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Determination of transport CO_2 emission using the General Method of Moments: Empirical evidence from 16 countries

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ABSTRACT

This study investigated the influence of economic growth, trade openness, and urbanization on transport CO_2 emission by using the General Method of Moments in 16 industrialized countries from 2000 to 2008. From the results of this study, trade openness has a negative impact on transport CO_2 emission and is not consistent with current theories. While economic growth was found to have a positive impact on transport CO_2 emission, urbanization has a negative one. The result of economic growth and urbanization is consistent with the theories and also many studies. Lastly, taxes and fees, eco-driving, and environmental zone policies are recommended in order to lower transport CO_2 emission in these 16 countries.

1. Introduction

Climate change is one of the most important problems facing the world today, and every country is attempting to solve it. In 2010, global CO_2 emission increased by more than 5%, due to the continued growth of developing countries and economic recovery within the industrialized world. A report on the long-term trend in global CO_2 emission (2011), states that nuclear and renewable energy, and more efficient energy end-use, cannot cope with increasing demand for power and transport.

In order to have a clear picture, let us look at global CO_2 emission by sector. According to a report on CO_2 emissions from fuel combustion (2011), the electricity and heat sector took the highest share in 2009, followed by the transport sector with 23%. The segment with the smallest share was the residential sector. Furthermore, Khan et al. (2007) mentioned that world transport energy use is set to increase by 2% per year, to become 80% higher than the current level in 2030. Undoubtedly, future CO_2 emission will increase dramatically in the transport sector.

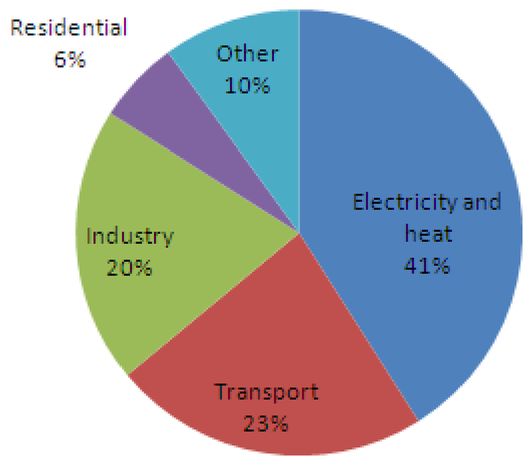

Figure 1. World CO_2 emission by sector in 2009.
Source: CO_2 emissions from fuel combustion (2011)

A combination of the two sectors that control transport, and electricity, heat and power, account for more than two-thirds of worldwide CO_2 emission, and they continue to play an important role in CO_2 release from fuel combustion. It can be seen from Table 1 that the transport sector share is approximately 23% of total CO_2 emission, of which around 73% is fuel combustion from on-road transportation. CO_2 emission from the transport sector is, more or less, represented in the broadest sense by on-road data. Furthermore, the study of on-road transport and CO_2 emission is very important, as Unger (2010) states that on-road transport is a clear contributor to current climate change.

2. Literature review

This review is categorized into two groups in order to develop a clear picture. The first part briefly reviews overall economic growth and environmental problems. The last part focuses mainly on the transport sector.

Let us begin with the theoretical relationship between economic growth and environmental pollution, which is explained in the Environmental Kuznets Curve (EKC) hypothesis. As mentioned by Kaika and Zervas (2011), the EKC hypothesis states that economic growth can lead to environmental degradation during early economic development and through transformation from agricultural to industrial intensity. Then, degradation would diminish at a later stage of economic development. Therefore, the relationship between economic growth and environmental degradation is formed as an inverted U curve.

Overall economic growth and environmental problems have been studied widely in numerous researches, with varied techniques carried out to look at these issues. Sharma (2011) summarized and categorized these researches in the following three strands: economic growth-environment pollution nexus, economic growth-energy consumption nexus, and a combination of the first two nexuses.

The economic growth-environmental pollution nexus tests validity of the EKC hypothesis. Most empirical results [Cropper and Griffiths (1994), Seldon and Song (1994), Grossman and Kruger (1995), Meers (2000), Wang (2012), Stern (2004), Azomahou et al. (2006), Dinda and Coocoon (2002, 2006), and Sanglimsuwan (2011)] support the EKC hypothesis, but Shafik (1994), Holtz-Eakin and Seldon (1995), Akbostanci et al. (2009), and Lee and Lee (2009) show the monotonic income-CO_2 emission relationship. The methodology ranges from standard regression to Granger Causality.

The economic growth-energy consumption nexus tests whether economic growth is related closely to energy consumption. All of the studies employed the Granger causality method, which shows that most of them are based on individual or multi-countries [Masih and Masih (1996), Stern (2000), Yang (2000), Wolde-Rufael (2004), Lee and Chang (2005), Wolde-Rufael (2010), Hooi and Smith (2010), Narayan and Narayan (2010a), and Narayan and Narayan (2010b)], with a long-term relationship between economic growth and energy consumption in one or two ways. However, Abosedra (2009), and Ozturk and Acaravci (2010) show no unique long-term relationship.

The last nexus tests a combination of the previous two or the relationship between economic growth, energy consumption, and pollution emission in a multivariate framework. From the individual or multi-country Granger causality study, Ang (2007), Soytas et al. (2007), Soytas and Sari (2009), Zhang and Cheng (2009), Halicioglu (2009), and Hooi and Smith (2010) show a long-term relationship in either one or two ways.

The study based on transport CO_2 emission can be categorized into two strands: validity of the EKC hypothesis in the transport sector and decomposition of the transport CO_2 emission growth. The first strand is the same as the economic growth-environmental pollution nexus. Ubaidillah (2011) tested the relationship between income and environment (CO emission) in the UK road transport sector from 1970 to 2008 by using the co-integration technique. The result showed a long-term relationship between income and CO_2 emission from road transport in the UK. In other words, the result supported the EKC hypothesis.

TABLE 1. CO_2 emission from the transport sector between 2000 and 2008

Transport and the Economy	2000	2001	2002	2003	2004	2005	2006	2007	2008	1990-2008 (% growth of 2008 from 2000)
CO_2 from fuel combustion (Mt)*	23496.55	23674.57	24069.94	25110.50	26357.32	27129.14	28023.96	28945.33	29381.43	40.15%
Transport CO_2 (Mt)*	5659.04	5684.06	5797.84	5922.84	6172.89	6285.03	6434.74	6614.87	6604.66	44.09%
Transport* as a percentage of total	0.24	0.24	0.24	0.24	0.23	0.23	0.23	0.23	0.22	
- Road (Mt)	4143.25	4208.74	4305.86	4402.69	4553.77	4614.72	4708.40	4824.29	4848.42	47.52%
- Rail (Mt)	117.27	114.25	116.91	123.07	115.04	123.38	128.60	130.61	107.65	-26.60%
- Domestic Aviation (Mt)	320.27	309.69	292.69	291.30	306.67	310.95	304.75	310.85	297.34	5.89%
- International Aviation (Mt)	354.42	347.13	365.61	366.79	393.40	421.57	436.25	446.59	454.85	76.15%
- Domestic Navigation (Mt)	107.49	108.75	107.46	116.69	112.77	118.84	122.58	126.36	128.39	31.44%
- International Shipping (Mt)	468.61	446.70	462.25	470.45	523.39	522.28	556.62	589.09	578.20	62.98%
- Other Transport (Mt)	147.73	148.82	147.06	151.86	167.83	173.29	177.53	187.08	189.81	19.54%

Source: Data from the International Transport Forum: ITF

The decomposition strand is aimed to analyze the potential factors that influence the growth of transport CO_2 emission. Timilsina and Shresta (2008) studied the underlying factors that determine this growth in 20 Latin American and Caribbean countries. The study employed the Logarithmic Mean Divisia Index (LMDI) approach to provide residual-free decomposition and determine potential factors such as fuel switching, modal shifting from less to more intensive emission modes, changes in sectoral energy intensity and economic growth. The result showed that sectoral energy intensity and economic growth are the only driving forces. Timilsina and Shresta (2009) repeated the same type of research to investigate the potential factors that influence transport CO_2 emission in 12 Asian countries from 1980 to 2004 by looking at previous potential factors and also possible factor-population growth and urbanization. This study found that changes in GDP per capita, transport energy intensity and population growth are the main factors that influence increasing transport CO_2 emission.

Therefore, this study examined the influence of economic growth, trade openness and urbanization on transport CO_2 emission in 16 countries.

3. Data and descriptive statistics

This study employed the panel data of transport CO2 emission (metric tons per capita), trade openness (trade as % of GDP), economic growth (GDP per capita in 2000 constant US$) and urbanization (urban population as % of total) from 2000 to 2008. The data were a balanced panel that covered the 16 countries: Austria, Belgium, Denmark, Finland, France, Greece, Hungary, Israel, Japan, South Korea, Netherlands, Poland, Switzerland, Turkey, United Kingdom (UK) and United States of America (USA). The data for transport CO_2 emission were downloaded from the International Transport Forum (IFS). Trade, GDP per capita and urban population figures were downloaded in the same way from the World Bank's World Development Indicators (WDI), and all data in this study are in log form.

TABLE 2. Descriptive statistics for all variables employed in this study

Statistics	Transport CO_2 emission (Mt per capita)	Trade (% of GDP)	GDP per capita (constant 2005 US$)	Urban population
Mean	185.9365	80.66393	27618.59	75.22083
Median	39.55500	76.58405	29997.51	74.64000
Maximum	1954.890	170.5263	43710.28	97.36000
Minimum	9.470000	20.48539	9136.024	59.70000
Std. Dev.	447.3138	37.59868	8501.588	11.39062

The USA was found to have the highest transport CO_2 emission, and Hungary the lowest. Regarding trade openness, Belgium showed the most openness, while Japan the least. Not surprisingly, the USA had the highest GDP, and Greece the lowest. Lastly, Belgium had the highest share of urban population and Greece the lowest.

4. Empirical model and conceptual framework

4.1 Empirical model

The proposed empirical model is based partly on ideas from Timilsina and Shresta (2008, 2009) and Sharma (2011). The model is in the form of

$$TCO_2 = f\left(T, GDP, Ur\right) \quad (1)$$

Equation (1) shows that potentially, transport CO_2 emission (TCO_2) is determined by trade (T) (trade openness), Gross Domestic Production (GDP) (economic growth) and the share of urban population (Ur) (urbanization), which form a plausible relationship in order to estimate the above equation, as follows:

$$TCO_{2i,t} = \beta_0 + \beta_1 GDP_{i,t} + \beta_2 T_{i,t} + \beta_3 Ur_{i,t} + \varepsilon_{i,t} \quad (2)$$

where *i* represents country (16 countries) and *t* time (2000-2008).

4.2 Conceptual framework

As mentioned earlier, the share of transport CO_2 emission is approximately 23% of global CO_2 emission and rising in the future. According to Finel and Tapio (2012), transport and economy have been connected to one another for many decades. Furthermore, as mentioned by Bialas-Motyl (2008), a flourishing economy leads to higher demand for transport and consequently higher transport CO_2 emission. In other words, increased economic activities require higher energy consumption in the transport sector, which results in a greater amount of CO_2 emission. Consequently, a positive relationship between transport CO_2 emission and economic growth is expected, as such a relationship between overall CO_2 emission and economic growth has been confirmed by many authors, as mentioned above.

Trade can occur from movement of goods from one place to another, as mentioned in Sharma (2011). Furthermore, Halicioglu (2009) also found a positive relationship between carbon emission and foreign trade. Trade can lead to more carbon emission in two ways. Firstly, trade openness can lead to increased goods processing and manufacturing. Secondly, it also can lead to higher transportation activities. In addition, as mentioned by Kahn et al. (2007), the availability of transport stimulates economic development by allowing trade and economic specialization. Therefore, a positive relationship between trade openness and transport CO_2 emission is expected.

Urbanization is another factor that determines transport CO_2 emission. According to Martinez-Zarzoso (2008), urbanization demonstrates a different impact on a varied group of countries. Elasticity of emission-urbanization is positive in countries with low and lower-middle income, and negative in those with upper-middle and high income. Martinez-Zarzoso (2008) mentioned further that emission has grown faster than population, and this situation appears more in developing rather than developed countries. This happens when urbanization reaches a certain level in developed countries, which then reduce CO_2 emission through concern of the people, experts and policymakers. In the case of transport CO_2 emission, urbanization definitely seems to have negative impact on this group of countries.

5. Econometric methodology

The specification of the proposed model is the dynamic panel, as in Sharma (2011), which shows that the lagged level of transport CO_2 emission also is taken into account. Therefore, the proposed model is in the following form:

$$TCO_{2i,t} = a_0 TCO_{2i,t-1} + a_1 X_{i,t} + \mu_{i,t} + \varepsilon_{i,t} \tag{3}$$

where TCO_2 is the transport CO_2 emission of country i at time t; a_0 is the parameter to be estimated, X is the vector of core explanatory variables - trade *(T)*, Gross Domestic Production *(GDP)* and urbanization *(Ur)*; μ is country specific effects; ε is the error term; and all variables are in log form.

There seems to be problems in using panel ordinary least squares (OLS), with fixed and random effects, to estimate the above equation. For example, the term, lagged transport CO_2 emission gives rise to an autocorrelation problem. To solve it, Arellano and Bond (1991) used the general method of moments (GMM) approach to estimate the above equation by firstly differentiating the model. Consequently, the fixed country-specific effects are removed: $E\left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right) = 0$. However, $\left(TCO_{2i,t} - TCO_{2i,t-1}\right)$ still depended on $\left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)$. Therefore, a few more lags of the first-differentiated lagged dependent variable are instrumental in solving the problem.

6. Empirical results

The study starts by performing a panel unit root test. LLC, Fisher-PP and Fisher-ADF tests were conducted to find the level of all variables in order to check whether the variables in both panels are stationary or non-stationary. If all the variables are stationary at their level, they would enter the model in their level form. The result in Table 3 shows that all variables are overwhelmingly stationary at their level and consequently, enter the model directly.

TABLE 3. Unit root test based on the level of all variables

Test	LnTCO$_2$	LnGDP	LnT	LnUr
LLC	-2.51334***	-6.60218***	-10.6136***	-1.86222**
	(0.00)	(0.00)	(0.00)	(0.03)
Fisher-PP	51.0111**	43.9097*	57.2898***	56.0285***
	(0.02)	(0.00)	(0.00)	(0.00)
Fisher-ADF	49.1360**	26.5086	46.1257**	519531***
	(0.03)	(0.7407)	(0.05)	(0.01)

*** Statistical significance at the 1% level
** Statistical significance at the 5% level
* Statistical significance at the 10% level
(.) shows the probability values

Since all variables are stationary at their levels, the Arellano and Bond (1991) GMM estimator can be carried out to determine transport CO_2 emission. The results reported in Table 4, show all variables which are statistically significant at 1%, except for urbanization at 10%. Therefore, it can be proclaimed that economic growth has a positive impact on transport CO_2 emission, but trade openness and urbanization have a negative one. This result is consistent with many other studies, which state that the more the economy expands the more pollution occurs. For example, Sundar and Dhingra (2008) mentioned that transport activity grows continuously as economies develop, and the consequent increase in transport activity, together with more fossil fuel consumption, leads to pollution.

However, from the trade theory, trade is supposed to have a positive effect on transport CO_2 emission, but estimations show a negative impact. This result is the same as that in Sharma (2011), but it is not consistent with the Hecksher-Ohlin trade theory, because that states trade can create higher production of goods and services, which finally leads to higher consumption. This result may state an important policy implication. When countries are more developed, as they are in this study, trade contributes less damage to the environment.

Urbanization or urban population has a negative impact on transport CO_2 emission. This result is the same as that in Martinez-Zarzoso (2008), which states that urbanization in upper-middle and high income countries has a negative impact on transport CO_2 emission. As mentioned by Kahn et al. (2007), this may arise from the fact that around 75% of people in industrialized countries live in an urban area. Additionally, Kenworthy and Laube (1999) stated that urbanization is associated with a lower level of car ownership or private car use and higher level of mass transit utilization. Consequently, it could be said that higher urbanization leads to higher use of public transport, which results in lower transport CO_2 emission.

Furthermore, as mentioned earlier, when urbanization reaches a certain level, its population, experts and policymakers become increasingly concerned with environmental sustainability. For instance, an entry toll and high parking fees have been introduced in London, England, in order to cut down traffic congestion. Cullinane (2002), Willoughby (2001), Cameron et al. (2004) and Sperling and Salon (2002) stated that strong governments can pursue strategies actively and effectively in order to slow motorization by providing high quality public transport and coordinating land use and transport planning. Abbott (2001) and Lundqvist (2003) showed examples of successful land use and transport systems in the USA and Stockholm, Sweden. Mixed-use and compact land development together with better public transport can lead to low auto dependence. With supporting statements such as those mentioned above, it is not surprising that transport CO_2 emission actually contributes to the reduction of environmental damage.

TABLE 4. Results from the Arellano and Bond (1991) GMM estimator

Variables	Estimated coefficients
Dependent variable: transport CO_2 emission	
Lagged transport CO_2 emission (TCO_2)	.3825*** (0.002)
Gross Domestic Production (GDP)	1.2651*** (0.000)
Trade (T)	-.4032*** (0.000)
Urbanization (Ur)	-2.1983** (0.050)

*** Statistical significance at the 1% level
** Statistical significance at the 5 % level
* Statistical significance at the 10% level
(.) shows the probability values

7. Conclusion and policy recommendations

This paper tries to determine potential factors that apply to transport CO_2 emission such as economic growth, trade openness and urbanization in 16 developed countries from 2000 to 2008. Although many studies set out to determine CO_2 emission in general, they have not looked into transport CO_2 emission, which is the most problematic. This research employed the Arellano and Bond GMM estimation method and found that all factors are statistically significant, as mentioned above. All parameters are theoretically reasonable, except for trade openness. The increase in GDP supports the increase in transport CO_2 emission, but increased urbanization can lead to lower transport CO_2 emission. As mentioned earlier, on-road transportation accounts for approximately 73% of transport CO_2 emission, therefore, policy recommendations are targeted for road transport.

From the above results, the policy implications that emerged from this study focused firstly on the issue of taxes and fees. The study of Goodwin et al. (2004), which was based on price elasticity of fuel, found that if the real price of fuel in developed countries rises by 10%, and stays at that level, the volume of fuel consumed by road vehicles would fall by 2.5% within one year, and around 6% over 5 years. The example given by Kahn et al. (2007) shows that the three times higher fuel price in the UK, when compared with the USA, leads to twice the amount of fuel-efficiency, 20% fewer miles travelled and lower vehicle ownership. Judging from this information, a high tax rate related to high fuel CO_2 emission must be imposed.

Not only high tax rates on fuel, but also high fees for licenses, parking and traffic congestion avoidance must be imposed in urban areas. Licensing and anti traffic congestion fees have been very successful in controlling private vehicles in Singapore and London, England. The anti traffic congestion fee came into force in London in 2003, with the aim of reducing private and commercial on-road transport in the city. The Transport for London Impacts Monitoring Report (2007) shows that the anti traffic congestion fee has led to a 16.4% reduction of CO_2 emission within the restricted zone. In addition, the revenue earned from these fees should be used to finance alternative public transportation that emits less pollution. Also, high powered cars and large-sized engines must be taxed at progressive rates. Lastly, owners of more than one car must pay a progressive rate of tax depending on how many cars they own.

Apart from taxes and fees, the Ecodrive Programme policy, which was introduced in the Netherlands in 2004, can be implemented in reducing transport CO_2 emission. According to the European Environmental Agency (EEA) (2008), the Ecodrive Programme has been successful in increasing fuel efficiency and reducing CO_2 emission. The Programme tries to educate drivers in many ways such as setting up a driving school curriculum for ecodriving, encouraging purchase of cars with low CO_2 emission, and suggesting that drivers install fuel saving in-car devices such as cruise control.

A policy of environmental zones is another way of reducing transport CO_2 emission. This policy has been implemented in Prague for almost ten years by targeting private and public transport that pay to drive through permitted areas of the inner city. As mentioned by the EEA (2008), launching environmental zones has decreased transport CO_2 emission by 1,650 tonnes per year. However, improvement of transit services and non-motorized facilities must be carried out as well, in order that city dwellers can commute and travel conveniently.

In conclusion, the aim of this study was to collate its results in order to formulate policies for decreasing transport CO_2 emission in the countries mentioned above.

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