# The sheer scale of China's urban renewal and CO2 emissions: Multiple structural breaks, long-run relationship and short-run dynamics

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**Abstract**

In the light of urban environmental transition (UET) theory, this study explores the relationship between carbon dioxide ($CO_2$) emissions, economic growth, urbanization and trade openness using updated Chinese data over the extended period (1971-2013). After confirming that all the underlying series are stationary and adjusted with single structural break point, the results of auto-regressive distributed lag (ARDL) bounds test approach to cointegration confirms the cointegration between the variables. The long- and short-run dynamics reveal that urbanization reduces the $CO_2$ emissions both in short- and long-run, but statistically insignificant. These findings contrast with previous literature and sounds the validation of urban environmental transition theory (UET). However, economic growth and trade openness contribute environmental degradation both in long- and short-run paths. The causality analysis reports bi-directional causal link between trade openness and urbanization in the short-run. However, in the long-run, economic growth ranger cause carbon dioxide emissions, urbanization and trade openness. Similarly, trade openness Granger cause carbon dioxide emissions, economic growth and urbanization in the long-run. The overall results imply that rural to urban immigration is still mostly driven by exports related manufacturing sectors. In addition, the higher GDP also contributes to urbanization as a feedback effect. In the end, stability of the model is also checked, model found stable and findings are suitable for environmental policy control use.

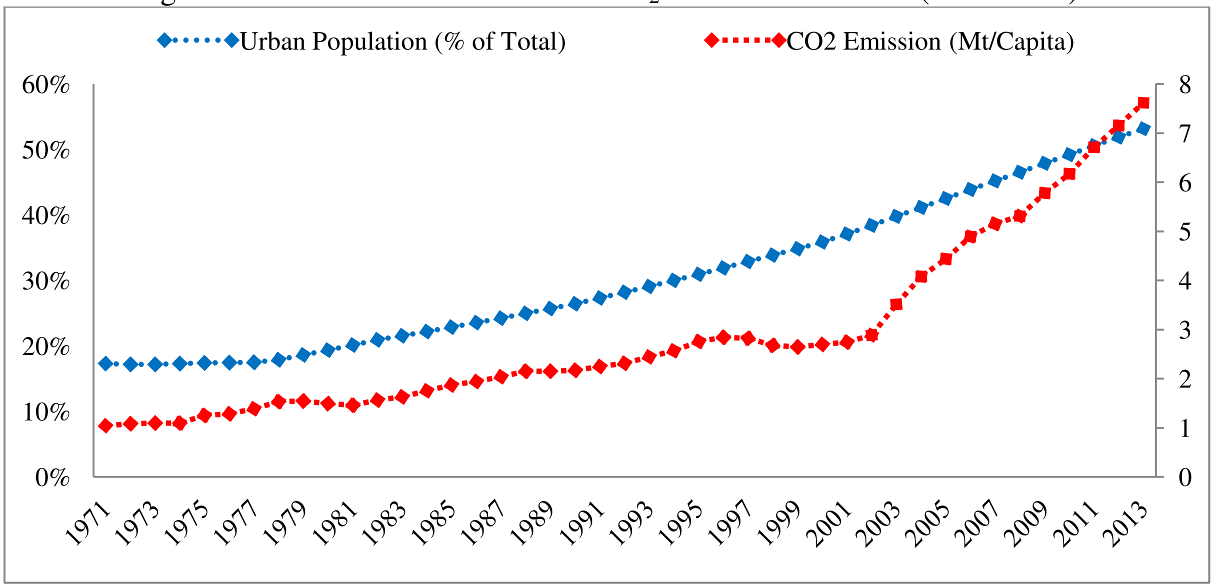
**Key Words:** Carbon dioxide; Urbanization; Long-run dynamics; Multiple structural breaks; Bounds test; China

## 1. Introduction

China has been booming for more than three decades. It has been consistently a world's fastest growing economy and continued to expand even during the global recession. Owing to mindful perusal of socio-economic development, it smoothly transformed from centrally planned to market economy (World Bank, 2014a). Since the reforms and opening policy initiated in 1979, the country miraculously maintained an average growth rate 10% annually. Meanwhile, in search of high living standard, a large proportion of population converged in urban areas and the cities grew faster than expected. However, the sheer scale of urban renewal in China simultaneously inflicts huge environmental cost as well (Zhang and Lin, 2012). Fig.1 shows the trend in China's urbanization and $CO_2$ emissions between 1971-2013. The share of urban population as a percent of total population has increased from 17.3% in 1971 to 50.3% in 2013. Similarly, the per capita $CO_2$ emissions has also increased from 1.1 ~ 7.6 metric tons during the same period. In 2013, the emissions intensity in China further rose by 4.2%. As per the latest estimates, by 2030 the Chinese cities will contain 70% of total population, which roughly makes 1 billion people (World Bank, 2014b). Although, there is an extensive literature available on the various determinants of environmental degradation, yet little is explored on the urbanization side (Marcotullio et al., 2014). Despite of serious environmental challenges associated with rapidly changing urban landscape in emerging economies (i.e. China), the development economics literature considers urbanization a key indicator of socio-economic well being (Lloyd-Jones and Rakodi, 2014). Whereas, the sustainable development goals require inclusive policy tool, sufficient for both the sustainable environment and sustainable economic growth in the country

(Vervoort et al., 2014, Ahmed et al., 2016). Thus, this study takes up the case of China to empirically explore the emission-urbanization nexus using unique statistical techniques.

Figure 1. Trend in Urbanization and $CO_2$ emissions in China (1971-2013)




In China, urbanization is considered critical for industrial and economic growth. Therefore, the urbanization is placed on the top priority list while the national policies are framed. China's 12th five year plan reveals massive urban restructuring and transformation. The key targets include the creation of 45 million new jobs in urban areas, whilst keeping the urban unemployment rate not more than 5%. The rate of urbanization is set to increase by 4%, which means 30 million more people to be allocated in the cities (NDRC)[1]. The rise in domestic consumption and strategic industrial breakthroughs are additional targets of economic transformation. However, such an ambitious urbanization targets entail China's increasing $CO_2$ emissions profile. The rising income level comes up with higher consumption of goods, which are mainly manufactured in emission intensive industries. For example: the number of privately owned vehicles in 2013 were 108.92 million, up by 17% to preceding year. Accordingly, the rate of electricity

[1] National Development and Reforms Commission (NDRC), 2011. http://en.ndrc.gov.cn/ (Accessed:10.10.2015)

consumption is also increased by 7.5% (NBSC, 2014)[2]. Furthermore, China surpassed U.S and became the world's largest $CO_2$ emitter in 2006. In 2014, China alone accounted 29% of total global emissions (twice as of U.S's). China is already at the cross-roads of sustainable development challenge, where emissions reduction and climate change adaptation have emerged as the key policy priorities. China's growth miracle has been a source of great motivation in the developing world. However, the country has yet to set an example in sustainable development path. This notion necessitates China to have an effective and comprehensive national environmental policy.

The environmental consequence of urbanization are extensively discussed both in terms of higher population density and as well as change in economy wide resource utilization (Gibbs, 2010). In the first case, the rising urban densities reduce absorption capacity and detriment local environment. In the second case, perceived industrialization and consumption patterns affect global environmental quality. In summary, the rising income levels in the rapidly growing urban areas fetch direct and indirect energy demand through the production and consumption patterns, which ultimately cause overall environment degradation. The current literature on the global GHG emissions and climate change impacts is mainly focused on the developing and newly industrializing economies. Similarly, China is undergoing an extensive economic transformation and likely to face increasing environmental degradation. Thus, the country is also likely to receive domestic and international pressure to attain sufficient trade-offs between economic growth and environmental sustainability. Furthermore, before the suitable options are considered it is imperative to analyze the various channels of environmental degradation in the country.

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[2] National Bureau of Statistics of China (NBSC), 2014.

http://www.stats.gov.cn/enGLISH/PressRelease/201402/t20140224_515103.html (Accessed:10.10.2015)

This study is an attempt to empirically examine the long-run relationship and short-run dynamics between urbanization and $CO_2$ emissions in the presence of two additional explanatory variable of macroeconomic nature (i.e. economic growth and trade openness) for China. The updated time series data over an extended period of 1971-2013 is utilize for estimation purpose. Unlike previous studies, this study considers the multiple structural break points that may have arisen due to rapid economic transformation during the sample period and may influence the estimation results. Thus, the each variable is checked for two structural break point using test procedure proposed by Lumsdaine and Papell (1997) (LP). Later, the long-run association between $CO_2$ emission, urbanization, economic growth and trade openness is checked using the bounds test approach to cointegration in an auto-regressive distributed lag (ARDL) model. Once the long-run dynamic equilibrium relationship is confirmed between the variables, the paper move forward to estimate short-run dynamics of the $CO_2$ emissions with respect to urbanization, economic growth and trade openness by using error-correction model. The long- and short-run elasticities obtained in this study are unique in a way that they are adjusted for more than one possible structural shocks. The robust econometric analysis enables us to determine the contribution of urbanization and macro economics channels (i.e. economic growth and trade openness) to the emissions profile of China. However, the exclusive purpose of this study is to see the impact of urbanization on the $CO_2$ emission intensity of China. Finally, the paper concludes the key findings, discusses the policy implications and how the findings assist relevant national and international agencies and other developing countries to strategize the future environmental policy.

## 2. Theoretical background

The environmental Kuznets curve is believed as the sole hypothetical approach on the relationship between income and environmental degradation, until McGranahan et al. (1996) introduce urban environmental transition (UET) theory. The theory states, as the wealth increases in the cities due to economic transformation, the environmental impacts also undergo different stages, i.e. temporal and geographical scales. However, this study mainly inclined to the socio-ecological system (SES), a newly explored aspect of UET by Marcotullio (2011). Marcotullio further compares the experience of Asia Pacific economies and technologically developed economies and found unique SESs patterns in Asia Pacific region because of the fast paced economic growth. Hence, the environmental policy controls in today's emerging economies need contemporary approaches rather than replicating the past and current experiences of the developed countries and regions.

Nevertheless, when it comes to mutual consensus, there is a persistent difference of opinion among the hardliners on the each side of the environmentalist and development propagandist. For more than a decade, the ecological modernization theory (EMT) developed by optimists is a single approach that offers reconciliation. The EMT based environmental policy structure works under the collaborative design of economy's self correcting market mechanism and essential social restructuring. Here, self correcting market mechanism refers to the restoration of environmental equilibrium that society attains during the low and high income transition[3]. Whereas, the essential social restructuring includes extra policy and awareness measures towards the creation of more efficient, innovative and self sustained green society. For detailed exploratory research on UET (see Crenshaw and Jenkins, 1996; McGrnahan et al.,

[3] for details see Sadorsky (2014)

1996; Gouldson and Murphy, 1997; Marcotullio and McGranahan, 2012) and for EMT (see Spaargaren and Mol, 1992; Mol and Spaargaren, 2000; Mol et al., 2013 ).

The core objective of EMT is to bridge the policy gap between economic, environmental and sustainable development. It is currently practiced in the developed world both at the national[4] and regional[5] levels. By establishing SES as the theoretical base, this study attempts to investigate the environmental spin-off of fast paced urbanization in China.

## 3. Review of relevant literature

The applied environmental economics literature on urbanization and emissions nexus is mostly focused on cross country analysis. For example; most of the earlier studies show that the increase in urbanization leads to higher level of carbon emissions. For instance, Parikh and Shukla (1995) found that urbanization has positive impact on carbon emissions and other greenhouse gases in a set of 83 developed and developing countries. Their estimate of carbon emissions elasticity of urbanization is recorded at 0.036. Later, their findings are supported by York et al. (2003) while studying the larger dataset of 137 countries. The study by Cole and Neumayer (2004) comprising 86 countries also show that a 10% increase in urbanization leads to 7% increase in carbon emissions. However, some of the studies carried out in recent years contradict with these findings. For example, in the context of developing countries, Fan et al. (2006) claim that there is a negative relationship between urbanization and CO2 emissions. In the case of 17 developed countries, Liddle and Lung (2010) conclude that the positive impact of urbanization on carbon emissions is insignificant when carbon emissions are used in aggregate.

[4] See for example the UK's Environmental Policy (https://www.gov.uk/government/organisations/environment-agency)

[5] See for example the European Union's Environmental Action Programme(s) (http://ec.europa.eu/environment/archives/action-programme/)

A sectoral analysis using carbon emissions from transport sector, however, shows a positive and significant impact of urbanization on carbon emissions. Poumanyvong and Kaneko (2010) examine the dataset of 99 countries for the period of 1975-2005, and find that urbanization increases environmental degradation in the both low and middle income countries. Their results further suggest that impact varies in terms of income, where the impact in low income countries is higher than middle income countries. The large panel data analysis without country specific results may have policy implication in a multilateral framework, but my not be suitable for national and regional policy architecture.

Notwithstanding the cross-country studies, the majority of literature on urbanization and environment linkage focuses the energy led emission fallout. The early study of Dhal and Erdogan (1994) investigate the relationship between urban population and oil consumption, found that the rise of urbanization has a positive effect industrialization which raises oil demand. Kalnay and Cai, (2003) put forward that urbanization generates pressure on agriculture sector to overproduce. It has negative effects such as massive land use and raise of energy demand in agriculture sector. Bryant (2005) found out that urbanization is related to industrialization, technological involvement, globalization and migration. All these variables contribute to increasing energy demand. Hemmati (2006) studied the impact of income and urbanization on energy demand for Iran using annual data. He stated that urbanization leads industrialization and commercialization that result of rising raw material demand and consumer goods which by the way affect energy demand. Halicioglu (2007) used the vector error correction method Granger causality technique to determine the causal relationship between economic growth, energy prices, urbanization and energy consumption in Turkey. He pointed out that urbanization Granger causes energy consumption in the long run but not vice versa. By examining the impact of demographic factors on energy consumption in European Union countries, York (2007) found that energy demand is source of fast urbanization and industrialization in these economies. Taking Iran as country case, Abouie-Mehrizi et al. (2012) used energy demand function to explore the impact of population growth, urbanization and affluence on energy consumption. The empirical results exposed that population growth, urbanization and affluence on energy consumption have long run relationship and these variables raise energy demand. The recent work of Solarin and Shahbaz (2013) also analyzed the relationship between economic growth, urbanization and electricity consumption for Angola using several econometric estimation techniques and concluded long-run association among the variables and also found bidirectional Granger causality between urbanization and electricity consumption in case of Angola. Does energy represents overall emission profile caused by urbanization? While the ignoring the various other channels involved in a macro economy, i.e. land use, population density, solid waste, consumption habits. Thus, the urbanization has direct impact on the emissions along with development indicators. Trade is an essential controlling macroeconomic variable associated with emissions as export led growth policy is the key factor behind most of the emerging countries.

There are also number of studies recently conducted in case of China. For example: Ma and Du (2012) explore the relationship between urbanization, industrialization, energy prices and energy consumption for China. Their empirical results revealed that industrialization leads urbanization and urbanization is positively linked with energy consumption. This is a result of a rise in urban density. Moreover; impact of tertiary industrial value added has negative effect on energy use because of advanced technology used. The Chinese energy policies as well as environmental regulations have played a key role to reach this situation. Zhang and Lin, (2012) have also examined the impact of urbanization on energy consumption by applying STIRPAT model for China. The results confirmed that urbanization has a positive effect on energy demand; however it varies from region to another. Regional results showed that urbanization lowers energy demand in West, Central and Eastern regions due to use of energy efficient technology. Empirical research also examines the issue using the model STIRPAT and reveals the nonlinear nature of the relationship. According to Zhao et al. (2014) and Sugar et al. (2014) China become the heaven for pollution because of fossil energy consumption and electricity production, heating and industrial fuel use, urbanization, agriculture activities, rural life demands, and trade openness are the main elements increases carbon flow in urban cities in China. Recently, Cao et al. (2015) reported that migration of population to Anhui province is main driver of environmental degradation. Wang and Zhao (2015) also reported that urbanization deteriorates environment in less regions but energy intensity increases $CO_2$ emissions in developed regions of China. These studies combine hold four main drawbacks. First, most of the recent empirical studies seem just econometric or statistical exercise and lacks theoretical foundation. Second, like previous studies, these studies mainly focus energy consumption and their primary reason is to assist the energy security problem in the China. Third, the Chinese economy has passed through structural transformations, but these studies assume no structural break in the series and give biased results. Fourth, linear equation model is more robust in time series analysis than non-linear relationship technique (i.e. STIRPAT) which are recently utilized.

However, this study incorporate linear equation model after applying LP unit root test with two structural break test to investigate the direct impact of urbanization on emissions. In addition, the paper has theoretical base of SES and utilizes latest time series data over extended period of 1971-2013.

## 3. Data, model construction and results

The annual time series data over the period of 1971-2013 is obtained from World Bank's development indicators (WDI)[6]. Taking the $CO_2$ emissions as the function of economic growth, urbanization and trade openness, the general form of the model can be expressed as follows:

$$C_t = f(Y_t, U_t, T_t) \qquad (1)$$

Where; $C_t$ denotes the carbon dioxide ($CO_2$) emission (metric tons per capita), $Y_t$ denotes economic growth (real GDP per capita in U.S dollars), $U_t$ denotes urbanization (urban population density) and $T_t$ denotes trade openness (value of trade per capita in U.S dollars). $t$ calculates the time varying effect for each variable. We further transform the functional form of the model (eq.1) in to the log linear model as follows:

$$\ln C_t = \beta_1 + \beta_Y \ln Y_t + \beta_U \ln U_t + \beta_T \ln T_t + \mu_t \qquad (2)$$

Here; $\mu_t$ represents the random variable, which calculates the residual in the model.

Before starting the formal analysis, the basic diagnostics is performed on the sample data. Table-1 displays the descriptive statistics, where the data is normally distributed. The mean and the degree of standard deviation are also up to the standard values.

Table-1: Descriptive Statistics

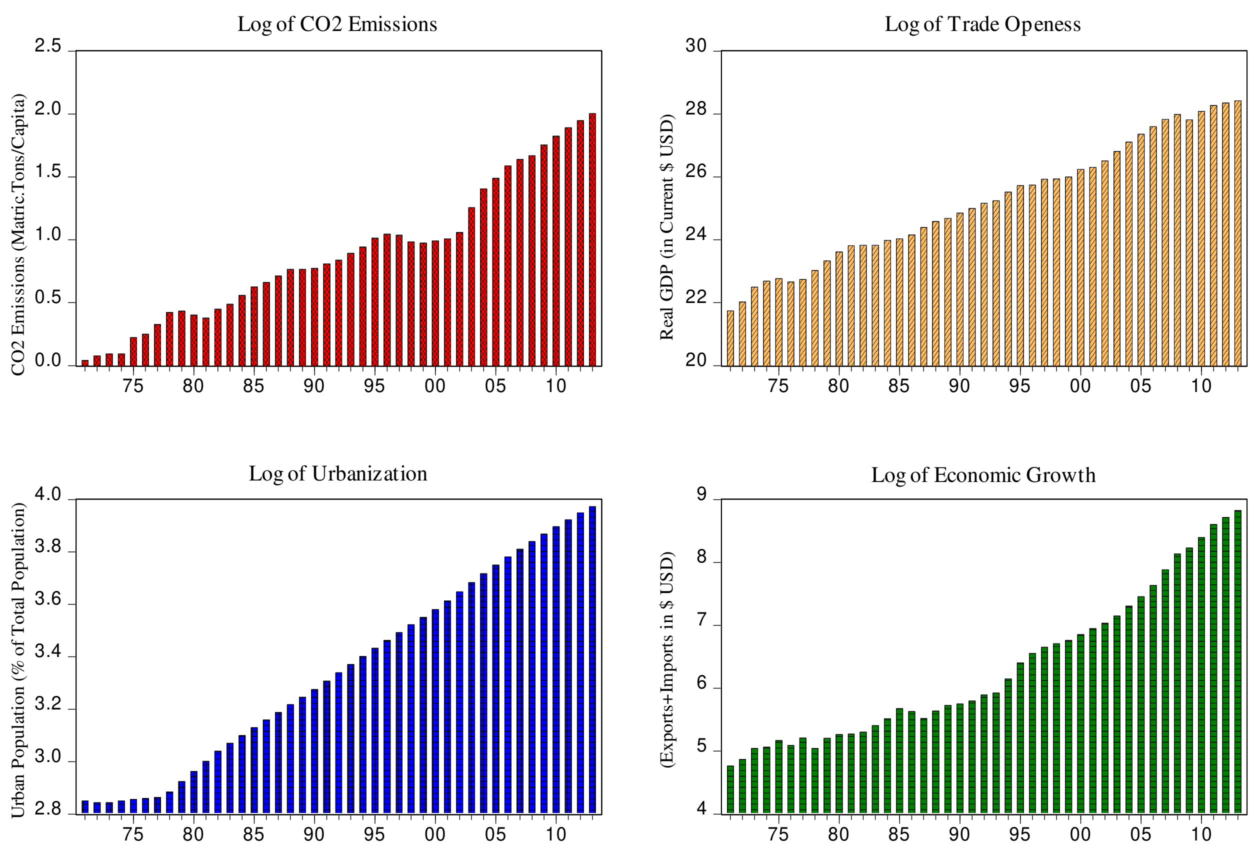
| Descriptive Statistics | | | | |
|---|---|---|---|---|
| Variable | Mean | Standard Deviation | Min | Max |
| $\ln C_t$ | 0.898 | 0.555 | 0.041 | 2.002 |

[6] World Bank's World Development Indicators (WDI). http://databank.worldbank.org/data/home.aspx (Accessed 03.09.2015).

| | | | | |
|---|---|---|---|---|
| $\ln Y_t$ | 6.330 | 1.195 | 4.763 | 8.825 |
| $\ln UB_t$ | 3.350 | 0.371 | 2.843 | 3.973 |
| $\ln TO_t$ | 25.214 | 1.942 | 21.746 | 28.423 |

Furthermore, Fig-2 shows the trend in the variables after taking the natural log. The graphs of $CO_2$ emissions, economic growth, urbanization and trade openness show the strong positive correlation. The abrupt upward trend in urbanization after the year 1980 reveal the impact of development policy reforms adopted in late 70's.

Figure-2: Trend in the variables




Source: World Development Indicators (2015)

The applied time series econometrics necessitate that the underlying time series must be stationary, otherwise the regression may turned out to be spurious due to unit root problem (Karfakis and Moschos, 1989). Thus, it is now a standard practice to check the degree of integration and stationary property of the all underlying variables. There are number of unit root tests available, i.e. ADF test by Dickey and Fuller, (1981); PP test by Philips and Perron, (1988) and DF-GLS test by Elliott et al. (1996) to check the stationary property of the variables, but these test assume no structural shock during the sample period. However, Banerjee et al. (1992) argues that the unit root test hypothesis could be biased if there is endogenous structure shock in the macroeconomic variables. In the same year, Zivot and Andrews (1992) proposed a unit root test, which identifies the single break point in the series. Later on, Lumsdaine and Papell (1997) further extended the ZA unit root test to identify two break points. Recently, the application of LP test has been popular especially in applied research which uses long time series data (Narayan and Popp, 2013). Hence, this study also adopts LP test that serves two key purposes at the same time. First, it tells us whether the series is stationary or having unit root. Second, it accommodates the two endogenous structural breaks in each series. The LP test[7] results are reported in Table-2. The results show that $\ln C_t$, $\ln Y_t$, $\ln U_t$ and $\ln T_t$ are stationary at statistical significance of 1%. TB1 and TB2 show the time breaks identified in each series. The time breaks are mainly consistent with the economic reforms started in 1980's and post Asian financial crisis recovery. Figure-3 shows the graphical representation of the two break points in each series.

[7] As the unit root test has become the standard procedure and the literature is also well established. Therefore, LP unit root test equations are not mentioned, but are available upon request.

**Table-2: LP test results**

| Variables | First Time Break (TB1) | Second Time Break (TB2) | T-statistic (for-α) | Decision |
|---|---|---|---|---|
| $\ln C_t$ | 1999 | 2003 | -9.021* | Stationary |
| $\ln Y_t$ | 1988 | 2006 | -8.319* | Stationary |
| $\ln U_t$ | 1982 | 2001 | -11.095* | Stationary |
| $\ln T_t$ | 1985 | 2004 | -7.087* | Stationary |
| Note: (*) represent significant at 1%level of significance. Lag order is based on automatic selection under Schwarz criterion. | | | | |

Furthermore, the estimation results adjusted with two break points give more accurate forecasts than those which assume that there no or single structural change in the time series (Zivot and Andrews, 1992, 2002; Perron, 1997; Narayan, 2005; Narayan and Popp, 2013; Ahmed et al., 2016).

Figure-3: Break Points ( $\ln C_t$ )

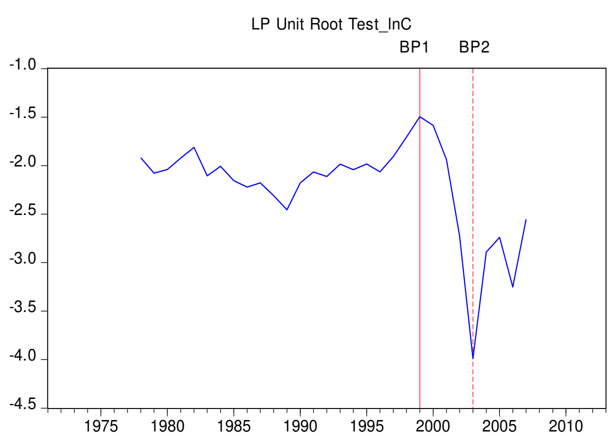



Figure-4: Break Points ( $\ln Y_t$ )

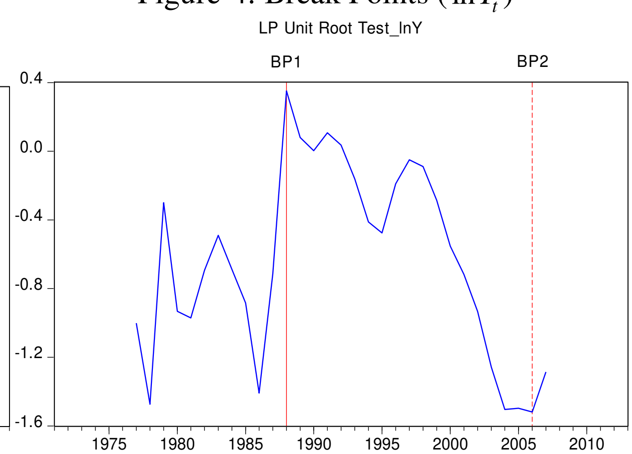


Figure-5: Break Points ( $\ln U_t$ )

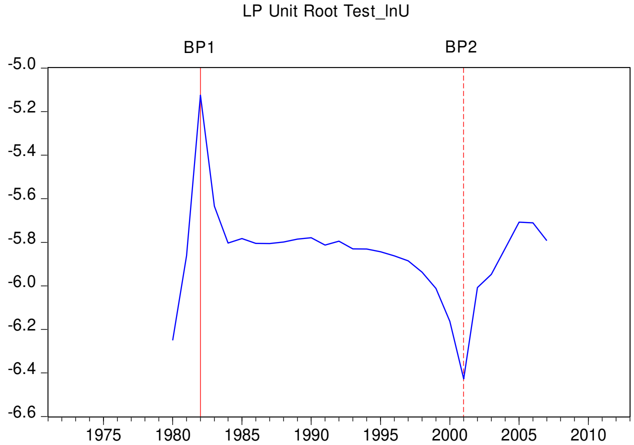
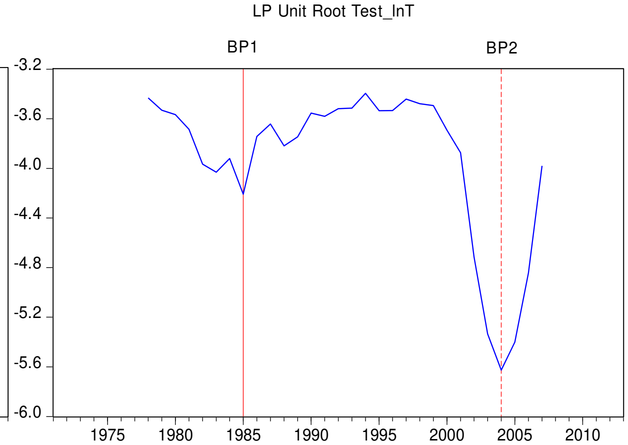



Figure-6: Break Points ( $\ln T_t$ )




After confirming the series are stationary and integrated at I(1), the model is ready for cointegration analysis. In doing so, we choose auto-regressive distributed lag (ARDL) bound test approach to cointegration developed in Pesaran et al. (2001). The ARDL bounds test approach to cointegration has two distinctions over Engle-Granger[8] and Johansen-Juselius[9] methods of cointegration. First; it concludes the relationship even under the uncertain condition whether the variables are trend or first-difference stationary, because the decision to reject the null hypothesis depends on the two sets of lower and upper bound values rather than probabilities. Second, this procedure is suitable for relatively small sample size[10]. However, the selection appropriate lag length is an important part before applying ARDL test. Therefore, using vector auto-regression (VAR) lag order selection criterion, Table-3 displays the optimal lag length based on three main lag length criterion, i.e. AIC, HQIC and SBIC. The results identify lag 2 as an appropriate lag length under AIC criterion for our sample size.

[8] Engle-Granger two step residual based method of cointegration developed in Engle and Granger (1987).

[9] Johansen-Juselius maximum likelihood approach to cointegration developed in Johansen and Juselius (1990).

[10] For recent studies using ARDL bounds testing approach to cointegration, see. (Solarin, 2014; Ling et al., 2015; Al-Mulali et al., 2016; Shahbaz et al., 2016)

Table-3: Lag length selection

| VAR Lag order selection criteria | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lag | LL | LR | DF | P | FPE | AIC | HQIC | SBIC |
| 0 | 75.317 | N/A | 1 | N/A | 0.001 | -3.606 | -3.529 | -3.392 |
| 1 | 86.420 | 22.205 | 1 | 0.000 | 0.000 | -4.124 | -4.032 | -3.868 |
| **2** | **88.879** | **4.918*** | **1** | **0.027** | **0.000*** | **-4.198*** | **-4.091*** | **-3.900*** |
| 3 | 89.081 | 0.403 | 1 | 0.525 | 0.000 | -4.158 | -4.035 | -3.816 |
| 4 | 89.772 | 1.383 | 1 | 0.240 | 0.000 | -4.142 | -4.004 | -3.758 |

*Indicates lag order selected by the criterion.

LR: Sequential modified LR test statistic (each test at 5% level).

FPE: Final prediction error

AIC: akaike information criterion.

HQIC: Hannan-Quinn information criterion.

SBIC: Schwarz bayesian information criterion

The ARDL bounds test approach to cointegration involves two step operation; (i) the long-run relationship using conditional error-correction-model[11] (ECM), and (ii) specifying ARDL in the short-run dynamics. As the first step, I identify the long-run relationship between the variables

[11] ECM is mainly used for cointegrated series and their function is to estimate the speed at which a dependent variable return to its equilibrium position after a change occurs in an independent variable. ECM also helps to estimate the long- and short-run impacts between the series (for details see. Engle and Granger, 1987; Banerjee et al., 1998).

based on the dynamic unrestricted error-correction-model (UECM). The test equation for $\ln C_t$ [12] is as follows:

$$\Delta \ln C_t = \beta_0 + \beta_C \ln C_{t-1} + \beta_Y \ln Y_{t-1} + \beta_U \ln U_{t-1} + \beta_T \ln T_{t-1} + \sum_{i=1}^{p} \beta_i \Delta \ln C_{t-i} + \sum_{j=0}^{q} \beta_j \Delta \ln Y_{t-j} + \sum_{k=0}^{r} \beta_k \Delta \ln U_{t-k} + \sum_{l=0}^{s} \beta_l \Delta \ln T_{t-l} + \mu_t \quad (3)$$

Where, $\Delta$ stands for difference operator. The null hypothesis no cointegration is tested for $\langle H_0 : \beta_C = \beta_Y = \beta_U = \beta_T = 0 \rangle$ against alternate hypothesis $\langle H_a : \beta_C \neq \beta_Y \neq \beta_U \neq \beta_T = 0 \rangle$. Table-4 shows the hypothetical illustration of relationship between dependant and independent variables in this study. For example: The economic growth may have positive impact on the $CO_2$ emissions due industrial expansion and resource mobilization. So, we expect $\beta_Y > 0$ otherwise $\beta_Y = 0$ or $\beta_Y < 0$ refers to no-effect and negative-effect, respectively. Similarly, $\beta_U > 0$ implies that urbanization causes environmental degradation through $CO_2$ emissions otherwise $\beta_U = 0$ or $\beta_U < 0$. As openness has been the key factor behind China's tremendous economic growth, so we expect trade openness is also $\beta_T > 0$ otherwise $\beta_T = 0$ or $\beta_T < 0$.

Table-4 demonstrates the results of ARDL bounds test approach to cointegration. We estimated four models [ $C_t = f(Y_t, U_t, T_t)$, $Y_t = f(C_t, U_t, T_t)$, $U_t = f(C_t, Y_t, T_t)$ and $T_t = f(C_t, Y_t, U_t)$ ] and based on the calculated F-statistics[13], we could reject the null hypothesis and confirm the

[12] Similarly, the number of test equations will be equal to the number of variables. However, we just mentioned single equation to conserve the space.

[13] If the calculated F-statistics in column (4) of Table-4 lies above the upper bound *I*(1) value, the decision favors the rejection of null hypothesis and confirms the cointegration relationship. However, the value below the lower bound *I*(0) value and within the upper *I*(1) and lower *I*(0) bound values refers to do not

cointegration between the variables for only first two models [i.e. $C_t = f(Y_t, U_t, T_t)$ and $Y_t = f(C_t, U_t, T_t)$] at 1% and 5% significant level, respectively. In other words, when $CO_2$ emissions and economic growth are taken as dependant variable, all the variables ($CO_2$ emissions, economic growth, urbanization and trade openness) found to have long-run association in case of China. The economic growth, urbanization and trade openness has long-run equilibrium impact on $CO_2$ emissions. The model is adjusted with structural break points and the diagnostic analysis test confirm that the model does not suffer the problems like, heteroskedasticity, serial correlation, normality and omitted variable bias.

Table-4: The Results of ARDL Cointegration Test

| Bounds Testing Approach to Cointegration | | | | | Diagnostic tests | | | |
|---|---|---|---|---|---|---|---|---|
| Estimated Models | Optimal lags | TB1 | TB2 | F-statistics | $\chi^2_{NORMAL}$ | $\chi^2_{ARCH}$ | $\chi^2_{RESET}$ | $\chi^2_{SERIAL}$ |
| Model-1 $C_t = f(Y_t, U_t, T_t)$ | (2,0,0,0) | 1999 | 2003 | 5.606* | 4.243 [0.120] | 1.816 [0.178] | 1.124 [0.289] | 0.210 [0.646] |
| Model-2 $Y_t = f(C_t, U_t, T_t)$ | (1,0,2,1) | 1988 | 2006 | 4.801** | 3.174 [0.192] | 0.018 [0.893] | 1.801 [0.362] | 0.075 [0.784] |
| Model-3 $U_t = f(C_t, Y_t, T_t)$ | (2,0,1,1) | 1982 | 2001 | 1.802 | 2.143 [0.231] | 1.401 [0.152] | 1.119 [0.290] | 2.751 [0.097] |
| Model-4 $T_t = f(C_t, Y_t, U_t)$ | (1,1,0,2) | 1985 | 2004 | 1.541 | 0.410 [0.815] | 0.254 [0.614] | 1.678 [0.324] | 0.002 [0.957] |

reject the null hypothesis (no-cointegration relationship) and inconclusive relationship, respectively. For details refer Pesaran et al. (2001).

| Level of Significance | Critical values (T=42)# | | |
|---|---|---|---|
| | Lower bounds $I(0)$ | Upper bounds $I(1)$ | |
| 1% | 4.13 | 5.00 | |
| 5% | 3.10 | 3.87 | |
| 10% | 2.63 | 3.35 | |
| Note: The asterisks (*) and (**) denote the significant at 1 and 5 per cent levels, respectively. The optimal lag length is determined by AIC. [ ] is the order of diagnostic tests. # Critical values are collected from Pesaran (2001). | | | |

Once the cointegration relationship is established among the underlying variables, the second step is to specify the ARDL model in the short-run dynamics using error-correction-term. The test equation is as follows:

$$\Delta \ln C_t = \beta_0 + \sum_{k=1}^{p} \beta_{1k} \Delta \ln C_{t-k} + \sum_{k=1}^{q} \beta_{2k} \Delta \ln Y_{t-k} + \sum_{k=1}^{r} \beta_{3k} \Delta \ln U_{t-k} + \sum_{k=1}^{s} \beta_{4k} \Delta \ln T_{t-k} + \theta ECT_{t-1} + \mu_t \quad (4)$$

Table-5 shows the results of long-run and short-run elasticity of $CO_2$ emissions with respect to economic growth, urbanization and trade openness. The findings reveal positive and statistically significant relationship between economic growth and $CO_2$ emissions, where 1% increase in GDP increases $CO_2$ emission by 0.19% and 0.43% in long-run and short-run, respectively. However, there is a negative but statistically insignificant relationship between urbanization and $CO_2$ emissions. These results are contradictory to Zhang and Lin (2012) and partially consistent with Dhakal (2009). However, it necessitate to explore the urbanization-emissions nexus at regional and sub-regional levels in case of China because the country has achieved significant progress in emissions abatement and energy savings between 2006 to 2013. Such achievement is associated with Government's strong policy intervention and firm commitment during 11th five year plan[14] (FYP) and its continuation during 12th FYP[15] (OECD, 2013). Trade openness spur $CO_2$ emissions both in long-run and short-run, where 1% increase trade volume adds $CO_2$ emissions by 0.25% and 0.05%, respectively.

Table-5: ARDL Long-run and short-run results

| Long-run Coefficients | | |
|---|---|---|
| Dependent Variable: $\ln C_t$ | | |
| | Coefficients | T-statistics |
| Constant | -5.305** | -2.654 |
| $\ln Y_t$ | 0.196*** | 1.752 |
| $\ln U_t$ | -0.445 | -0.436 |
| $\ln T_t$ | 0.258 | 1.208 |
| Short-run Coefficients | | |
| Dependent Variable: $\ln C_t$ | | |
| | Coefficients | T-statistics |
| Constant | -3.425** | -1.963 |
| $\Delta \ln Y_t$ | 0.043 | 1.539 |
| $\Delta \ln U_t$ | -0.099 | -0.416 |
| $\Delta \ln T_t$ | 0.057 | 1.016 |
| $ecm_{t-1}$ | -0.223** | -2.568 |
| Note: ** & *** show the 5 and 10 percent statistical significance | | |

[14] 11th Five Year Plan (2006-2010)

[15] 12th Five Year Plan (2011-2015)

| |
|---|
| level. |

Although this study has already accommodated two structural breaks in each series, yet to overcome the possibility of more structural unbalances in the series which may limit the ability of results for effective policy control use. Following Brown et al. (1975), this study further tests the structural stability of the model using cumulative sum of recursive residual (CUSUM) and cumulative sum of square of recursive residual ($CUSUM_{SQ}$) tests as shown in Figure-7 and Figure-8, respectively. The blue line within the two straight lines[16] indicates that the model is stable and the results obtained are appropriate for policy use.

Figure-7: CUSUM

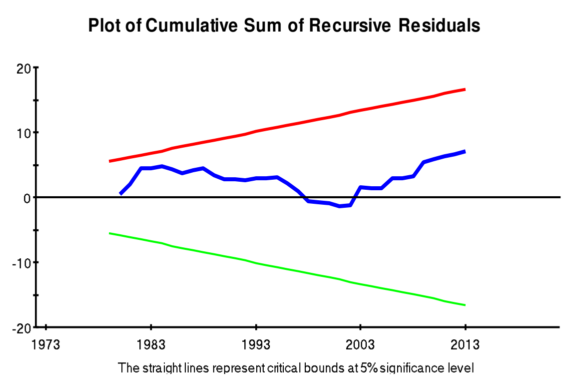
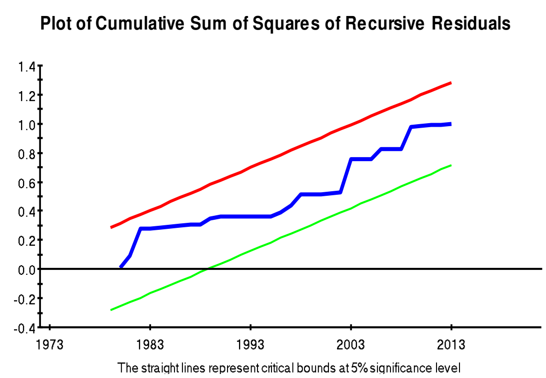



Figure-8: $CUSUM_{SQ}$




The recent applied economics literature using cointegration technique mostly incorporate causality tests to determine the causal link between the variables. Therefore, this study uses Granger causality approach proposed by Granger (1969, 1988) using vector-error correction model (VECM). The results of both short- and long-run causality are reported in Table-6. It is found that in short-run, there is bi-directional causal link between trade openness and urbanization, and uni-directional causality running from GDP to $CO_2$ emissions. economic

[16] The straight lines (i.e. red and green) in figure-7 and Figure-8 represent the upper and lower bound limits, respectively.

growth and trade openness to $CO_2$ emissions. It means trade openness is major contributing factor to urbanization and in return urbanization feedback trade openness. GDP causes $CO_2$ emissions in China. Whereas, in the long-run, there is uni-directional causality running from GDP to $CO_2$ emissions, urbanization and trade openness. These findings are consistent with the findings of ARDL model-2. Similarly, trade openness granger cause $CO_2$ emissions, urbanization and GDP. However, no any evidence is found in case of urbanization-emissions nexus during causality analysis. This further communicates that the urbanization in China has indirect effect on $CO_2$ emissions through trade openness and GDP. The overall findings of causality analysis suggest that in China trade openness and economic growth are the key sources of $CO_2$ emission intensity.

**Table-6. The VECM Granger Causality Analysis**

| Dependent Variable | Direction of Causality | | | | |
|---|---|---|---|---|---|
| | Short Run | | | | Long Run |
| | $\Delta \ln C_{t-1}$ | $\Delta \ln Y_{t-1}$ | $\Delta \ln U_{t-1}$ | $\Delta \ln TO_{t-1}$ | $ECT_{t-1}$ |
| $\Delta \ln C_t$ | …. | 0.3955 [0.6768] | 0.9619 [0.3936] | 0.0030 [0.9970] | -0.0315 [-0.4775] |
| $\Delta \ln Y_t$ | 2.9581** [0.0672] | …. | 0.9304 [0.4055] | 0.7479 [0.4820] | -0.1265* [-2.7531] |
| $\Delta \ln U_t$ | 0.0166 [0.9835] | 3.3678 [0.6953] | …. | 4.9977** [0.0134] | -0.0169 [-0.6924] |
| $\Delta \ln T_t$ | 2.0560 [0.1456] | 0.4323 [0.6529] | 3.3862** [0.0472] | …. | -0.4011*** [-0.0925] |

Note: *, ** and *** show significance at 1, 5 and 10 per cent levels respectively.

## 4. Policy rationale

The empirical findings obtained in the previous section possess deep environmental and sustainable development policy implications for China in particular and emerging countries in general. The causality analysis reveals that urbanization Granger cause trade openness and trade openness Granger cause both economic growth and $CO_2$ emissions. It means the urbanization has indirect effect on $CO_2$ emissions through trade openness. It further implies that the rural to urban migration in China is driven by exports related manufacturing industries. The trade openness also granger cause economic growth. This means astringent environmental policies on manufacturing sector or any trade restrictive measures lead to economic slowdown.

While looking at the short- and long-run dynamics results, the environmental degradation (in terms of elasticity) has increasing effect for economic growth and trade openness. The current state of environmental and sustainable development goals may reduce carbon emissions in the short-run, but the effect increases in the long-run path. However, urbanization helps to reduce carbon intensity from short-run to long-run transition. This means urbanization supports sustainable development goals in China. Moreover, the energy reduction and trade restriction policies impede economic growth and as well as the speed of urbanization in China.

## 5.Conclusion

There is an extensive literature exploring the energy-urbanization and emissions-energy nexus separately. However, very little is investigated on the direct relationship between urbanization and carbon emissions. In addition, the most of the recent literature lack theoretical base and findings seem to perceive only energy security agenda instead of environmental security. Therefore, based on social environmental system of urban transition theory, this study attempts to investigate the dynamic relationship between $CO_2$ emissions, urbanization, trade and economic growth in case of China.

After adjusting the two structural break points in the series, the bounds test approach to cointegration confirms the cointegration relationship between $CO_2$ emissions, urbanization, trade and economic growth. While assessing the long- and short-run dynamics, trade openness and economic growth spur environmental degradation in the country. Furthermore, the detrimental effect is increases from short-run to long-run transition. However, urbanization reduces $CO_2$ emission both in long- and short-run with statistical insignificance and requires further investigation and regional and sub-regional level data. The VECM Granger causality results are consistent with the findings of cointegration. The causality analysis reports bi-directional causal link between trade openness and urbanization in the short-run. However, in the long-run, economic growth ranger cause carbon dioxide emissions, urbanization and trade openness. Similarly, trade openness granger cause carbon dioxide emissions, economic growth and urbanization in the long-run.

In the light of our empirical results, urbanization in China follows ecological modernization theory, where environmental equilibrium is restored during economic development transitions. The efforts taken during last decade have shown significant improvement in environmental conditions of rapidly urbanizing China. Furthermore, the findings suggest that Chinese economy still rely on export led growth policy, where trade restrictive and astringent environmental policies hider economic the GDP growth. The suitable environmental policy for energy intensive, yet growth supportive industries would be the adoption of efficient technologies along with increasing proportion of renewable energy sources in total energy resource in order to meet their future demands.

Furthermore, the findings put strong case for investment in alternate energy technologies and to increase the share of trade in services.

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