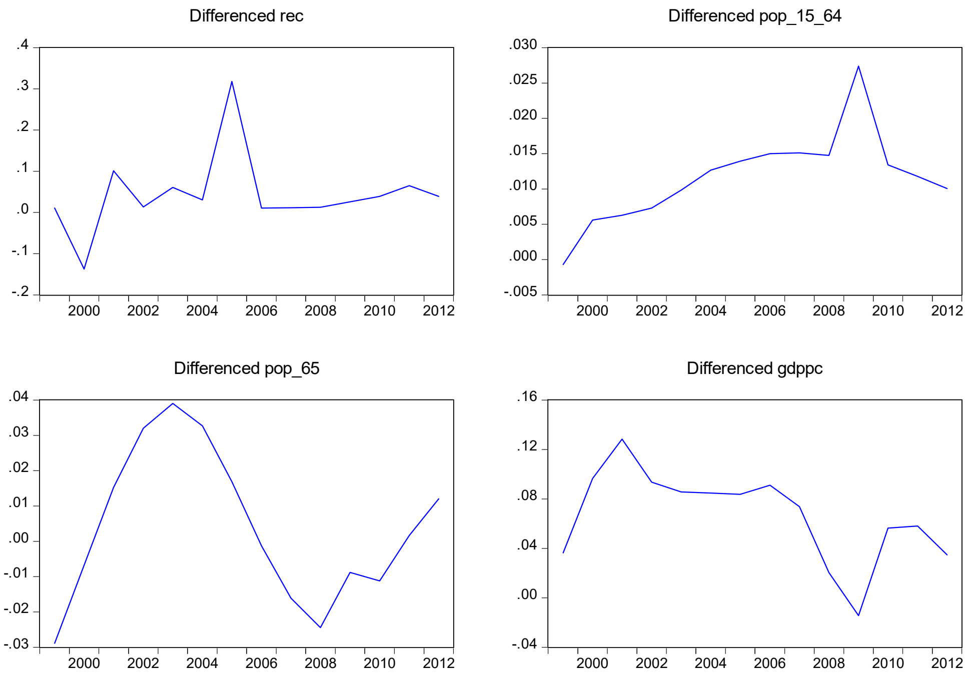
During the period 2000–2012, population group ages 15–64 and GDP per capita in Kazakhstan also exhibit increasing trends.

The POP_65 can be characterised by some cyclicality over the period 1990–2012. The unconventional trend in population age group of 65 and above might be due to the following reasons. The population began declining in the 1990s due to emigration, declining fertility rates, and lower life expectancy. Then, the government encouraged Kazakhs who lived abroad to return. During the '90s, there was an organised return of 70,000 Kazakhs from Mongolia, Iran and Turkey and almost 82,000 Ukrainians, 16,000 Belarussians, 614,000 Russians and 480,000 ethnic Germans returned to Germany. In addition, many Kazakhs had been displaced internally or had left for other CIS countries.

Figure 1 Time profile of the variables, (a) Panel A: log level of the variables (b) Panel B: growth rate of the variables (see online version for colours)



(a)



(b)

Note that in the empirical analysis, we used the natural logarithm expressions of the variables, which are denoted with small letters: *rec*, *gdppc*, *pop_15_64*, *pop_65*.

4.1 Econometric method

In the following sub-sections, we discuss the UR tests of Augmented Dickey-Fuller (ADF) and cointegration methods of the autoregressive distributed lag bounds testing (ARDLBT).

4.1.1 UR test

It is essential to examine the integration order of variables through UR tests before conducting a cointegration analysis. To do that, we use the ADF (Dickey and Fuller, 1981) method. Advantages and disadvantages of univariate UR tests, in particular ADF, have been discussed by Dickey and Fuller (1981), Stock and Watson (1993), Dolado et al. (1990), Brouwer and Ericsson (1998) and Enders (2010, pp.237–239) among others.

The test takes the null hypothesis of non-stationarity of a given time series.

For a variable *y*, the ADF statistics are the *t*-ratio on b_1 in the regression below:

$$\Delta y_t = b_0 + \psi trend + b_1 y_{t-1} + \sum_{i=1}^{k} \alpha_i \Delta y_{t-i} + \varepsilon_t \tag{4}$$

Here, Δ and *k* represent the first difference operator and number of the lags, respectively. b_0 is a constant term, *trend* and ε_t are linear time trend and white noise residuals, and *i* is lag order. We will skip discussing this test here because of space limitation.

4.1.2 ARDLBT approach

We apply the ARDLBT cointegration approach developed by Pesaran et al. (2001) and Pesaran and Shin (1999). It is a powerful approach when samples are small, and is easy to perform by using OLS. Moreover, there is no endogeneity problem in the method, and it is possible to estimate long and short-run coefficients simultaneously. One of the advantages of the method is that it can be employed regardless of whether regressors are I(1), I(0), or a mixture of both (Pesaran et al., 2001; Oteng-Abayie and Frimpong, 2006; Sulaiman and Muhammad, 2010). This approach is more suitable for our empirical assessment since the number of observations in our study is relatively small.

Pesaran et al. (2001) describe the following stages of the approach:

a Construction of an unrestricted error correction model (ECM).

$$\Delta y_t = c_0 + \theta y_{t-1} + \theta_{yxx} x_{t-1} + \sum_{i=1}^{n} \varpi_i \Delta y_{t-i} + \sum_{i=0}^{n} \varphi_i \Delta x_{t-i} + u_t \tag{5}$$

where *y* is a depended variable and *x* is explanatory variable; *u* indicates white noise errors; c_0 is a drift coefficient; θ_i denotes long-run coefficients, while ϖ_i and φ_i are short-run coefficients. It is worth mentioning that correct specification of lag length of the first differenced right-hand side variables in the ARDLBT estimations is one of the main issues since finding cointegration relationships between variables are sensitive to lag length [Pesaran et al., (2001), p.23].

Following Pesaran et al. (2001), among others, optimal lag length can be specified by minimising the Akaike and Schwarz information criteria while removing the serial autocorrelation of residuals. It is advisable to rely on the Schwarz information criterion when samples are small (Pesaran and Shin, 1999; Fatai et al., 2003).

b After constructing an unrestricted ECM, one can test if cointegrating relationships exist. The Wald-test (or the F-test) on the θ_i coefficients above is performed for this purpose.

The null hypothesis of no cointegration is H_0: $\theta_1 = \theta_2 = \theta_3 = 0$, while an alternative hypothesis of cointegration is: H_1: $\theta_1 \neq \theta_2 \neq \theta_3 \neq 0$.

If in the given significance level, the computed/sample F-statistic is greater than the upper bound of the critical value, then one can reject the null hypothesis of no cointegration. Similarly, the null of no cointegration cannot be rejected if at a given significance level, the sample F-statistic is smaller than the lower bound of the critical value. As a third option, the test results will be inconclusive when the sample value falls between critical values of the upper and low bands.

It is worth mentioning that in the ARDLBT cointegration test, the F-statistics have non-standard distribution. Thus, F-distribution's conventional critical values are no longer valid. Hence, the table of critical values developed by Pesaran and Pesaran (1997) or Pesaran et al. (2001) must be used.

The cointegrating relationship is stable if θ is statistically significant and negative. In other words, short-run deviations from the long-run equilibrium path are temporary and correct towards it.

c If a cointegrating relationship is found among the variables, then the long-run coefficients can be estimated. We calculate these coefficients based on equation (5) by either applying a Bewley transformation (Bewley, 1979) or manually setting $c_0 + \theta y_{t-1} + \theta y_{xxt-1}$ to zero and solving for y as follows.

$$y = -\frac{c_0}{\theta} - \frac{\theta_{yxx}}{\theta} x + u \tag{6}$$

4.2 Small sample bias correction in the ARDLBT approach

Pesaran and Pesaran (1997) used large sample sizes of 500 and 1,000 as well as 20,000 and 40,000 replications, respectively to calculate the F-distribution's upper and lower critical values. However, Narayan (2005) mentions that these critical values are calculated based on large sample points so they are not accurate for small sample sizes (Narayan, 2004, 2005). Indeed, he compared the critical value generated based on 31 observations with those value reported in Pesaran et al. (2001) at the 5% significance level and in the case of four regressors. He found that the critical value (3.49) from Pesaran and Pesaran (1997) is 18.3% lower than his critical value of (4.13). Narayan, thereby, calculated critical values for small sample sizes ranging from 30 to 80 data points (see Narayan, 2005). To correct for small sample bias, we employ Narayan's critical values in our ARDLBT cointegration test.

5 Empirical results and discussion

By following the methodological section, we checked integration properties of the variables using the ADF test. Note that equation (4) is used in all testing exercises. In other words, a trend and intercept are in all the ADF test specifications regardless of whether we tested the level or difference of the variables. Our justification is that, as econometrically explained, if a trend is a part of data generating process and we miss it, then we will have biased results, which is a serious problem. On the other hand, if a trend is not a part of data generating process and we have it redundantly, then we will only lose one degree of freedom.

Table 1 reports the ADF test results.

Table 1 The ADF test results

Variable	*Panel A: at the level*		*Panel B: at the first difference*		*Panel C: at the second difference*		*Conclusion*
	k	*Actual value*	*k*	*Actual value*	*k*	*Actual value*	
rec	0	–2.512278	0	–3.911778**			I(1)
gdppc	1	–1.882518	1	–2.917351	1	–4.292989**	I(2)
pop_15_64	0	–3.199770	0	–2.073872	1	–5.985103*	I(2)
pop_65	2	–5.105226*	2	–5.230702			I(0)

Notes: Maximum lag order is set to two and optimal lag order (*k*) is selected based on Schwarz criterion; *, ** and *** indicate statistical significance at the 1%, 5% and 10% significance levels respectively. The critical values are taken from MacKinnon (1996). Estimation period: 1999–2012.

As Table 1 concludes, *rec* is integrated at the order of one, i.e., it is an I(1) process. In other words, it is non-stationary in its logarithm level, but stationary in its first difference of logarithm level, which is its growth rate.

On the other hand, the test statistics suggest that *gdppc* and *pop_15_64* are stationary only after second differencing. Common sense about the integration order of these variables, however, does not support these statistical results. Moreover, the ADF test statistics indicate that *pop_65* is trend stationary. However, the Phillips-Perron (Phillips and Perron, 1988) UR test statistics, as well as graphical inspection of the variable indicates that the series is not trend stationary at level form. We think that such contrasting results for *gdppc* and *pop_15_64* and *pop_65* are mainly caused by the small number of observations. We have only 14 observations at the best case, which is still insufficient to get accurate critical values and probabilities. Note that Hasanov et al. (2016) and Mikayilov and Hasanov (2015) also faced similar problems due to small sample sizes. In spite of the fact that the test results are quite disappointing, as a research decision and by relying on the conventional view about integration orders of socio-economic variables, we consider that all the variables are non-stationary in their log level and stationary in their growth rate.

We estimated equation (5) for Kazakhstan in two different specifications (i.e., one with *pop_15_64* and another one with *pop_65*, respectively) as expressed below:[5]

$$\Delta rec_t = c_0 + \theta_1 rec_{t-1} + \theta_2 gdppc_{t-1} + \theta_3 pop\_15\_64_{t-1} + \sum_{i=1}^{n} \omega_i \Delta rec_{t-i} + \sum_{i=0}^{n} \varphi_i \Delta gdppc_{t-i} + \sum_{i=0}^{n} \tau_i \Delta pop\_15\_64_{t-i} + u_t \quad (7)$$

$$\Delta rec_t = c'_0 + \theta'_1 rec_{t-1} + \theta'_2 gdppc_{t-1} + \theta'_3 pop\_65_{t-1} + \sum_{i=1}^{n} \omega'_i \Delta rec_{t-i} + \sum_{i=0}^{n} \varphi'_i \Delta gdppc_{t-i} + \sum_{i=0}^{n} \tau'_i \Delta pop\_65_{t-i} + u'_t \quad (8)$$

We set the maximum lag order to be one for equations (7) to (8) since the small number of observations does not allow for the serial correlation LM test to run in more than one lag order. The test results together with the Schwarz information criterion are tabulated in Table 2.

Table 2 Statistics for choosing optimal lag size

	K	*SBC*	$F_{SC}(2)$
Equation (7)	0*	–4.366756	1.987364
			[0.2317]
	1	–4.563904	31.43241
			[0.0308]
Equation (8)	0	–3.859767	0.317201
			[0.7381]
	1*	–4.087104	0.264622
			[0.7800]

Notes: *k* is a lag order while SBC denotes Schwarz information criterion. $F_{SC}(2)$ is the LM statistics for testing no residual serial correlation against lag orders 1. Probabilities are in brackets.

We chose zero lag for equation (7) and one lag for equation (8) based on the Schwarz information criterion and the F-statistics of the serial correlation LM test.

We checked for the existence of long-run (cointegrating) relationships among the lagged level variables in equations (7) and (8) in the second stage of the ARDLBT approach. Table 3 reports the cointegration test results.

Two kind of critical values were used in the testing process: Pesaran et al. (2001) critical values and those from Narayan (2005), with the latter used to avoid potential biases caused by small sample size of the estimations. Results of the cointegration test show there is no cointegrating relationship among the lagged level variables in equation (7). We additionally investigated cointegration properties of REC, population and GDP per capita. It can be seen from Table 3, that there is a cointegrating relationship at 10% significance level, between *rec* and *pop_15_64*, when we excluded $gdppc_{t-1}$ from the cointegration space in equation (7). Equation (8) was a similar case, which demonstrated no long-run co-movement among the lagged level variables of the equation. Furthermore, detailed investigation of the cointegration relationship among the variables showed that there is no cointegration relationship even in the combination of any two lagged level variables in equation (8).

Table 3 Cointegration test statistics

	Equation (7)	*Equation (8)*
	F_{sample}	F_{sample}
	3.757330[a]	*1.593500*[b]
	Narayan (2005)	Pesaran et al. (2001)
At the 1% significance level:	6.760	5.580
At the 5% significance level:	4.663	4.160
At the 10% significance level:	3.797	3.510
At the 1% significance level:	6.265	5.000
At the 5% significance level:	4.428	3.870
At the 10% significance level:	3.695	3.350

Notes: [a]In the case of one regressor, restricted intercept and no trend.
[b]In the case of two regressors, restricted intercept and no trend.
The first three upper bound critical values of Narayan (2005) and Pesaran et al. (2001) are in the case of two regressors, restricted intercept and no trend, while the last three upper bound critical values are in the case of one regressor, restricted intercept and no trend.

Thus, we found cointegrating relationship between *rec* and *pop_15_64* in equation (7) and only short-run relationship for the first differenced regressors in the equation (8).

As a next stage of the ARDLBT approach, we specified the final ECM specifications. The final specifications are presented in Table 4.

Table 4 The final ARDL specification

Regressor	*Coef. (std. error)*
Panel A: the estimated final ARDL specification of equation (7)	
rec_{t-1}	–0.212997 (0.070586)
$pop\_15\_64_{t-1}$	0.972618(0.295416)
Intercept	–15.35966 (4.777056)
$\Delta pop\_15\_64_t$	0.931658 (1.154106)
$\Delta gdppc_t$	0.323134 (0.196360)
DP05	0.261101 (0.022297)
DP00	–0.164320 (0.022519)
Panel B: the estimated final ARDL specification of equation (8)	
Δpop_65_t	0.562013 (0.287682)
Δrec_{t-1}	–0.158072 (0.063311)
Intercept	0.039739 (0.006894)
DP05	0.273428 (0.022991)
DP00	–0.171509 (0.022916)

Note: Dependent variable is Δrec_t; method: least squares; estimation period: 1999–2012.

Each of the final specifications in Table 4 succeeded residual diagnostics tests of the serial correlation, autocorrelation, heteroscedasticity, normality, and Ramsey reset's misspecification test. We do not report the results of tests here. However, they can be obtained upon request.

According to the results, the population group ages 15–64 is statistically significant in the final specification of equation (7). The elasticity of the REC with respect to this age group is 4.568 (0.973/0.213). Putting it differently, a 1% increase in the age group leads to a 4.56% increase in REC in the long-run. Despite the higher magnitude of the coefficient, the sign of it is consistent with the conventional interpretation of the STIRPAT framework. Note that the growth rates of the age group and affluence are positive in the final specification of equation (7), which is consistent with the STIRPAT framework. However, they are statistically insignificant most probably due to small number of observation.

As panel A of Table 4 demonstrates, SoA coefficient is 0.213, which means 21.3% of disequilibrium in the short-run can be corrected towards long-run equilibrium path during a year.

Panel B of Table 4 reports that the growth rate of the population group ages 65 and above has a positive impact on the growth rate of REC in the short-run. Numerically, a 1% increase in the growth rate of this population group causes a 0.56% increase in the growth rate of electricity consumption. The positive impact of the population age group on the electricity consumption is also consistent with the STIRPAT framework. Moreover, there is a dynamic relationship in REC as its one year lagged growth rate has a statistically significant impact on the current year's growth rate.

Additionally, as reported in the both panels of Table 4, dummy variables for capturing extraordinary decrease and increase in REC in 2000 and 2005 respectively are statistically significant.

6 Concluding remarks

A great deal of studies has examined energy consumption effects of population, its age groups, and affluence in developed and developing countries. However, the number of studies focusing on oil-exporting countries of the CIS, in particular for Kazakhstan, is limited to either panel or cross sectional analyses. In the absence of time series studies, it is difficult to discover country specific features of energy effects of population and affluence. To our knowledge, there is one time series analysis for Kazakhstan, Hasanov et al. (2016) in the STIRPAT framework, where the dependent variable is aggregated energy use, which does not allow using specific energy types and offer related policy suggestions. With these considerations in mind, we examined the impacts of population age groups and affluence on REC in Kazakhstan by applying an ARDLBT cointegration method, a powerful method in the case of small sample in the STIRPAT framework. As the number of observations is small, results of our empirical estimations and conclusions are presented cautiously. We found that one of the driving forces of the REC in the long-run is the population age group of 15–64, whereas the age group of 65 and above exhibit only short-run effects. The affluence was not found to have any statistically significant influence on the REC. Moreover, the analysis revealed that 21.3% speed of convergence towards long-run equilibrium path in the relationship of REC and the 15–64 population age group.

Findings of this study may offer useful insights for policymakers in making better electricity demand forecasts and taking adequate measures on residential electricity use in

Kazakhstan. The policymakers should take into account trend of the population group aged 15–64 in their decision on the long-run stance of residential energy consumption. As Figure 1 illustrates population age group 15–64, which has a significant long-run effect on REC, has a strict upward trend over the period of analysis. Such a strong upward trend in the group is related to national and traditional customs of the Kazakhstan, and therefore may not easily be curbed in future. Further, the SoA coefficient is as small as 21.3%. Combining these two findings, we can conclude that, in the long-run, adequate policy measures should include increase in the efficiency of electricity consumption and applying energy conservation measures. As Liddle (2011) notes, the size of the family is proportional with the age of family head in general, which is also the case for Kazakhstan. Promoting more efficient (and economically viable) electricity appliances with these household is a suggestion for increasing efficiency of electricity usage. Policymakers should also pay attention to the finding that REC is not income dependent, perhaps due to cheap electricity prices subsidised by the government. In the short-run, the policymakers should consider the population age group of 65–above among other factors in their REC related measures. Furthermore, policymakers should be careful not to create a policy shock to the REC system, since convergence towards the long-run equilibrium path takes about six years.

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References

Bewley, R.A. (1979) 'The direct estimation of the equilibrium response in a linear model', *Economics Letters*, Vol. 3, No. 4, pp.357–361.

Bozoklu, S. and Yilanci, V. (2013) 'Energy consumption and economic growth for selected OECD countries: further evidence from the Granger causality test in the frequency domain', *Energy Policy*, Vol. 63, No. 100, pp.877–881.

Brizga J., Feng K. and Hubacek, K. (2013) 'Drivers of CO2 emissions in the former Soviet Union: A country level IPAT analysis from 1990 to 2010', *Energy*, Vol. 59, pp.743–753.

Damette, O. and Seghir, M. (2013) 'Energy as a driver of growth in oil exporting countries?', *Energy Economics*, Vol. 37, No. 100, pp.193–199.

Brouwer, G. and Ericsson, N.R. (1998) 'Modeling inflation in Australia', *Journal of Business and Economic Statistics*, Vol. 16, No. 4, pp.433–449.

Dergiades, T. and Tsoulfidis, L. (2008) 'Estimating residential demand for electricity in the United States.1965–2006', *Energy Economics*, Vol. 30, pp.2722–2730.

Desai, P. (2000) 'Why did the Ruble collapse in August 1998?', *The American Economic Review*, Vol. 90, No. 2, pp.48–52, JSTOR 117190, subscription required.

Dickey, D. and Fuller, W. (1981) 'Likelihood ratio statistics for autoregressive time series with a unit root', *Econometrica*, Vol. 49, No. 4, pp.1057–1072.

Dietz, T. and Rosa, E.A. (1994) 'Rethinking the environmental impacts of population, affluence, and technology', *Human Ecology Review*, Vol. 1, pp.277–300.

Dietz, T. and Rosa, E.A. (1997) 'Effects of population and affluence on CO_2 emissions', *Proceedings of the National Academy of Sciences*, Vol. 94, pp.175–179, USA.

Dolado, J., Jenkinson, T. and Sosvilla-Rivero, S. (1990) 'Cointegration and unit roots', *Journal of Economic Surveys*, Vol. 4, No. 3, pp.249–273.

Enders, W. (2010) *Applied Econometrics Time Series*, 3rd ed., Wiley Series in Probability and Statistics, University of Alabama, John Wiley and Sons, New York.

Engle, R.F. and Granger, C.W.J. (1987) 'Co-integration and error correction: representation, estimation and testing', *Econometrica*, Vol. 55, No. 2, pp.251–276.

Ehrlich, P.R. and Holdren, J.P. (1971) 'Impact of population growth', *Science*, Vol. 171, No. 3977, pp.1212–1217.

Fang, W. and Miller, S. (2013) 'The effect of ESCOs on carbon dioxide emissions', *Applied Economics*, Vol. 45, No. 34, pp.4796–4804.

Fang, W., Miller, S. and Yeh, C. (2012) 'The effect of ESCOs on energy use', *Energy Policy*, December, Vol. 51, pp.558–568.

Fatai, K., Oxley, L. and Scrimgeour, F.G. (2003) 'Modeling and forecasting the demand for electricity in New Zealand: a comparison of alternative approaches', *The Energy Journal*, Vol. 24, No. 1, pp.75–102.

Grunewald, N. and Martínez-Zarzoso, I. (2009a) 'Carbon dioxide emissions, economic growth and the impact of the Kyoto protocol' [online] http://www.webmeets.com/files/papers/EAERE/2011/1163/Grunewald%20and%20Martinez-Zarzoso_Carbon%20Dioxide%20Emissions,%20Economic%20Growth%20and%20the.pdf (accessed 10 February 2016).

Grunewald, N. and Martínez-Zarzoso, I. (2009b) *Driving Factors of Carbon Dioxide Emissions and the Impact from Kyoto Protocol*, CESIFO Working paper No. 2758.

Grunewald, N. and Martínez-Zarzoso, I. (2011) *How Well Did the Kyoto Protocol Work? A Dynamic-GMM Approach with External Instruments*, Ibero-America Institute for Economic Research (IAI) Discussion papers 212.

Halicioglu, F. (2007) 'Residential electricity demand dynamics in Turkey', *Energy Economics*, Vol. 29, No. 2, pp.199–210.

Hasanov, F., Bulut, C. and Suleymanov, E. (2016) 'Do population age groups matter in the energy use of the oil-exporting countries?', *Economic Modelling*, Vol. 54, pp.82–99.

Holtedahl, P. and Joutz, F.L. (2004) 'Residential electricity demand in Taiwan', *Energy Economics*, Vol. 26, No. 2, pp.201–224.

Hsiao, C. (2003) *Analysis of Panel Data*, 2nd ed., Cambridge University Press, UK.

Iwata, H. and Okada, K. (2014) 'Greenhouse gas emissions and the role of the Kyoto protocol', *Environmental Economics and Policy Studies*, Vol. 16, pp.325–342.

Jorgenson, A.K. (2011) 'Carbon dioxide emissions in central and eastern European nations, 1992–2005: a test of ecologically unequal exchange theory', *Human Ecology Review*, Vol. 18, No. 2, pp.105–114.

Kasprzyk, D., Duncan, G., Kalton, G. and Singh, M.P. (1989) *Panel Surveys*, John Wiley, New York.

Kick, E.L. and McKinney, L.A. (2014) 'Global context, national interdependencies, and the ecological footprint: a structural equation analysis', *Sociological Perspectives*, Vol. 57, No. 2, pp.256–279.

Knight, K.W. (2008) *The Ecological Implications of population Aging: A Cross-National Analysis of the Ecological Footprint*, December, Washington State University.

Kraft, J. and Kraft, A. (1978) 'Note and comments: on the relationship between energy and GNP', *The Journal of Energy and Development*, Vol. 3, pp.401–403.

Lamb, W.F., Steinberger, J.K., Bows-Larkin, A., Peters, G.P., Roberts, J.T. and Wood, F.R. (2014) 'Transitions in pathways of human development and carbon emissions', *Environ. Res. Lett.*, Vol. 9, No. 1, p.014011, 10pp.

Lankao, P.R., Nychka, D. and Tribbia, J.L. (2008) 'Development and greenhouse gas emissions deviate from the 'modernization' theory and 'convergence' hypothesis', *Climate Research*, Vol. 38, pp.17–29.

Liddle, B. (2011) 'Consumption-driven environmental impact and age structure change in OECD countries: a cointegration-STIRPAT analysis', *Demographic Research*, Vol. 24, pp.749–770.

Liddle, B. (2013) 'Population, affluence, and environmental impact across development: evidence from panel cointegration modeling', *Environmental Modelling and Software*, Vol. 40, pp.255–266.

Liddle, B. (2014) 'Impact of population, age structure, and urbanization on carbon emissions/ energy consumption: evidence from macro-level, cross-country analyses', *Population and Environment*, Vol. 35, No. 3, pp.286–304.

Liddle, B. and Lung, S. (2010) 'Age structure, urbanization, and climate change in developed countries: revisiting STIRPAT for disaggregated population and consumption-related environmental impacts', *Population and Environment*, Vol. 31, No. 5, pp.317–343.

MacKinnon, J. (1996) 'Numerical distribution functions for unit root and cointegration tests', *Journal of Applied Econometrics*, Vol. 11, No. 6, pp.601–618.

Martínez-Zarzoso, I. (2009) *A General Framework for Estimating Global CO_2 Emissions*, Ibero-America Institute for Economic Research, Discussion paper No. 180.

Martínez-Zarzoso, I. and Maruotti, A. (2011) 'The impact of urbanization on CO_2 emissions: evidence from developing countries', *Ecological Economics*, Vol. 70, pp.1344–1353 [online] http://www.sciencedirect.com/science/article/pii/S0921800911000814 (accessed 23 October 2015).

Mattos, E.J. and Filippi, E.E. (2014) 'Drivers of environmental impact: a proposal for nonlinear scenario designing', *Environmental Modelling and Software*, Vol. 62, No. C, pp.22–32.

Mikayilov, C. and Hasanov, F. (2015) *Residential Electricity Use Effects of Population in Azerbaijan*, Unpublished paper.

Narayan, P.K. (2004) *An Econometric Model of Tourism Demand And A Computable General Equilibrium Analysis of the Impact of Tourism: The Case of the Fiji Islands*, Unpublished PhD thesis, Department of Economics, Monash University, Melbourne, Australia.

Narayan, P.K. (2005) 'The saving and investment nexus for China: evidence from cointegration tests', *Applied Economics*, Vol. 37, No. 17, pp.1979–1990.

Narayan, V., Ramaswamy, S. and Menon, N. (2007) 'Long-lived giant number fluctuations in a swarming granular nematic', *Science*, Vol. 317, No. 5834, pp.105–108.

Nouri, M., Mohaghegh, M. and Azizi, A. (2012) *A Comparative Study on the Relationship between Energy Consumption and Main Demographic and Economic Indicators among ECO Member States*, Formal Report, Population studies and Research Center for Asia and the Pacific [online] http://www.ecosn.org/documents/projects.aspx (accessed 15 August 2015).

Oteng-Abayie, E.F. and Frimpong, J.M. (2006) 'Bounds testing approach to cointegration: an examination of foreign direct investment trade and growth relationships', *American Journal of Applied Sciences*, Vol. 3, No. 11, pp.2079–2085.

Ozturk, I. (2010) 'A literature survey on energy-growth nexus', *Energy Policy*, Vol. 38, No. 1, pp.340–349.

Pesaran, H.M. and Pesaran, B. (1997) *Working with Microfit 4.0: Interactive Econometric Analysis*, Oxford University Press, Oxford, UK.

Pesaran, M. and Shin, Y. (1999) 'An autoregressive distributed lag modeling approach to cointegration analysis', in Strom, S. (Ed.): *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch centennial Symposium*, Cambridge University Press, Cambridge.

Pesaran, M.H., Shin, Y. and Smith, R.J. (2001) 'Bounds testing approaches to the analysis of level relationships', *Journal of Applied Econometrics*, Vol. 16, No. 3, pp.289–326.

Phillips, P.C.B. and Perron, P. (1988) 'Testing for a unit root in time series regression', *Biometrika*, Vol. 75, No. 2, pp.335–346, DOI: 10.1093/biomet/75.2.335.

Poumanyvong, P., Kaneko, S. and Dhakal, S. (2012) 'Impacts of urbanization on national transport and road energy use: evidence from low, middle and high income countries', *Energy Policy*, Vol. 46, pp.268–277, DOI: 10.1016/j.enpol.2012.03.059.

Prew, P. (2010) 'World-economy centrality and carbon dioxide emissions: a new look at the position in the capitalist world-system and environmental pollution', *Journal of World-Systems Research*, Vol. 16, pp.162–191.

Saleheen, K., Ahmed, J.F. and Muhammad, S. (2012) *Electricity Consumption and Economic Growth in Kazakhstan: Fresh Evidence from a Multivariate Framework Analysis*, MPRA paper No. 43460, posted 28 December 2012 07:24 UTC.

Scarrow, R.M. (2010) *Uncovering the Energy Efficiency of the Post-Industrial World: An Analysis of Ecological Factors in Energy Use Across Nations, 1960–2007*, The Ohio State University.

Shafiei, S. (2013) *Economic Growth, Energy Consumption, and Environment: Assessing Evidence from OECD Countries*, Curtin University, School of Economics and Finance [online] http://espace.library.curtin.edu.au/R?func=dbin-jump-full&local_base=gen01-era02&object_id=200881 (accessed 3 May 2015).

Stock, J.H. and Watson, M. (1993) 'A simple estimator of cointegrating vectors in higher order integrated systems', *Econometrica*, Vol. 61, No. 4, pp.783–820.

Sulaiman, D.M. and Muhammad, U. (2010) 'The bound testing approach for co-integration and causality between financial development and economic growth in case of Pakistan', *European Journal of Social Sciences*, Vol. 13, No. 4, pp.525–531.

World Bank (2015) *Countries and Economies* [online] http://data.worldbank.org/country (accessed 10 March 2015).

York, R. (2007) 'Demographic trends and energy consumption in European Union Nations: 1960–2025', *Social Science Research*, Vol. 36, No. 3, pp.855–872.

York, R. and Rosa, E.A. (2012) 'Choking on modernity: a human ecology of air pollution', *Social Problems*, Vol. 59, No. 2, pp.282–300.

York, R., Rosa, E.A. and Dietz, T. (2003a) 'Footprints on the earth: the environmental consequences of modernity', *American Sociological Review*, Vol. 68, No. 2, pp.279–300.

York, R., Rosa, E.A. and Dietz, T. (2003b) 'A rift in modernity? Assessing the anthropogenic sources of global climate change with the STIRPAT model', *International Journal of Sociology and Social Policy*, Vol. 23, No. 10, pp.31–51.

Notes

1 According to econometric theory, obtained regression results are spurious if a linear combination of non-stationary variables is not stationary, i.e., there is no cointegrating relationship among them (see Engle and Granger, 1987; inter alia).

2 Half the distance to equilibrium will take 2.89 years [ln(0.5) / ln(1 + adjustment coefficient) = ln(0.5) / ln(1 + (–0.213)) = 2.89].

3 Time series studies for Kazakhstan have been preferred to review. In the case of absence of such studies, cross-sectional and or panel studies for Kazakhstan have been reviewed.

4 Dependent variables of these studies were either CO_2 emission or ecological footprint.

5 The reason for running two different specifications (i.e., not including the both age groups in one specification) is small number of observations.