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# Empirical Investigation of the Environmental Kuznets Curve Hypothesis for Nitrous Oxide Emissions for Mongolia

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**ABSTRACT**

A comprehensive set of econometric methods were employed on annual data for 1981-2012 to investigate the environmental Kuznets curve (EKC) hypothesis for nitrous oxide ($NO_x$) emissions for Mongolia; the short- and long-run relationships between $NO_x$ emissions, income, exports, urbanization, and growth in the different sectors of the economy; and their consequent Granger causal relationships. A highly significant and robust long-run U-shaped relationship between $NO_x$ emissions and income was found; thereby, discrediting the existence of the environmental EKC. Furthermore, exports, urbanization, and growth in the industrial and services sectors were found to decrease - while growth in the agricultural sector was found to increase - $NO_x$ emissions. Finally, the findings have also exhibited significant short- and long-run Granger causal relationships amongst the variables; thereby, leading to policy recommendations which are briefly discussed.

**Keywords:** Mongolia, Environmental Kuznets Curve Hypothesis, Nitrous Oxide Emissions
**JEL Classifications:** C32, O13, O53, Q53, Q56

## 1. INTRODUCTION

In recent decades, we have borne witness to unprecedented global economic growth, with developing and emerging markets leading the wave, and advanced economies maintaining its economic prowess in the face of intense international competition. The multitude of benefits stemming from this sudden increase in worldwide prosperity has positively impacted the well-being of citizens around the world in numerous ways; however, one of the consequences accompanying affluence has undoubtedly been that of environmental degradation, seen to originate from nations lowering their environmental protection standards willingly in order to advance their global competitiveness, trade relations, and foreign direct investment flows. This has led citizens, scholars, and national authorities alike to question the long-run costs and sustainability associated with the prioritization of economic growth in spite of the risks inherent in rising pollution on both the national and global level.

Since the early 1990s, this issue pertaining to the apparent trade-off between economic growth and environmental degradation has instigated a flood of studies aimed at analyzing their dynamic interactions, from which the environmental Kuznets curve (EKC) hypothesis was born. In 1991, Grossman and Krueger published their seminal study on the potential impacts of the North American free trade agreement on the environment, from which they deciphered an inverted U-shaped relationship between national income level and pollution. In other words, they found pollution to rise with increases in per capita income until it reached a certain threshold, after which further increases in per capita income served to decrease pollution levels. However, the term "environmental EKC" was coined by Panayotou in 1993, who highlighted the relationship's resemblance to that of the EKC developed by Simon Kuznets in 1955. The presence of the EKC is explained primarily through the: (1) Shift in the production and consumer preferences, (2) priority accorded to environmental preservation - as opposed to the nation's development - by the public once their livelihood has reached a certain level of economic comfort, and (3) increasing openness of political systems that afford the citizens the power to exert pressure on the ruling authorities. Therefore, the EKC is considered a reflection of a nation's changing attitude in response to its good fortunes (Dinda, 2004); therefore, suggesting that every nation should prioritize its economic development without inhibition, as the environmental consequences would be resolved in time.

Since then, the EKC hypothesis has been tested in numerous countries in Africa and the Middle East (Abdallah et al., 2013; Alkhathlan and Javid, 2013; Al-Mulali et al., 2016; Farhani et al., 2014; Jebli and Youssef, 2015; Jebli et al., 2015; Kohler, 2013; Lacheheb et al., 2015; Nasr et al., 2015; Osabuohien et al., 2014; Shahbaz et al., 2014; Shahbaz et al., 2015; Shahbaz et al., 2016); the Americas (Al-Mulali et al., 2015a; Dogan and Turkekul, 2016; Flores et al., 2014; Robalino-López et al., 2014; Robalino-López et al., 2015); Asia (Ahmed, 2014; Ahmed and Long, 2012; Ahmed et al., 2015; Apergis and Ozturk, 2015; Begum et al., 2015; Chandran and Tang, 2013; Elliott et al., 2013; Govindaraju and Tang, 2013; Hao et al., 2016; Heidari et al., 2015; Jayanthakumaran and Liu, 2012; Javid and Sharif, 2016; Kanjilal and Ghosh, 2013; Lau et al., 2014; Li et al., 2016a; Li et al., 2016b; Ozturk and Al-Mulali, 2015; Rafindadi, 2016; Ren et al., 2014; Saboori et al., 2012; Saboori and Sulaiman, 2013a; Saboori and Sulaiman, 2013b; Shahbaz et al., 2013a; Stern and Zha, 2016; Tiwari et al., 2013; Wang et al., 2015; Yang et al., 2015); Europe (Ang, 2007; Esteve and Tamarit, 2012; Fosten et al., 2012; Giovanis, 2013; López-Menéndez et al., 2014; Seker et al., 2015; Shahbaz et al., 2013b; Shahbaz et al., 2013c; Tutulmaz, 2015); as well as inter-continently with countries grouped according to national income levels (Al Mamun et al., 2014; Aşıcı and Acar, 2016; Bernard et al., 2015; Selden and Song, 1994). Moreover, many differing methodologies have been used, with the Johansen cointegration test (Abdallah et al., 2013; Ahmed, 2014; Ang, 2007; Azam and Khan, 2016; Chandran and Tang, 2013; Farhani et al., 2014; Kohler, 2013; Saboori and Sulaiman, 2013b; Shahbaz et al., 2013b; Shahbaz et al., 2013c; Shahbaz et al., 2014; Tiwari et al., 2013; Tutulmaz, 2015); vector error-correction model (VECM) (Abdallah et al., 2013; Ahmed, 2014; Ahmed et al., 2015; Alkhathlan and Javid, 2013; Al-Mulali et al., 2015a; Ang, 2007; Chandran and Tang, 2013; Dogan and Turkekul, 2016; Esteve and Tamarit, 2012; Farhani et al., 2014; Govindaraju and Tang, 2013; Jebli and Youssef, 2015; Jebli et al., 2015; Lau et al., 2014; Saboori et al., 2012; Saboori and Sulaiman, 2013a; Saboori and Sulaiman, 2013b; Shahbaz et al., 2012; Shahbaz et al., 2013a; Shahbaz et al., 2013c; Shahbaz et al., 2014; Tiwari et al., 2013; Wang et al., 2015); and the autoregressive distributed lag (ARDL) bounds testing approach to cointegration (Ahmed and Long, 2012; Ahmed et al., 2015; Alkhathlan and Javid, 2013; Al-Mulali et al., 2016; Ang, 2007; Begum et al., 2015; Dogan and Turkekul, 2016; Farhani et al., 2014; Javid and Sharif, 2016; Jebli and Youssef, 2015; Kanjilal and Ghosh, 2013; Kohler, 2013. p. 46, Lau et al., 2014; Rafindadi, 2016; Saboori et al., 2012; Saboori and Sulaiman, 2013a; Saboori and Sulaiman, 2013b; Shahbaz et al., 2013a; Shahbaz et al., 2013b; Shahbaz et al., 2014; Shahbaz et al., 2016; Tiwari et al., 2013) being popular choices.

Furthermore, apart from the country or region of study and the methodology in use, a vast array of pollution indicators have been studied internationally, with carbon dioxide ($CO_2$) emissions remaining the indicator of choice as it is the most prevalent in the empirical literature. Nonetheless, the use of $NO_x$ as an indicator of pollution (Cho et al., 2014; Cole, 2004; Giovanis, 2013; Grossman and Krueger, 1991; Khan et al., 2014; Liddle, 2015; List and Gallet, 1999; Panayotou, 1993; Selden and Song, 1994) is also well - albeit slightly less compared to $CO_2$ - documented. The latter is slightly disappointing considering that the Environmental Protection Agency (EPA) categorizes $NO_x$ as one of the strongest greenhouse gases, whose contribution to global warming is 298 times that of $CO_2$ (US EPA, 2016a, 2016b). Moreover, although $NO_x$ occurs naturally, 40 percent of $NO_x$ emissions are seen to stem from human activities, with the most prominent source being agricultural synthetic fertilizers (79%), fuel combustion from transportation mechanisms, and fossil fuel combustion from industry (US EPA, 2016a); and its detrimental effect is magnified when the extensive duration of its presence in our atmosphere, which is more than 100 years, is realized (US EPA, 2016b).

Equally, many determinants of pollution have also been studied and identified; amongst which growth in the different economic sectors (Al Mamun et al., 2014; Aşıcı and Acar, 2016; Bernard et al., 2015; Culas, 2012; Li et al., 2016a; Ren et al., 2014), exports (Al-Mulali et al., 2015b; Culas, 2012; Jebli and Youssef, 2015; Jebli et al., 2015; Lacheheb et al., 2015; Rafindadi, 2016; Ren et al., 2014), and urban population (Al-Mulali et al., 2015a; Al-Mulali et al., 2016; Azam and Khan, 2016; Disli et al., 2016; Dogan and Turkekul, 2016; Li et al., 2016b; Jebli et al., 2015; Omri et al., 2014; Ozturk and Al-Mulali, 2015) have been broadly studied and considered to significantly contribute to the relationship between pollution and economic growth. Moreover, despite the popularity of the gross domestic product (GDP) and GDP growth rate variables in measuring economic growth; GDP per capita income (Ahmed, 2014; Ahmed and Long, 2012; Ahmed et al., 2015; Alkhathlan and Javid, 2013; Al-Mulali et al., 2015b; Ang, 2007; Apergis and Ozturk, 2015; Aşıcı and Acar, 2016; Begum et al., 2015; Bernard et al., 2015; Chandran and Tang, 2013; Culas, 2012; Disli et al., 2016; Elliott et al., 2013; Esteve and Tamarit, 2012; Farhani et al., 2014; Flores et al., 2014; Fosten et al., 2012; Hao et al., 2016; Heidari et al., 2015; Javid and Sharif, 2016; Jebli et al., 2015; Kanjilal and Ghosh, 2013; Kohler, 2013; Lacheheb et al., 2015; Li et al., 2016a; Li et al., 2016b; Liddle, 2015; López-Menéndez et al., 2014; Nasr et al., 2015; Omri et al., 2014; Osabuohien et al., 2014; Rafindadi, 2016; Saboori et al., 2012; Saboori and Sulaiman, 2013a; Saboori and Sulaiman, 2013b; Shahbaz et al., 2013a; Shahbaz et al., 2013b; Shahbaz et al., 2013c; Shahbaz et al., 2014; Shahbaz et al., 2015; Shahbaz et al., 2016; Stern and Zha, 2016; Tiwari et al., 2013; Tutulmaz, 2015; Wang et al., 2015; Yaduma et al., 2015) is still the most widely employed economic indicator thus far.

As for studies involving Mongolia, few have investigated the EKC hypothesis using panel data on numerous countries that involved Mongolia (Al Mamun et al., 2014; Bernard et al., 2015; Yaduma et al., 2015); however, not only have the findings from these studies been inconsistent, but inter-continental panel-data analyses cannot be trusted to fully reflect Mongolia's circumstance. To my knowledge, there is only one published study that analyzes the EKC solely for Mongolia, which is that of Ahmed (2014) who studied the relationship between $CO_2$ emissions, per capita income, energy consumption, and trade openness using the Johansen and

Juselius maximum likelihood approach to cointegration, and the Granger causality test based on the VECM. His findings supported the EKC hypothesis for Mongolia in both the short- and long-run. Moreover, he found trade to have an insignificant impact on pollution in Mongolia. However, there has not been a study to date that investigates the relationship between income and $NO_x$ emissions for Mongolia.

Following a turbulent period of economic instability resulting from the sudden dual political and economic transition in 1991; increases in trade relations and foreign direct investment inflows, high world copper prices, combined with the development of its booming mining industry pushed Mongolia's previously almost non-existent growth rate to 10.6% in 2004, and a record 17.3% in 2011, effectively turning Mongolia into the fastest growing economy in Asia, even above China (World Bank, 2012a). This had enormous impacts on the traditional livelihood of the Mongolians who customarily subsisted on nomadic herding, leading to a transition from a mostly wandering rural livelihood to a mostly sedentary urban living and industrial production. GDP per capita more than doubled, exports increased by 2139%, and the urban population increased by 16.8% of the total population from 1981 to 2012. As for the different economic sectors, the services sector grew the most with a 2154% growth rate, followed by the industry sector with 265%, ending with the agricultural sector with 160% in the same time span. With these changes came suffocating air pollution that caused concern over the health consequences of the children and youth of Mongolia (Enkhzul, 2016), and turned the capital city of Ulaanbaatar into one of the most polluted city in the world (World Bank, 2012b).

In response to these unique historical circumstances, the inconsistency found in the previous empirical literature, the serious gap in research pertaining to the relationship between economic growth and various indicators of pollution in Mongolia, combined with the necessity for testing the EKC hypothesis on an individual-country basis for effective policy formulation (Bernard et al., 2015; Busa, 2013; Choumert et al., 2013; Chowdhury and Moran, 2012; Dinda, 2004; Kaika and Zervas, 2013; Pablo-Romero and De Jesús, 2016) and Mongolia's status as a developing economy; together they serve as motivation for the study at hand. Therefore, the aim of this study is four-fold: (1) examine the presence of cointegrating, long-run equilibrium relationships between $NO_x$ emissions and the variables of interest; (2) investigate the presence of the EKC pertaining to $NO_x$ emissions, (3) determine the short- and long-run relationships between $NO_x$ emissions and its determinants, and (4) decipher the direction of Granger causal relationships between the variables studied, for Mongolia. This study was conducted in the hopes that the findings it presents would provide Mongolian policymakers with more reliable and robust estimation results upon which they may base and formulate policies to increase their energy security, and achieve sustainable economic growth. Apart from the methodology of choice, the novelty of the present study also resides in the use of variables never previously used in a pollution model for Mongolia.

The remainder of this paper will continue with a brief description of the data and research methodologies employed; followed by reports and discussion of the empirical findings; and finally ending with concluding remarks.

## 2. RESEARCH METHODOLOGIES

### 2.1. Empirical Model and Data

This study employed annual data obtained from the World Development Indicators by the World Bank (http://databank.worldbank.org/), spanning from 1981 to 2012. The period under study was heavily influenced by data availability. In acknowledgment of the problems associated with the omitted variable bias, this study chose to extend beyond the traditional bivariate pollution model and endeavored to include other relevant variables that may influence the relationship between economic growth and environmental degradation. Therefore, following recent empirical literature in energy economics, the following models (equations 1-3) involving per capita income and its quadratic form, which is one of the most popular specifications to capture the shape of the relationship between pollution and income, were considered:

$$NOx_t^{AG} = \beta_0 + \beta_1 PC_t + \beta_2 PCsq_t + \beta_3 EX_t + \beta_4 URB_t + \beta_5 AG_t + e_t \quad (1)$$

$$NOx_t^{IND} = \beta_0 + \beta_1 PC_t + \beta_2 PCsq_t + \beta_3 EX_t + \beta_4 URB_t + \beta_5 IND_t + e_t \quad (2)$$

$$NOx_t^{SER} = \beta_0 + \beta_1 PC_t + \beta_2 PCsq_t + \beta_3 EX_t + \beta_4 URB_t + \beta_5 SER_t + e_t \quad (3)$$

Where NOx is thousand metric tons of $CO_2$ equivalent $NO_x$ emissions; PC is per capita income; PCsq is the square of per capita income; EX is exports; URB is urban population; and AG, IND, and SER are agricultural, industrial, and services value added, respectively. For the sake of consistency, ease of interpretation, and the reduction of complications that stem from heteroskedasticity, all variables were converted into natural logarithmic forms. Moreover - apart from NOx, and URB - all variables were calculated using constant prices (2010 = 100).

The objectives of the paper at hand are four-fold: First, examine the presence of cointegrating, long-run equilibrium relationships between $NO_x$ emissions and the variables of interest; second, investigate the presence of the EKC hypothesis for $NO_x$ emissions in Mongolia; third, determine the short- and long-run relationships amongst the variables under study; and fourth, decipher the direction of Granger causality amongst the variables.

### 2.2. Methodology Specification

#### *2.2.1. Cointegration analysis*

Although one of the attractive features of the bounds testing approach to cointegration advanced by Pesaran et al. (2001) is the option to forgo the use of unit root pre-tests - as the calculated F-statistics are valid regardless of whether the variables are purely I(0), I(1), or mutually integrated - the computed F-statistics will nonetheless crash in the presence of variables integrated of order I(2). Therefore, the augmented Dickey-Fuller (ADF), Dickey-Fuller test with GLS de-trending (DF-GLS), Phillips-Perron (PP), and

Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests were utilized to ensure that none of the variables were integrated of order higher than I(1). Subsequently, the ARDL bounds testing approach to cointegration was employed to determine the presence of long-run equilibrium relationships between $NO_x$ emissions and the variables of interest in the case of Mongolia, which consisted of estimating the following three dynamic unrestricted error-correction models (equations 4-6) using ordinary least squares:

$$NOx_t^{AG} = \delta_0 + \sum_{i=1}^{a}\alpha_{1i}\Delta NOx_{t-i}^{AG} + \sum_{i=0}^{b}\alpha_{2i}\Delta PC_{t-i} + \sum_{i=0}^{c}\alpha_{3i}\Delta PCsq_{t-i} + \sum_{i=0}^{d}\alpha_{4i}\Delta EX_{t-i} + \sum_{i=0}^{e}\alpha_{5i}\Delta URB_{t-i} + \sum_{i=0}^{f}\alpha_{6i}\Delta AG_{t-i} + \lambda_1 NOx_{t-1}^{AG} + \lambda_2 PC_{t-1} + \lambda_3 PCsq_{t-1} + \lambda_4 EX_{t-1} + \lambda_5 URB_{t-1} + \lambda_6 AG_{t-1} + u_t \quad (4)$$

$$\Delta NOx_t^{IND} = \delta_0 + \sum_{i=1}^{a}\alpha_{1i}\Delta NOx_{t-i}^{IND} + \sum_{i=0}^{b}\alpha_{2i}\Delta PC_{t-i} + \sum_{i=0}^{c}\alpha_{3i}\Delta PCsq_{t-i} + \sum_{i=0}^{d}\alpha_{4i}\Delta EX_{t-i} + \sum_{i=0}^{e}\alpha_{5i}\Delta URB_{t-i} + \sum_{i=0}^{f}\alpha_{6i}\Delta IND_{t-i} + \lambda_1 NOx_{t-1}^{IND} + \lambda_2 PC_{t-1} + \lambda_3 PCsq_{t-1} + \lambda_4 EX_{t-1} + \lambda_5 URB_{t-1} + \lambda_6 IND_{t-1} + u_t \quad (5)$$

$$\Delta NOx_t^{SER} = \delta_0 + \sum_{i=1}^{a}\alpha_{1i}\Delta NOx_{t-i}^{SER} + \sum_{i=0}^{b}\alpha_{2i}\Delta PC_{t-i} + \sum_{i=0}^{c}\alpha_{3i}\Delta PCsq_{t-i} + \sum_{i=0}^{e}\alpha_{4i}\Delta EX_{t-i} \sum_{i=0}^{e}\alpha_{5i}\Delta URB_{t-i} + \sum_{i=0}^{f}\alpha_{6i}\Delta SER_{t-i} + \lambda_1 NOx_{t-1}^{SER} + \lambda_2 PC_{t-1} + \lambda_3 PCsq_{t-1} + \lambda_4 EX_{t-1} + \lambda_5 URB_{t-1} + \lambda_6 SER_{t-1} + u_t \quad (6)$$

Where Δ represents the first difference operators, $\delta_0$ is the drift component in the equations, $\alpha_1$-$\alpha_6$ are the short-run dynamics, $\lambda_1$-$\lambda_6$ are the long-run multipliers, and $u_t$ is white noise.

Thereafter, the existence of a long-run equilibrium relationship in level-form between the variables is tested via a joint F-test on the one period lagged level variables; with the null hypothesis of no cointegration, $H_0$: $\lambda_1=\lambda_2=\lambda_3=\lambda_4=\lambda_5=\lambda_6=0$, against the alternative hypothesis, $H_1$: $\lambda_1\neq\lambda_2\neq\lambda_3\neq\lambda_4\neq\lambda_5\neq\lambda_6\neq0$. If the F-statistics exceed the upper bounds of the small sample critical value provided by Narayan (2005), I(1), then the null hypothesis of no cointegration is rejected; however, if the F-statistics are inferior to the lower bounds of the critical value, I(0), the null hypothesis of no cointegration among the variables cannot be rejected. In addition, if the generated F-statistics fall in between the upper and lower bounds of the critical values, the null hypothesis of no cointegration can neither be accepted nor rejected; thereby, leading the results to be deemed inconclusive. Due to the relatively small sample size of the present study, as mentioned above, the small sample critical values calculated by Narayan (2005) for 30 observations were used.

The bounds testing approach to cointegration was the methodology of choice for this study primarily due to its capacity to estimate the short- and long-run relationships simultaneously within a single model; superior performance compared to other notable cointegration tests, such as the Johansen cointegration test, in studies with relatively small number of observations; application regardless of whether the models consist of variables that are purely I(0) and I(1), or a mixture of both; and the freedom it grants in allowing uneven lag orders of the variables.

*2.2.2. Long-and short-run relationship analyses*

Should the bounds test support cointegration of the variables, the following conditional ARDL long-run models (equations 7-9) are estimated using fully modified ordinary least squares (FMOLS):

$$NOx_t^{AG} = \vartheta_0 + \sum_{j=1}^{l}\vartheta_{1j} NOx_{t-j}^{AG} + \sum_{j=0}^{m}\vartheta_{2j} PC_{t-j} + \sum_{j=0}^{n}\vartheta_{3j} PCsq_{t-j} + \sum_{j=0}^{o}\vartheta_{4j} EX_{t-j} + \sum_{j=0}^{p}\vartheta_{5j} URB_{t-j} + \sum_{j=0}^{q}\vartheta_{6j} AG_{t-j} + e_t \quad (7)$$

$$NOx_t^{IND} = \vartheta_0 + \sum_{j=1}^{l}\vartheta_{1j} NOx_{t-j}^{IND} + \sum_{j=0}^{m}\vartheta_{2j} PC_{t-j} + \sum_{j=0}^{n}\vartheta_{3j} PCsq_{t-j} + \sum_{j=0}^{o}\vartheta_{4j} EX_{t-j} + \sum_{j=0}^{p}\vartheta_{5j} URB_{t-j} + \sum_{j=0}^{q}\vartheta_{6j} AG_{t-j} + e_t \quad (8)$$

$$NOx_t^{SER} = \vartheta_0 + \sum_{j=1}^{l}\vartheta_{1j} NOx_{t-j}^{SER} + \sum_{j=0}^{m}\vartheta_{2j} PC_{t-j} + \sum_{j=0}^{n}\vartheta_{3j} PCsq_{t-j} + \sum_{j=0}^{o}\vartheta_{4j} EX_{t-j} + \sum_{j=0}^{p}\vartheta_{5j} URB_{t-j} + \sum_{j=0}^{q}\vartheta_{6j} SER_{t-j} + e_t \quad (9)$$

Where $\vartheta_0$ is the drift components in the equations, and $e_t$ represents the error term that is assumed to be independent and identically distributed. The FMOLS estimator was similarly chosen for this study, also due to its reported superior performance in providing optimal estimates and test statistics in studies with small samples, and models with mixed I(0), I(1) regressors and unit roots (Phillips, 1995; Phillips and Hansen, 1990).

Following the estimation of the long-run relationships amongst the variables - and the consequent attainment of the long-run coefficients - the following short-run error-correction models (equations 10-12) are estimated:

$$\Delta NOx_t^{AG} = \theta_0 + \sum_{k=1}^{s}\theta_{1k}\Delta NOx_{t-k}^{AG} + \sum_{k=0}^{t}\theta_{2k}\Delta PC_{t-k} + \sum_{k=0}^{u}\theta_{3k}\Delta PCsq_{t-k} + \sum_{k=0}^{v}\theta_{4k}\Delta EX_{t-k} + \sum_{k=0}^{y}\theta_{5k}\Delta URB_{t-k} + \sum_{k=0}^{x}\theta_{6k}\Delta AG_{t-k} + \varphi ecm_{t-1} + \varepsilon_t \quad (10)$$

$$\Delta NOx_t^{IND} = \theta_0 + \sum_{k=1}^{s}\theta_{1k}\Delta NOx_{t-k}^{IND} + \sum_{k=0}^{t}\theta_{2k}\Delta PC_{t-k} + \sum_{k=0}^{u}\theta_{3k}\Delta PCsq_{t-k} + \sum_{k=0}^{v}\theta_{4k}\Delta EX_{t-k} + \sum_{k=0}^{y}\theta_{5k}\Delta URB_{t-k} + \sum_{k=0}^{x}\theta_{6k}\Delta AG_{t-k} + \varphi ecm_{t-1} + \varepsilon_t \quad (11)$$

$$\Delta NOx_t^{SER} = \theta_0 + \sum_{k=1}^{s}\theta_{1k}\Delta NOx_{t-k}^{SER} + \sum_{k=0}^{t}\theta_{2k}\Delta PC_{t-k} + \sum_{k=0}^{u}\theta_{3k}\Delta PCsq_{t-k} + \sum_{k=0}^{v}\theta_{4k}\Delta EX_{t-k} + \sum_{k=0}^{y}\theta_{5k}\Delta URB_{t-k} + \sum_{k=0}^{x}\theta_{6k}\Delta SER_{t-k} + \varphi ecm_{t-1} + \varepsilon_t \quad (12)$$

Where $\theta_0$ is the drift component in the equations; $ecm_{t-1}$ is the error correction term obtained from the long-run associations (equations 7-9), whose negative significance denotes the disposition of the variables to revert to their long-run equilibrium relationships; and $\varepsilon_t$ represents white noise.

#### *2.2.3. Granger causality*

Finally, a VECM is employed to test for short- and long-run Granger causality, which is expressed by the following systems equation (equation 13):

$$\Delta\begin{bmatrix} NOx \\ PC \\ PCsq \\ EX \\ URB \\ AG \\ IND \\ SER \end{bmatrix}_t = \begin{bmatrix} \omega_1 \\ \vdots \\ \omega_8 \end{bmatrix} + \sum_{j=1}^{k}\begin{bmatrix} \psi_{11} & \cdots & \psi_{18} \\ \vdots & \ddots & \vdots \\ \psi_{81} & \cdots & \psi_{88} \end{bmatrix}_j \times \Delta\begin{bmatrix} NOx \\ PC \\ PCsq \\ EX \\ URB \\ AG \\ IND \\ SER \end{bmatrix}_{t-j} + \begin{bmatrix} \alpha 1 \\ \vdots \\ \alpha 8 \end{bmatrix} \times ECM_{t-1} + \begin{bmatrix} \xi_1 \\ \vdots \\ \xi_8 \end{bmatrix}_t \quad (13)$$

Where $\omega_i$ (i=1,…,n) are the intercepts, and $ECM_{t-1}$ are the one period lagged error-correction terms, whose negative significance advocates long-run causality. The null hypothesis of no short-run causality, $H_0$: $\psi_{ij}=0$ (i,j=1,…,n), is tested against the alternative hypothesis, $H_1$: $\psi_{ij}\neq 0$, via an F-test. Owing to sample size restrictions, the optimal lag lengths of equations 4-13 were all chosen based on the Schwarz Information Criterion - due to its tendency to select more parsimonious models than the Akaike information criterion - with the maximum lag order set to 2, as we are dealing with annual data.

## 3. RESULTS AND DISCUSSION

### 3.1. Normality, Stationarity and Cointegration Test Results

In this section, the results of the econometric tests described in section 2 are reported and analyzed. Table 1 reports the descriptive statistics of the variables, from which we can see the results of the Jarque-Bera test that confirms all variables - namely $NOx_t$, $PC_t$, $PCsq_t$, $EX_t$, $URB_t$, $AG_t$, $IND_t$, and $SER_t$ - to be normally distributed.

Furthermore, from the results of the ADF, DF-GLS, PP, and KPSS unit root tests recorded in Table 2, we can conclude that none of the variables are integrated of order higher than I(1). As the variables of interest are found to be mutually integrated of orders I(0) and I(1), the bounds testing approach to cointegration is considered a fitting methodology for this study.

Table 3 reports the results of the bounds test (equations 4-6), from which we can see that the null hypothesis of no cointegration is strongly rejected at the 1% significance level for all estimated models, indicating that the variables do share meaningful long-run equilibrium relationships. Additionally, the results of the Jarque-Bera, Breusch-Godfrey, Breusch-Pagan-Godfrey, ARCH LM, and Ramsey RESET tests suggest that the models are free from problems associated with normality, serial correlation, heteroskedasticity, or/and model misspecification. These coupled with the relatively high R-squared statistics propose the suitability of the selected ARDL models, and the high reliability and consistency of the cointegration estimates.

### 3.2. Long- and Short-run Equation Results

Now that we have established the existence of cointegrating relationships, the ensuing step is to investigate the long- and short-run relationships amongst the variables (equations 7-12), the results of which are reported in Table 4. From Table 4, we can witness that all the independent variables included in the study significantly impacts $NO_x$ emissions at the 5% level or lower in all the long-run models. A highly significant quadratic long- and short-run relationship is found between $NO_x$ emissions and income; however, instead of an inverted U-shaped relationship characteristic of the EKC, we are greeted with a robust upright U-shaped long-run relationship, which discredits the existence of the EKC in Mongolia. This suggests that despite its rapid growth

**Table 1: Descriptive statistics**

| Variable | NOx | PC | PCsq | EX | URB | AG | IND | SER |
|---|---|---|---|---|---|---|---|---|
| Mean | 8.385 | 13.845 | 192.366 | 27.584 | 14.112 | 26.851 | 27.250 | 27.634 |
| Median | 8.395 | 13.893 | 193.026 | 27.822 | 14.093 | 27.245 | 27.255 | 27.493 |
| Maximum | 8.798 | 15.367 | 236.153 | 29.475 | 14.484 | 28.031 | 29.037 | 29.457 |
| Minimum | 8.126 | 12.577 | 158.177 | 25.566 | 13.725 | 25.184 | 25.876 | 26.370 |
| Standard deviation | 0.178 | 0.836 | 23.184 | 1.232 | 0.201 | 0.993 | 0.981 | 0.869 |
| Skewness | 0.299 | 0.032 | 0.127 | -0.189 | 0.000 | -0.561 | 0.277 | 0.427 |
| Kurtosis | 2.320 | 2.054 | 2.096 | 1.749 | 2.367 | 1.681 | 1.986 | 2.318 |
| Jarque-Bera | 1.094 | 1.198 | 1.175 | 2.278 | 0.535 | 3.998 | 1.781 | 1.594 |
| Probability | 0.579 | 0.549 | 0.556 | 0.320 | 0.765 | 0.135 | 0.410 | 0.451 |
| Number of observations | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |

**Table 2: Unit root test results**

| Variable | ADF | | | | | | DF-GLS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I (0) | | | I (1) | | | I (0) | | I (1) | |
| | No C or T | C | C+T | No C or T | C | C+T | C | C+T | C | C+T |
| NOx | −0.540 (2) | −2.595 (0) | −3.538 (0)* | −7.418 (0)*** | −7.315 (0)*** | −7.243 (0)*** | −2.606 (0)** | −3.620 (0)** | −7.082 (0)*** | −7.315 (0)*** |
| PC | 1.111 (1) | −0.277 (1) | −2.991 (1) | −3.430 (0)*** | −3.625 (0)** | −3.793 (0)** | −0.412 (1) | −2.394 (1) | −3.585 (0)*** | −3.929 (0)*** |
| PCsq | 1.189 (1) | −0.130 (1) | −2.893 (1) | −3.460 (0)*** | −3.689 (0)*** | −3.905 (0)** | −0.289 (1) | −2.309 (1) | −3.645 (0)*** | −4.044 (0)*** |
| EX | 1.508 (0) | −0.451 (0) | −3.945 (2)** | −5.401 (0)*** | −5.731 (0)*** | −5.681 (0)*** | −0.171 (0) | −2.531 (0) | −5.823 (0)*** | −5.861 (0)*** |
| URB | 1.899 (2) | 0.080 (2) | −3.595 (3)** | −0.940 (1) | −2.134 (1) | −2.006 (1) | 0.750 (2) | −3.681 (3)** | −1.936 (1)* | −2.036 (1) |
| AG | 1.103 (0) | −0.727 (0) | −2.631 (1) | −4.121 (0)*** | −4.187 (0)*** | −4.123 (0)** | −0.531 (0) | −2.525 (1) | −4.258 (0)*** | −4.273 (0)*** |
| IND | 1.886 (0) | 0.201 (0) | −2.257 (0) | −4.670 (0)*** | −5.090 (0)*** | −5.213 (0)*** | 0.379 (0) | −2.046 (0) | −5.150 (0)*** | −5.393 (0)*** |
| SER | 1.259 (1) | 0.596 (2) | −3.350 (1)* | −2.712 (0)*** | −3.009 (0)** | −3.970 (1)** | −0.220 (1) | −2.525 (1) | −2.980 (0)*** | −4.119 (1)*** |
| **Variable** | **PP** | | | | | | **KPSS** | | | |
| | I (0) | | | I (1) | | | I (0) | | I (1) | |
| | No C or T | C | C+T | No C or T | C | C+T | C | C+T | C | C+T |
| NOx | −1.350 (31) | −2.595 (0) | −3.526 (1)* | −11.044 (30)*** | −13.666 (30)*** | −18.381 (30)*** | 0.558 (3)** | 0.152 (3)** | 0.098 (3) | 0.074 (3) |
| PC | 1.335 (2) | 0.120 (2) | −2.367 (1) | −3.430 (0)*** | −3.638 (1)** | −3.819 (1)** | 0.659 (4)** | 0.103 (4) | 0.248 (2) | 0.084 (1) |
| PCsq | 1.454 (2) | 0.271 (2) | −2.312 (1) | −3.463 (1)*** | −3.699 (1)*** | −3.926 (1)** | 0.664 (4)** | 0.110 (4) | 0.270 (2) | 0.080 (1) |
| EX | 2.290 (9) | −0.255 (7) | −2.542 (6) | −5.424 (2)*** | −5.804 (6)*** | −5.749 (6)*** | 0.690 (4)** | 0.069 (2) | 0.180 (9) | 0.173 (10)** |
| URB | 6.031 (4) | −0.726 (4) | −1.940 (4) | −0.800 (3) | −1.509 (3) | −1.290 (3) | 0.759 (4)*** | 0.104 (4) | 0.169 (4) | 0.161 (4)** |
| AG | 0.989 (1) | −0.853 (1) | −2.159 (2) | −4.145 (1)*** | −4.187 (0)*** | −4.123 (0)** | 0.607 (4)** | 0.080 (4) | 0.084 (1) | 0.083 (1) |
| IND | 1.673 (3) | 0.016 (3) | −2.360 (2) | −4.789 (3)*** | −5.138 (3)*** | −5.255 (3)*** | 0.671 (4)** | 0.086 (3) | 0.145 (3) | 0.058 (3) |
| SER | 1.836 (1) | 0.852 (2) | −2.539 (9) | −2.614 (8)** | −2.612 (14) | −3.026 (17) | 0.670 (4)** | 0.160 (3)** | 0.437 (1)* | 0.088 (5) |

Variable denotes "variable"; () denotes the optimal lag order or bandwidth for the ADF, DF-GLS, PP, and KPSS unit root tests. The optimal lag order for the ADF and DF-GLS tests were selected using the SIC. The optimal bandwidth for the PP and KPSS tests were selected using the Bartlett Kernel Newey-West method. C denotes the constant term, T denotes the trend term, * denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level, ADF: Augmented Dickey-Fuller, KPSS: Kwiatkowski-Phillips-Schmidt-Shin, SIC: Schwarz Information Criterion

**Table 3: Results from the bounds test**

| Model | F-statistic | Jarque-Bera | Breusch-Godfrey | Breusch-Pagan-Godfrey | ARCH LM | Ramsey reset | $R^2$ (adjusted) |
|---|---|---|---|---|---|---|---|
| F($NOx^{AG}$\|PC, PCsq, EX, URB, AG) | 16.608*** | 0.434 [0.805] | \|1\|2.178 [0.140]<br>\|2\|5.488 [0.064] | 12.117 [0.597] | \|1\|1.777 [0.183]<br>\|2\|1.563 [0.458] | \|1\|0.911 [0.357]<br>\|2\|0.462 [0.641] | 0.922 [0.843] |
| F($NOx^{IND}$\|PC, PCsq, EX, URB, IND) | 10.591*** | 2.558 [0.278] | \|1\|2.490 [0.115]<br>\|2\|4.509 [0.105] | 13.631 [0.693] | \|1\|1.625 [0.203]<br>\|2\|2.124 [0.346] | \|1\|1.687 [0.223]<br>\|2\|1.095 [0.375] | 0.923 [0.804] |
| F($NOx^{SER}$\|PC, PCsq, EX, URB, SER) | 6.509*** | 1.714 [0.424] | \|1\|0.340 [0.560]<br>\|2\|2.019 [0.365] | 15.342 [0.500] | \|1\|0.091 [0.763]<br>\|2\|0.619 [0.734] | \|1\|1.245 [0.286]<br>\|2\|1.900 [0.196] | 0.851 [0.668] |
| Nar (P) | Lower bound critical value for k=5 | | | 2.578* | 3.125** | 4.537*** | |
| | Upper bound critical value for k=5 | | | 3.858* | 4.608** | 6.370*** | |

Nar (P) denotes the upper- and lower-bound critical values obtained from Narayan (2005) for case III of unrestricted intercept and no trend; || refers to the diagnostics test order; [] refers to the P values; * denotes significance at the 10% level; ** denotes significance at the 5% level; and *** denotes significance at the 1% level

**Table 4: Long- and short-run equation results**

| Long-run equation results | | | | | | |
|---|---|---|---|---|---|---|
| Variable | $NO_{AG}$ model | | $NO_{IND}$ model | | $NO_{SER}$ model | |
| | Coefficient | t-statistics | Coefficient | t-statistics | Coefficient | t-statistics |
| C | 78.150 | 20.794 [0.000]*** | 39.465 | 5.097 [0.000]*** | 43.411 | 9.273 [0.000]*** |
| PC | −6.952 | −15.970 [0.000]*** | −1.995 | −2.328 [0.032]** | −2.221 | −3.558 [0.004]*** |
| PCsq | 0.255 | 16.913 [0.000]*** | 0.090 | 2.835 [0.011]** | 0.101 | 4.829 [0.000]*** |
| EX | −0.059 | −2.621 [0.021]** | −0.155 | −3.043 [0.007]*** | −0.179 | −3.385 [0.005]*** |
| URB | −1.921 | −13.948 [0.000]*** | −0.780 | −3.744 [0.002]*** | −0.715 | −5.051 [0.000]*** |
| AG | 0.237 | 6.825 [0.000]*** | - | - | - | - |
| IND | - | - | −0.192 | −2.777 [0.012]** | - | - |
| SER | - | - | - | - | −0.308 | −4.430 [0.001]*** |
| $R^2$ | 0.945 | | 0.816 | | 0.934 | |
| Adjusted $R^2$ | 0.886 | | 0.714 | | 0.847 | |
| F-statistic | 118.299 [0.000]*** | | 30.839 [0.000]*** | | 55.707 [0.000]*** | |
| Jarque-Bera | 0.253 [0.881] | | 0.728 [0.695] | | 0.145 [0.930] | |
| **Short-run equation results** | | | | | | |
| Variable | $\Delta NO_{AG}$ model | | $\Delta NO_{IND}$ model | | $\Delta NO_{SER}$ model | |
| | Coefficient | t-statistics | Coefficient | t-statistics | Coefficient | t-statistics |
| C | 0.014 | 0.379 [0.709] | −0.061 | −1.367 [0.190] | 0.001 | 0.020 [0.984] |
| ΔPC | 5.192 | 2.695 [0.014]** | 6.760 | 3.868 [0.001]*** | 4.002 | 2.436 [0.026]** |
| ΔPCsq | −0.164 | −2.391 [0.027]** | −0.215 | −3.376 [0.004]*** | −0.132 | −2.213 [0.040]** |
| ΔEX | −0.184 | −2.875 [0.009]*** | −0.213 | −2.109 [0.051]* | −0.180 | −1.835 [0.083]* |
| ΔURB | −8.125 | −4.047 [0.001] *** | −11.073 | −4.491 [0.000]*** | −7.686 | −4.587 [0.000]*** |
| ΔAG | −0.062 | −0.644 [0.527] | - | - | - | - |
| ΔIND | - | - | −0.257 | −1.866 [0.081]* | - | - |
| ΔSER | - | - | - | - | 0.179 | 1.058 [0.304] |
| ecm(t-1) | −0.992 | −7.218 [0.000]*** | −1.395 | −7.298 [0.000]*** | −1.076 | −7.850 [0.000]*** |
| $R^2$ | 0.852 | | 0.882 | | 0.878 | |
| Adjusted $R^2$ | 0.793 | | 0.801 | | 0.810 | |
| F-statistic | 14.415 [0.000]*** | | 10.887 [0.000]*** | | 12.966 [0.000]*** | |
| Jarque-Bera | 3.872 [0.144] | | 3.212 [0.201] | | 0.481 [0.786] | |
| Breusch-Godfrey LM | \|1\|0.323 [0.570] | | \|1\|0.001 [0.977] | | \|1\|2.579 [0.108] | |
| | \|2\|0.657 [0.720] | | \|2\|0.209 [0.901] | | \|2\|2.234 [0.140] | |
| Breusch-Pagan-Godfrey | 3.820 [0.873] | | 7.110 [0.790] | | 8.314 [0.598] | |
| ARCH LM | \|1\|0.882 [0.348] | | \|1\|0.180 [0.671] | | \|1\|0.422 [0.516] | |
| | \|2\|1.009 [0.604] | | \|2\|1.061 [0.588] | | \|2\|1.851 [0.396] | |
| Ramsey RESET | \|1\|0.951 [0.342] | | \|1\|0.027 [0.872] | | \|1\|0.700 [0.415] | |
| | \|2\|0.901 [0.424] | | \|2\|2.908 [0.088]* | | \|2\|0.533 [0.597] | |

Coefficient denotes "Coefficients"; [] refers to the P values; || refers to the diagnostics test order; C denotes the constant term, *denotes significance at the 10% level, **denotes significance at the 5% level, and *** denotes significance at the 1% level $\Delta NO_{AG}$ model ecm(t-1) = NO - (78.15-6.952* PC+0.255* PCsq -0.059* EX -1.921* URB+0.237* AG), $\Delta NO_{IND}$ model ecm (t-1) = NO - (39.465-1.995* PC+0.090* PCsq -0.155* EX -0.780* URB -0.192* IND), $\Delta NO_{SER}$ model ecm (t-1) = NO - (43.411-2.221* PC+0.101* PCsq -0.179* EX -0.715* URB -0.308* SER)

in the past decade, on the aggregate, Mongolia is still not at a stage in its development where increases in per capita income renders pollution levels lower.

The impact of international trade on pollution has been extensively studied, and this study strived to focus on the influence of exports on $NO_x$ emissions, which was a different approach to that of Ahmed (2014), who used trade openness to account for both imports and exports in Mongolia. Surprisingly, the findings show that exports significantly decrease $NO_x$ emissions in both the short- and long-run; suggesting that the pollution-haven hypothesis does not exist for Mongolia.

In terms of economic significance, urbanization is revealed to be the leading factor reducing $NO_x$ emissions in Mongolia, as can be witnessed through its comparatively larger negative coefficients. This lends credence to the successful reduction of air pollution associated with the move from rural inhabitants who live in traditional Mongolian gers - who are highly dependent on coal burning to survive the harsh Mongolian winters - to urban dwellings equipped with central heating; thereby, drastically reducing the burning of coal. Moreover, the increasing levels of environmental awareness associated with the educated urban citizens, and their relatively higher income levels, may also be contributing to the decrease in pollution in relation to urbanization.

As for the impact of the various economic sectors on $NO_x$ pollution, the agricultural sector is found to increase $NO_x$ emissions in the long-run. On the other hand, the industrial and services sectors are found to exhibit a curtailing effect on $NO_x$ emissions. These results are not surprising as agricultural soil management is the leading human activity that contributes to $NO_x$ emissions. Therefore, the transfer of the GDP composition from the agricultural to the industrial or services sectors is sure to result in a decline in $NO_x$ emission.

Additionally, the coefficients of the error-correction terms are found to not only be highly significant with the appropriate negative sign for all models, but the coefficients imply a rapid speed in which the long-run equilibrium is reached. More specifically, the ecm(t-1) coefficients of the $\Delta NO_{AG}$, $\Delta NO_{IND}$, and $\Delta NO_{SER}$ models imply that these models are corrected back from the short-run disequilibrium to the long-run equilibrium by 99%, 140%, and 108% respectively; which means the disequilibrium would be corrected within 12, 9.6, and 11.5 months respectively.

### 3.3. VECM Results

Lastly, we are brought to the final step of our study, which is to determine the direction of causality running between the variables via the Granger causality technique within the VECM framework (equation 13) to further strengthen our findings, the results of which are reported in Table 5. From the results exhibited in Table 5, we can infer the bidirectional causality between $NO_x$ emissions, per capita income, and per capita income squared; and the unidirectional causality running from exports and urbanization to $NO_x$ emissions, in both the short- and long-run. In the case of the different economic sectors, a bidirectional causality is found between $NO_x$ emissions and the agricultural and services sectors in the long-run. However, a unidirectional causality is found to run from $NO_x$ emissions to the industrial sector in the short-run, and from the industrial sector to $NO_x$ emissions in the long-run.

Finally, Figures 1-3 display the plots of cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMQ) tests of the selected models. All the residuals were found to be within the critical bounds of the 5% significance level; thereby, reflecting the reliability, stability, and consistency of the estimates in the long- and short-run.

## 4. CONCLUSIONS AND POLICY IMPLICATIONS

The aim of this study was fourfold, to: (a) Investigate the existence of cointegration between the variables studied, (b) examine the presence of the EKC for $NO_x$ emissions in Mongolia, (c) determine the short- and long-run relations shared amongst the variables studied, and (d) finally, ascertain their Granger causal relationships. In order to achieve that, a series of econometric methods were methodically employed to ensure reliable and robust estimation results that include the ADF, DF-GLS, PP, and KPSS unit root tests to determine the order of integration of the variables; the most recently developed ARDL bounds testing approach to cointegration to prove the existence of meaningful long-run equilibrium relationships amongst the variables; the FMOLS estimation and error-correction model to establish the long- and short-run relationships between the variables; and the Granger causality test within the VECM framework to discover the direction of causality running between the variables. Ultimately, the results exhibit significant short- and long-run, as well as Granger causal, relationships between the variables studied.

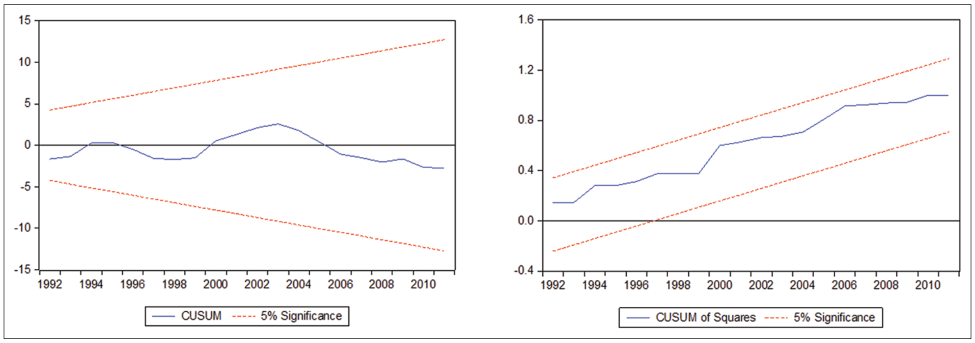
The fundamental finding of the study discredits the existence of the EKC hypothesis for $NO_x$ emissions in Mongolia; thereby stressing that Mongolia is still in its earlier stage of economic development. Moreover, exports, urbanization, and the industrial and services

**Table 5: Granger causality results based on the VECM framework**

| Variable | Models | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ΔNO | ΔPC | ΔPCsq | ΔEX | ΔURB | ΔAG | ΔIND | ΔSER |
| ∑ΔNO (t-i) | - | 3.389 [0.081]* | 3.288 [0.084]* | 0.164 [0.690] | 1.669 [0.211] | 1.242 [0.278] | 6.592 [0.018]** | 0.147 [0.705] |
| ∑ΔPC (t-i) | 32.244 [0.000]*** | - | 32.768 [0.000]*** | 8.198 [0.010]*** | 4.914 [0.038]** | 28.779 [0.000]*** | 17.271 [0.001]*** | 22.215 [0.000]*** |
| ∑ΔPCsq (t-i) | 35.808 [0.000]*** | 29.279 [0.000]*** | - | 5.192 [0.034]** | 4.152 [0.055]* | 21.161 [0.000]*** | 13.601 [0.002]*** | 17.718 [0.000]*** |
| ∑ΔEX (t-i) | 8.137 [0.010]*** | 4.552 [0.046]** | 3.977 [0.060]* | - | 0.675 [0.421] | 0.158 [0.695] | 1.538 [0.229] | 7.172 [0.015]** |
| ∑ΔURB (t-i) | 14.304 [0.001]*** | 0.099 [0.757] | 0.158 [0.696] | 0.083 [0.776] | - | 0.001 [0.972] | 2.592 [0.123] | 0.351 [0.560] |
| ∑ΔAG (t-i) | 0.416 [0.526] | 21.707 [0.000]*** | 19.403 [0.000]*** | 7.609 [0.012]** | 0.632 [0.436] | - | 7.813 [0.011]** | 14.183 [0.001]*** |
| ∑ΔIND (t-i) | 0.624 [0.439] | 6.018 [0.024]** | 5.396 [0.031]** | 3.045 [0.096]* | 0.209 [0.653] | 7.808 [0.011]** | - | 2.588 [0.123] |
| ∑ΔSER (t-i) | 0.145 [0.707] | 4.315 [0.051]* | 3.832 [0.064]* | 2.224 [0.152] | 0.931 [0.346] | 6.710 [0.018]** | 1.971 [0.176] | - |
| ECM (t-1) t-statistic | −7.992 [0.000]*** | −2.596 [0.017]** | −2.376 [0.028]** | −0.636 [0.532] | 0.643 [0.527] | −2.855 [0.010]*** | −1.112 [0.279] | −2.616 [0.017]** |

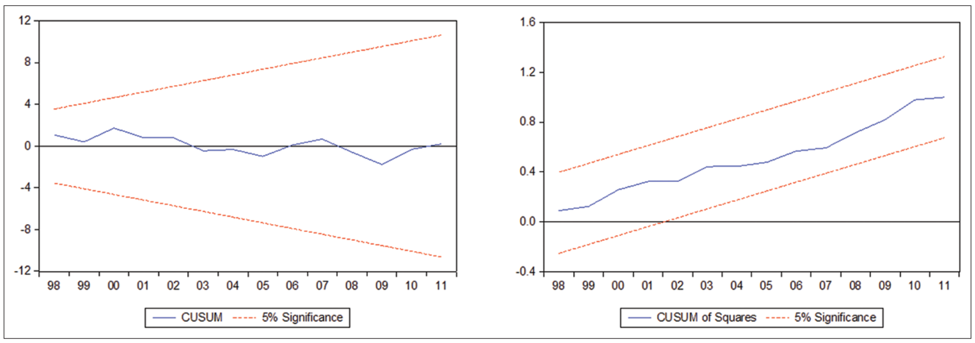
The SIC was used to select the optimal lag order. [] refers to the P values; * denotes significance at the 10% level; ** denotes significance at the 5% level; and *** denotes significance at the 1% level, SIC: Schwarz Information Criterion

**Figure 1:** F($NOx^{AG}$|PC, PCsq, EX, URB, AG) model CUSUM and cumulative sum of squares



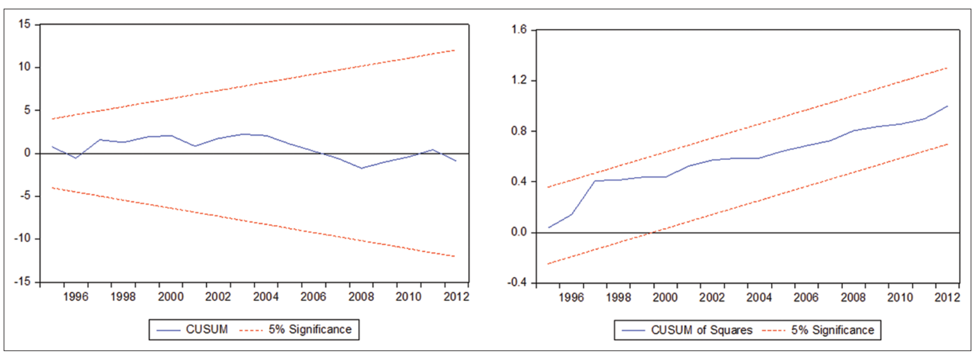

Source: Output retrieved from Eviews 9 software

**Figure 2:** F($NOx^{IND}$|PC, PCsq, EX, URB, IND) model cumulative sum and cumulative sum of squares




Source: Output retrieved from Eviews 9 software

**Figure 3:** F($NOx^{SER}$|PC, PCsq, EX, URB, SER) model cumulative sum and cumulative sum of squares




Source: Output retrieved from Eviews 9 software

sectors have been found to decrease $NO_x$ pollution; while on the other hand, the agricultural sector has been confirmed to exacerbate $NO_x$ pollution. As for Granger causality, bidirectional causality between $NO_x$ emissions, per capita income, and per capita income squared; and the unidirectional causality running from exports and urbanization to $NO_x$ emissions, in both the short- and long-run have been found. Moreover, bidirectional causality was also found between $NO_x$ emissions and the agricultural and services sectors; albeit only in the long-run. Lastly, unidirectional causality was found to run from $NO_x$ emissions to the industrial sector in the short-run, and from the industrial sector to $NO_x$ emissions in the long-run.

This study was conducted with the primary intention of assisting Mongolian policy makers in making a more informed decision when formulating policies aimed at achieving sustainable economic growth, whilst minimizing sacrifices to its energy security in favor of short-term economic development. Without making grand unfounded assumptions, the findings of this study ostensibly support policies aimed at: (i) increasing the efficient use and reduction of agricultural fertilizers that are based on nitrogen, and the proper management of manure, so as to limit the enhancing effects of agricultural activities on $NO_x$ emissions, (ii) increasing environmental education and advancing further integration of current traditional-ger-inhabitants into the central heating grid, so as to aggressively limit the burning of fossil fuel for domestic heat and to increase the urban population's environmental awareness; and, in general, (iii) promoting sustainable economic growth without exacerbating environmental issues, as the findings have showcased the feedback mechanism shared between $NO_x$ emissions and economic growth, as well as the fact that Mongolia is not at a stage where economic growth can be pursued without fearing the environmental costs.

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