ResearchLEAP
Journal of International Business Research and Marketing
Volume 1, Issue 5, July, 2016
journal homepage: www.researchleap.com

The Relationship between Economic Growth and Municipal Solid Waste & Testing the EKC Hypothesis: Analysis for Saudi Arabia

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ABSTRACT

This paper empirically investigates two main points: application of the VECM test to examine the relationship between economic growth and municipal solid waste (MSW) generation using municipal services, GDP and population growth; and the application of the OLS regression to validate the Environmental Kuznets Curve (EKC) hypothesis for MSW over the period of 1980-2012 in Saudi Arabia. The results show that there is a long-standing relationship between the variables under examination, and that the EKC hypothesis is not valid for MSW in Saudi Arabia. Even though there is an inverted U-shaped because the turning point is very high compared with GDP in that period. Saudi Arabia needs to implement new policies and adopt new technologies that help to reduce MSW generation in order to achieve sustainable development in future.

DOI: *10.18775/jibrm.1849-8558.2015.15.3003*
URL: *http://dx.doi.org/10.18775/jibrm.1849-8558.2015.15.3003*

Keywords:
VECM
Environmental Kuznets Curve
OLS regression
Economic growth
MSW

1. Introduction

Municipal solid waste (MSW) is a significant environmental problem and a major source of environmental pollution, contributing to the pollution of soil, water, and air, and impacting human health. According to Basel Convention (2011),awaste defines as "materials or objects which are disposed of or are intended to be disposed of or required to be disposed of". Waste management has become a global issue, ass waste impacts on the environment: therefore, new technology is needed to exploit this solid waste as a resource (Rozenberg, 2013, p. 1). According to the DG Environment News Alert Service (2010), the amount of solid waste has a positive and causal relationship with Gross Domestic Product (GDP). For instance, municipal waste increased by 54% per person between 1980 and 2005 in the 15 countries of the EU along with GDP. Moreover, Sjöström & Östblom (2010) state that the quantity of municipal waste rose by 35% per person in the OECD countries and 29% in North America.

Over the past two decades, many researchers have been applied the EKC to examine the relationship between economic growth and environmental pollution for many of countries and through used several pollutants, which display in the part of literature review in this study. The remainder of this study is organized as follows: the paper begins with a brief background of the EKC hypothesis, followed by a summary review of the literature (section 3). Section 4 details the methodology and results for both models, and section 5 draws conclusions on the basis of these findings and the context to which they apply.

2. Background of EKC

The Environmental Kuznets Curve (EKC) is named after Kuznets (1955). Panayotou (2003) stated that the general idea of the EKC is to explain the inverted U-shaped relationship between economic growth and environmental pollution in low-income level environmental degradation increase, but at high GDP per capita levels, economic growth will improvement of environmental quality (See Figure 1).

Dinda (2004) summarised this, writing: “as the income of an economy grows over time, emission level grow first, reach a peak and then start declining after a threshold level of income has been crossed”. The ‘peak’ or ‘turning point’ (TP) comes when income begins relating to an improvement in environmental quality (at $x^* = (-\beta_1/2\beta_2)$).

3. Literature review

Literature review in this paper is divided into three themes:

3.1 Theoretical and empirical studies

Romer (2012) investigated several growth models and addressed the issue of how economic growth may be limited by environmental problems, stating that pollution created by production is likely to reduce output due to its impact on the process of global warming.

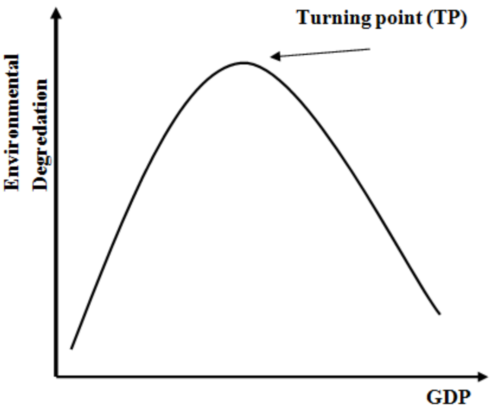

Figure 1: The environmental Kuznets curve (EKC)

In contrast, Hee (2008) argued that economic growth does not mean more waste is generated, through strategies adopted to address sustainable solid waste management. Writing about the reasons for waste generation, Visvanathan and Tränkler (2003) stated that rapid economic growth created serious problems, and Khatib (2011) maintained that growth in urbanization coupled with population growth and increased GDP per capita generated municipal solid waste.

On the other hand, there are studies that discuss the decoupling of economic growth and environmental pollution. Mazzanti, Montini and Zoboli (2008) examined the relationship between income and municipal waste generation for 103 Italian regions using the EKC hypothesis, with the results providing evidence in favor of the EKC. Everett et al. (2010) also explored the complicated relationship between the environment and economic growth using the EKC, and observed a turning point whereby a rise in GDP per capita led to diminutions in emissions of air pollution. A theoretical study by He (2007), validating the EKC for developing countries, found that none of them followed the EKC hypothesis.

Vassilis et al. (2014) focused on breaking the link between economic growth and environmental harms, and found that delinking occurs: on average, decoupling was found in all countries in the study. Khajuria et al. (2012) investigated decoupling municipal waste solid generation from economic growth in India based on the concept of the EKC, and found signs of delinking between MSW generation and economic growth. In contrast, Yang and Yuan (2012) investigated the relationship between economic growth and environmental pollution in Zhejiang's industrialization, finding no long-term relationship between GDP per capita and pollution indices.

3.2 Externalities

There are environmental impacts associated with municipal solid waste management, such as greenhouse gas (GHG) emissions and human health problems. In terms of health problems, Khatib (2011) described how the Millennium Development Goals (MDG) and the World Health Organization report on World Health (WHO, 2010) estimated that in 2008 over 2.5 billion people were not using proper sanitation facilities, resulting in a high level of environmental contamination and exposure to risk of microbial infection. Rozenberg (2013) stated that garbage disposal and health concerns are currently urgent, particularly in developing countries. A study conducted by the waste economics team of the UK's Environment and Growth Economics (2011) identified that waste is part of economic activity, and waste treatment affects the environment by producing greenhouse gas emissions.

3.3 Studies on Saudi Arabia

According to Zafer (2003), with a population of 29 million, Saudi Arabia generates more than 15 million tons of solid waste per year, at a rate of 1.5 to 1.8 kg per person per day. Along with the lack of waste disposal facilities and the absence of tipping fees in Saudi's waste management system, recycling is driven by an informal sector. A descriptive study addressing this volume of waste in Arab countries, including Saudi Arabia, found that Arab countries face challenges brought on by several factors, such as the absence of information and data for waste, limited technical infrastructure and low public awareness (Abou-Elseoud, 2008, pp. 112-125). Virotec Global Solutions published a case study on Jeddah, the second largest city in Saudi Arabia, which suffers environmental problems. The findings were that treatment with ViroFlow Technology was effective in demolishing unpleasant odour, pathogens, neutralising acid and binding heavy metals and that hazardous solid waste can be used in agriculture (Virotec, 2011, pp. 4-11). Husain and Khalili (2013) concluded that waste management is one of the region's major environmental problems, with millions of tons of waste every year caused by residential, commercial and industrial sectors with little concentration on recycling and reduction.

Based on our knowledge, there are currently no empirical studies examining both the long-term relationship between economic growth and municipal solid waste (MSW) in Saudi Arabia and the EKC hypothesis for MSW. Therefore, this paper contributes to the existing literature and helps fill the gap on this issue.

4. Empirical methodology

There are two models: The first model in this study is to examine the long-run relationship between economic growth and environmental pollution (MSW represents the environmental pollution). The empirical methodology for the first model begins with unit root tests to determine the degree of integration of series to avoid spurious regression. The next step is the Johansen and Juselius procedure (1990) for testing co-integration among variables, then the Vector Error Correction Model (VECM) approach. For the second model, the empirical methodology to test the EKC hypothesis is run OLS regression.

4.1 Hypothesis

This paper proposes two hypotheses:

1- High rates of economic growth lead to an increase in MSW generation in Saudi Arabia.

2- The EKC hypothesis is valid for MSW in Saudi Arabia.

4.2 Data

Table 1 presents the data used in this study and the data sources cover the period of 1981-2012.

Table 1: Description of variables

Variable	Description of explanatory variables	Source	Expected Signs
MS	Municipal services	SAMA database	
GDP	GDP per capita	The World Bank database	+
POP	Population growth	The World Bank database	+

4.3 Models and Econometric Results

This paper tests two models for Saudi Arabia, covering the period 1981- 2012.

4.3.1 First model

The functional form of the first equation is

$$MS_t = \alpha + \beta_1 GDP_t + \beta_2 POP_t + \varepsilon_t$$

Where: MS is municipal wastes services (dependent variable) measured in billions of Riyals, GDP is Gross Domestic Product measured in billions of Riyals (independent variable) and POP is the population growth (independent variable).

Process with the logarithmic version of the variables, the equation employed becomes:

$$lnMS_t = \alpha + \beta_1 lnGDP_t + \beta_2 POP_t + \varepsilon_t$$

L is the natural logarithm, α is the intercept, β_1 and β_2, are elasticity coefficients, ε is error term and t is time.

- **Unit Root Tests**

Before examining the problem of non-stationary data, the number of lags must be determined to eliminate residual autocorrelation. Thus, based on lag criteria, appropriate lag is 2 lags. Table 2-A and 2-B shows that both unit root tests (Augmented Dickey - Fuller (ADF) and Philips - Perron (PP)) gave the same answer, which is a rejection of the null hypothesis at a 5% significance level for all variables: the data is stationary at I (1).

Table 2-A: Unit Root Tests

Augmented Dickey-Fuller Unit Root Test			
Variable	First differences None	First differences C	First differences C+T
LMS	-3.51*(0)	-3.44* (0)	-5.06* (1)
LGDP	-3.45* (0)	-3.95* (0)	-4.84*(0)
POP	-4.60*(1)	-4.81*(1)	-4.97*(1)
Critical Value			
5%	-1.95	-2.96	-3.56

Table 2-B: Unit Root Tests

Phillips-Perron (PP) Unit Root Test			
Variable	First differences None	First differences C	First differences C+T
LMS	-3.51*(0)	-3.44*(0)	-9.89*(29)
LGDP	-3.43*(3)	-3.88*(2)	-4.84*(0)
POP	-2.12*(2)	-2.22 (2)	-2.33 (2)
Critical Value			
5%	-1.95	-2.96	-3.56

Note: * denotes rejection at 5%. C: represents test with constant, C+T: represents test with constant and trend. LMS is municipal services, LGDP is GDP and POP is population growth. The (ADF) test number in brackets is lag lengths, selected based on the SBC. The (PP) test number in brackets is bandwidth (west automatic using Bartlett kernel).

- **The Johansen Procedure**

Table 3 reports the Johansen co-integration test results for both J_{trace} and J_{max} with three lags, selected as the optimal lag length based on AIC, one of the lag order selection criteria. The Johansen results indicate those variables are co-integrated in the long-run. Both suggest at least one co-integration vector among the series.

Table 3: Johansen Co-integration Tests results

H_0	H_1	λ_{trace} statistic	5% Critical Value	Prob.
r =0*	**r> 1**	42.73	29.79	0.0010
r ≤ 1	**r> 2**	6.30	15.49	0.6596
r ≤ 2	**r> 3**	0.51	3.84	0.4736
H_0	**H_1**	**λ_{Max} statistic**	**5% Critical Value**	**Prob.**
r =0*	**r= 1**	36.43	21.13	0.0002
r =1	**r= 2**	5.79	14.26	0.6402
r =2	**r= 3**	0.51	3.84	0.4736

*indicates that the null hypothesis is rejected at 5% significance level.

- **Vector Error Correction Model (VECM)**

Table 4 presents VECM results, so the co-integrating equation defined as follows:

$$LMS = - 15.06 + 1.76\ LGDP + 0.11\ POP$$

These signs are as expected: with a 1% increase in GDP, municipal service rises by 1.76% and this estimate was significant at 5%. When population growth increases by 1%, it is likely to raise municipal waste by 0.11%, and this estimate was statistically significant. The error correction term (ECT) has a negative direction, meaning when municipal services deviate from equilibrium, the error correction term has an opposite adjustment effect, and the deviation degree is reduced. In other words, the above equation is satisfactory in terms of correct signs, meaning municipal services have a relationship with economic growth variables in the long-run. Also, VECM results for the short-run show that there is short-run causality running from GDP and population growth to municipal services.

Table 4: VECM Estimation of Variable Long-Run Coefficients

Dependent Variable LMS			
Variables	Coefficient	Standard Error	t-statistic
LGDP (-1)	1.76	0.15	11.71
POP (-1)	0.11	0.05	2.14
ECT	-0.31	0.05	-5.49
C	-15.06		
R^2	0.86		

LMS is the log of municipal services, LGDP is the log of GDP, POP is population growth, and C is the constant.

From diagnostic tests of the model, it can be concluded that the VECM model used passed the required diagnostic tests.

- **Granger Causality Tests**

Identifying the direction of causality between variables under consideration is the essential advantage of Granger causality tests. Table 5 (below) reports the results of the Granger causality test and measures causality between variables. The chi-square and probability (p-value) were used, finding unidirectional causality between GDP and municipal services and between population growth and municipal services in Saudi Arabia. In other words, GDP causes a change in MS but not vice versa, which means municipal services cannot cause GDP. Similarity, population growth causes MS, meaning municipal waste is affected by population growth, but MS cannot cause population growth. These results are consistent with the hypothesis (1): economic growth increases municipal waste generation.

Table 5: Granger Causality Tests

Null Hypothesis	Chi-sq	Prob.	Decision
LGDP does not cause LMS	**8.30**	**0.0402***	**Reject H_0**
LMS does not cause LGDP	**1.11**	**0.7740**	**Do not reject H_0**
LMS does not cause POP	**0.43**	**0.9326**	**Do not reject H_0**
POP does not cause LMS	**13.99**	**0.0029***	**Reject H_0**

*denotes does not reject the null hypothesis at 5% level of significance.

Thus, we can be fairly confident that the relationships estimated in the VECM are robust in terms of the hypothesis (1), and can conclude that the main results are in the line with most previous studies. Since the findings indicated a relationship between economic growth and municipal waste generation, the nature of this relationship was tested using the EKC hypothesis.

4.3.2 Second model

The functional form of the second model is

$$M_{st} = f\,(GDP_{t,}\,(GDP_t)^2)$$

Where: MS is municipal services (dependent variable) measured in billions of Riyals, GDP is gross domestic product measured in billions of Riyals (independent variable), GDP^2 is GDP squared (independent variable) and t is time.

The logarithmic transformation is deflated for data without much change of the characteristics of time series, following standard time series practice. Processed with the logarithmic version of the variables, the equation employed becomes:

$$lnMS_t = \alpha + \beta_1\ lnGDP_t + \beta_2\ (ln(GDP_t))^2 + \varepsilon_t$$

According to the EKC hypothesis the coefficients of GDP and $(GDP)^2$ must be $\beta_1>0$, $\beta_2 <0$ to achieve an inverted U-shaped.

The second model results

- **Ordinary Least Squares (OLS)**

The OLS results are reported in Table 6 (below). The equation representing the long-run relationship between variables is implicitly defined as follows:

$LMS_t = 0.71\ LGDP_t – 0.004\ L(GDP_t)^2 + 0.86\ AR(1) + \varepsilon_t$

The model showed evidence of autocorrelation, which has been removed by adding an autoregressive term (AR) within the model. A 1% increase in GDP will increase municipal waste by 0.71%, statistically significant, meaning, in the long-run, an increase in economic growth in Saudi Arabia will lead to increased municipal solid waste. The results also show the negative relationship between GDP squared and municipal waste, meaning with higher economic growth, municipal waste levels fall. The model passes all diagnostic tests.

With regard to the EKC, an inverted U-shaped occurs when $\beta_1$and β_2 are positive and negative respectively. Therefore, there is an reversed U-shaped in this model according to regression results: β_1 is equal to (+0.71) and β_2 is equal to (-0.004).

Table 6: OLS Estimation of Variable Long-Run Coefficients

Dependent Variable LMS			
Variables	Coefficient	Standard Error	t-statistic
LGDP	0.71*	0.22	3.23
$L(GDP)^2$	-0.004	0.01	-0.22
AR(1)	0.86*	0.07	12.74
R^2	0.91		

*denote significant at 5% level. LMS is log of municipal services, LGDP is log of GDP and $L(GDP)^2$ is log of GDP squared.

- **The EKC turning point (TP) for the MSW model**

Before calculating the turning point, an inverted U-shaped must be identified in the model, meaning the turning point is based on GDP and GDP squared coefficients signs. The steps of how to decide if the model follows the EKC hypothesis or not are as follows: TP= $(-\beta_1/2\beta_2)$. We can calculate the turning point (TP) for the municipal waste (MS) model:

$$LMS_t = 0.71\ LGDP_t – 0.004\ LGDP_t^2 :$$

the threshold income is 101.19 (in logarithm) and when converted to Riyals it is very high compared with GDP in that period. As a result, this model does not follow the EKC hypothesis, which is consistent with Saudi Arabia's position as a developing country. According to the 2030 vision of Saudi Arabia which approved by the Council of Ministers in April 2016, the government is now beginning to pay attention to disposal of municipal solid waste (see The Council of Economic and Development Affairs, 2016), so the turning point of the EKC may appear in the near future.

5. Conclusion

The purpose of this study is to examine two models: the first tests whether the municipal solid waste is influenced by economic activity or not, and the second to examine the validation of the Environmental Kuznets Curve (EKC) hypothesis about the relationship between economic growth and MSW in Saudi Arabia. A brief background was provided at the beginning of this paper about previous studies that investigated or discussed the relationship between economic growth and municipal waste generation, which were classified into three parts.

The findings of this study are as follows: after (ADF) and (PP) unit root tests are applied, the variables under consideration are separately integrated at first differences I (1). The Johansen co-integration test shows that the variables are co-integrated with r = 1. Thus, we applied the VECM to test the study's first hypothesis, and the result shows a long-run relationship between series, supporting this hypothesis. The EKC hypothesis validation is present in the second model in terms of an inverted U-shaped, but the TP is not valid.

In general, the results support the contention that economic growth increases municipal waste generation, but there is a turning point. Thus, Saudi Arabia needs to implement new policies and adopt new technologies that help reduce MSW generation in order to achieve sustainable development.

Acknowledgements

I wish to thank King Saud University for the opportunity to carry out this study and am particularly grateful to Dr. Dimitrious Vougas for his comments and suggestions.

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