Technological Forecasting & Social Change xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

The effect of corruption on carbon dioxide emissions in APEC countries: A panel quantile regression analysis

Yue-Jun Zhang [a,b,*], Yan-Lin Jin [a,b], Julien Chevallier [c,d], Bo Shen [e]

[a] Business School, Hunan University, Changsha 410082, PR China
[b] Center for Resource and Environmental Management, Hunan University, Changsha 410082, PR China
[c] IPAG Business School (IPAG Lab), 184 Boulevard Saint-Germain, 75006 Paris, France
[d] Université Paris 8 (LED), 2 rue de la Liberté, 93526 Saint-Denis Cedex, France
[e] Environmental Energy Technologies Divisions, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, United States

ARTICLE INFO

Article history:
Received 19 November 2015
Received in revised form 29 April 2016
Accepted 31 May 2016
Available online xxxx

JEL classification:
D73
Q57
C21

Keywords:
Corruption
CO_2 emissions
APEC
Panel quantile regression

ABSTRACT

The relationship between corruption and CO_2 emissions has been receiving increased attention in recent years, but little work has been conducted for the Asia-Pacific Economic Cooperation (APEC) countries even if they have determined to fight against corruption and address climate change. Using the quantile regression approach, this paper develops a panel data model for the effect of corruption on CO_2 emissions in APEC countries. The empirical results show that, first of all, the effect of corruption on CO_2 emissions is heterogeneous among APEC countries. Specifically, there is significant negative effect in lower emission countries, but insignificant in higher emission countries. Second, there exists an inverted U-shaped Environmental Kuznets Curve (EKC) between corruption and CO_2 emissions, and the per capita GDP at the turning point of the EKC may increase when CO_2 emissions increase. Finally, corruption may have not only a negative direct effect on CO_2 emissions, but also a positive indirect effect through its effect on per capita GDP. The total effect appears positive, which indicates corruption may worsen environmental quality overall in APEC countries.

1. Introduction

Among international politics and economies, the issue of climate change has gained critical attention. Combining the corruption issue in the political field with the environmental issue in the social economic field, many studies have started to find a new way to consider the factors affecting environmental quality, such as Shleifer and Vishny (1993), Lopez and Mitra (2000), Jain (2001) and Walter and Luebke (2013).

In recent years, both corruption and environmental problems have constituted great challenges for sustainable economic development (Seldadyo and De Haan, 2011; Wang et al., 2015; Zhang and Da, 2015). Nonetheless, corruption often relates to some specific cases and it is hard to quantitatively measure the extent of corruption in a society. Under this circumstance, many organizations or studies have tried to design some indicators or proxy variables to investigate the corruption status. Since the 1990s, numerous corruption indicators have begun to appear, which provided important instruments for relevant quantitative research, such as the Corruption Index published by the World Bank,[1,2] the Corruption Perception Index (CPI) published by the Transparency International (TI),[3] and the corruption index in the International Country Risk Guide (ICRG) published by the Political Risk Service (PRS) Group.[4,5]

* Corresponding author at: Business School, Hunan University, Changsha 410082, PR China.
E-mail address: zyjmis@126.com (Y.-J. Zhang).

[1] http://data.worldbank.org/indicator/IQ.CPA.TRAN.XQ
[2] Transparency, accountability, and corruption in the public sector assess the extent to which the executive can be held accountable for its use of funds and for the results of its actions by the electorate and by the legislature and judiciary, and the extent to which public employees within the executive are required to account for administrative decisions, use of resources, and results obtained. The three main dimensions assessed here are the accountability of the executive to oversight institutions and of public employees for their performance, access of civil society to information on public affairs, and state capture by narrow vested interests.
[3] http://www.transparency.org/
[4] http://www.prsgroup.com/about-us/our-two-methodologies/icrg
[5] The ICRG staff collect political information and financial and economic data and convert these into risk points for each individual risk component on the basis of a consistent pattern of evaluation. The political risk assessments (including corruption) are made based on the subjective analysis of the available information.

http://dx.doi.org/10.1016/j.techfore.2016.05.027
0040-1625/

The Asia-Pacific Economic Cooperation (APEC) was founded in 1989, which covers 21 countries and regions now, across the North America, South America, East Asia and Oceania. As the most influential international economic organization in the Asia-Pacific region, APEC has exerted important influence on economic growth, but also on the non-economic fields. Up to now, APEC has established 15 Working Groups,[6] including anti-corruption and transparency, energy, health and counter-terrorism. It should be noted that APEC has placed great emphasis on anti-corruption. During the 2004 Senior Officials Meetings (SOM) III in Santiago, APEC ministers approved on the Santiago Commitment to Fight Corruption and Ensure Transparency and the APEC Course of Action on Fighting Corruption and Ensuring Transparency (COA).[7] Afterwards, during the 2014 APEC Ministerial Meeting in Beijing, they endorsed the Beijing Declaration on Fighting Corruption (Annex H), the APEC Principles on the Prevention of Bribery and Enforcement of Anti-Bribery Laws, and the APEC General Elements of Effective Corporate Compliance Programs. Moreover, the APEC Network of Anti-Corruption and Law Enforcement Agencies (ACT-NET) was established in 2014.[8] All of these activities are aimed at fighting against corruption, bribery, money laundering and illegal trade, and promoting the capability building and sustainable development in the Asia-Pacific region. Taking China for example, the Bare Official Governance,[9] the Fox Hunting Action[10] and the Red Notice[11] have formulated a completely new pattern of anti-corruption. According to the Commission for Discipline Inspection of the Central Committee of the Communist Party of China (CPC),[12] China has recouped at least 38.7 billion Yuan economic loss from November 2012, when the 18th CPC National Congress was held, to June 2015, and the anti-corruption work has effectively cleansed the social environment and promoted the economic development.

Meanwhile, APEC countries have also attached great importance on addressing climate change. For instance, on November 12, 2014, China and the US declared the Joint Announcement on Climate Change,[13] in which they reaffirmed the importance of strengthening bilateral cooperation on climate change. Upon these premises, this paper attempts to investigate the connection among corruption, CO_2 emissions, economic growth and energy consumption of APEC countries in the past years. Specifically, due to the possible heterogeneity among APEC countries, we apply the quantile regression approach proposed by Koenker and Bassett (1978) to analyze the effect of corruption on CO_2 emissions. The two central goals are: (i) to empirically consider whether there exists heterogeneity of corruption among APEC countries with different levels of CO_2 emissions, and (ii) to quantitatively measure the direct, indirect and total effects of corruption on CO_2 emissions in APEC countries.

Overall, this paper may contribute the existing relevant literature from three aspects. First, it employs the panel quantile regression approach to empirically investigate the influence of corruption on CO_2 emissions at different levels of CO_2 emissions in APEC countries, which may provide more complete results compared to the commonly used ordinary least squares (OLS) regression approach and demonstrate the possible heterogeneity. Second, it quantitatively assesses the direct and indirect impacting mechanisms of corruption on CO_2 emissions. Third, due to the key role of CO_2 emission reduction in addressing climate change, the exploration of the effect of corruption on CO_2 emissions in APEC countries in this paper can (*i*) enable us to better understand the influence of anti-corruption, and (*ii*) provide some new references for CO_2 emission reduction methods.

The rest of the paper is organized as follows. Section 2 presents related literature review. Section 3 puts forward data descriptions and methodologies. Section 4 gives the empirical results and Section 5 concludes the research together with some policy implications.

2. Related literature review

A survey by the Organization for Economic Cooperation and Development (OECD)[14] indicated that corruption was a common issue in both developed and developing countries, and comparatively it had greater effect on CO_2 emissions in developing countries than that in developed countries. As for the impacting mechanisms of corruption on CO_2 emissions, an array of studies has provided some explanations. On the one hand, because of the imperfect environmental regulation and the complexity of environmental issues, corruption can run deep into most of the departments from legislation to law enforcement, thus it may affect the ecologic systems and environment quality eventually. For instance, from the Guardian report on August 24, 2015,[15] around 600 million tons of carbon was wrongly emitted under the Joint Implementation (JI) scheme of the United Nations Framework Convention on Climate Change (UNFCCC), which was hit by serious corruption allegations involving organized crime in Russia and Ukraine. Besides, using the data of 94 countries during 1987–2000, Cole (2007) examined the direct and indirect effects of corruption on carbon emissions and pointed out that corruption can not only directly affect carbon emissions by environmental regulation, but also indirectly affect carbon emissions through its effect on economic growth.

On the other hand, corruption may make environmental policies difficult to carry out, and then may affect the levels of CO_2 emissions. Callen and Long (2015) found considerable evidence about the relationship among political networks, weak institutions and election fraud, which could be called "governmental corruption" and was often defined as the sale by government officials of governmental property for personal gain (Jain, 2001; Shleifer and Vishny, 1993). Meanwhile, corruption in government was a key issue of ethics, especially the corruption in law enforcement (Glenn and Gordon, 2001). For example, the United States Agency for International Development (USAID) pointed out that corruption in the environmental sector diverted funds allocated for environmental programs to private pockets through embezzlement and bribery.[16] Winbourne (2002) held that corruption may contribute to the development of environmentally damaging policies and practices, and the unfair allocation of environmental resources, so that corruption always created harmful practices.

Overall, previous research on the effect of corruption on CO_2 emissions could be divided into two aspects, i.e., the direct and indirect effects. For one thing, many studies have considered the direct effect of corruption on the levels of CO_2 emissions by means of environmental regulations. Related literature is summarized in Table 1. We can find that most studies showed that corruption and environmental quality tend to be positively correlated, thus corruption might increase environmental pollution.

For another, there were also a number of studies discussing the indirect effect of corruption on CO_2 emissions by means of economic growth. Existing typical literature on the linkage between corruption and economic growth is described in Table 2, which indicated that corruption might be affected by power and economic interests, and the primary and significant harm caused by corruption was the loss of social

[6] http://www.apec.org/Groups/SOM-Steering-Committee-on-Economic-and-Technical-Cooperation/Working-Groups/Anti-Corruption-and-Transparency.aspx
[7] http://www.apec.org/Meeting-Papers/Ministerial-Statements/Annual/2004/2004_amm.aspx
[8] http://www.apec.org/Meeting-Papers/Ministerial-Statements/Annual/2014/2014_amm.aspx
[9] http://politics.people.com.cn/n/2014/0910/c1001-25631259.html
[10] http://world.people.com.cn/n/2015/0401/c1002-26785051.html
[11] http://politics.people.com.cn/n/2015/0423/c1001-26889338.html
[12] http://www.ccdi.gov.cn/xwtt/201507/t20150728_59902.html
[13] https://www.whitehouse.gov/the-press-office/2014/11/11/us-china-joint-announcement-climate-change
[14] http://www.oecd.org/daf/anti-bribery/ConvCombatBribery_ENG.pdf
[15] http://www.theguardian.com/environment/2015/aug/24/kyoto-protocols-carbon-credit-scheme-increased-emissions-by-600m-tonnes
[16] http://pdf.usaid.gov/pdf_docs/pnact876.pdf

Table 1
Typical literature related with the linkage between corruption and environmental quality.

Typical literature	Topic	Method	Main results
Ozturk and Al-Mulali (2015)	Corruption and CO_2 emissions	Generalized method of moments and two-stage least squares (2SLS)	The control of corruption could reduce CO_2 emissions.
Biswas et al. (2012)	Pollution, shadow economy and corruption	Panel data model	The relationship between the shadow economy and the levels of pollution was dependent on the levels of corruption.
Cole (2007)	Corruption, income and the environment	Instrumental variables (IVs)	For both sulfur dioxide and carbon dioxide, corruption had positive direct effect on per capita emissions. Indirect effect was found to be negative and larger in absolute value than direct effect for the majority of the sample income range.
Pellegrini and Gerlagh (2006b)	Corruption and environmental policies	Ordinary linear square (OLS) estimation	The differences in corruption levels across countries appeared to be more important than the income differences. Corruption levels were the most important factor in explaining the variance in environmental policies in the enlarged European Union (EU) countries.
Fredriksson et al. (2004)	Corruption and energy efficiency	Generalized linear square estimation (GLSE)	Greater corruptibility of policy makers reduced energy policy stringency.
Damania et al. (2003)	Corruption and environment policy	Random effect regression model	The effect of trade liberalization on the stringency of environmental policy depended on the level of corruption and corruption reduced environmental policy stringency.
Lopez and Mitra (2000)	Corruption, pollution, and the EKC	Structural equation model	Corruption was not likely to preclude the existence of an inverted U-shaped EKC, but the turning point of the Kuznets curve took place at income and pollution levels above those corresponding to the social optimum.

economic benefits. Shleifer and Vishny (1993) argued that corruption was one of the most serious threats to good governance, proper development of economic systems and political stability. Similarly, Banerjee (1997) also explained why government bureaucracies were often associated with red tape, corruption, and lack of incentives. As a result, corruption might set back the economic and social development in a country. Specifically, it may lead to misallocation of resources, transaction costs, political inefficiency, dilution of trade patterns and domestic or foreign investment.

In summary, the effect of corruption on CO_2 emissions stands out as a complex issue, due to different measurements of corruption, different economic levels, different political backgrounds and different levels of CO_2 emissions among countries. Most relevant studies considered the topic in a single country or the whole world, but few focused on that in the APEC region. Moreover, as for the methodology, most studies used the traditional ordinary least squares (OLS) regression approach, which could not reflect the complete picture of the effect on different levels of CO_2 emissions. In order to obtain a holistic view of the effect of (anti-) corruption on CO_2 emission in the APEC region, this paper develops a panel data model for the period from 1992 to 2012.

3. Data and methodologies

3.1. Data descriptions

This paper focuses on the effect of corruption on CO_2 emissions for APEC countries, excluding two special regions (Hong Kong and Taiwan). In total, 19 countries are included, i.e., Australia, Brunei,

Table 2
Typical literature related with the linkage between corruption and economic growth.

Typical literature	Topic	Method	Main results
Aparicio et al. (2016)	Corruption, opportunity entrepreneurship and economic growth	Panel data model	The control of corruption was fundamental to generating incentives for opportunity entrepreneurship, and had positive impact on economic growth.
van Soest et al. (2016)	Corruption and economics	Experimental design	Corruption could affect the provision of public goods in a development economics context.
Choi (2015)	Corruption and official development assistance (ODA)	Partial least squares	The economic performance of ODA could be influenced by the level of corruption.
Lalountas et al. (2011)	Corruption, globalization and development	IVs and OLS	Globalization was a powerful weapon against corruption only for the middle and high income countries, while for the low income countries, globalization had no significant impact on corruption.
Hakkala et al. (2008)	Corruption and foreign direct investment (FDI)	Causal effect analysis	Corruption reduced the probability that a firm will invest in a country, and the horizontal investments were deterred by corruption to a larger extent than vertical investments.
Fisman and Svensson (2007)	Corruption, taxation and growth	IVs	Both the rates of taxation and bribery were negatively correlated with firm growth. A one-percentage increase in the bribery rate was associated with a reduction in firm growth of three percentages, an effect that was about three times greater than that of taxation.
Gyimah-Brempong and de Gyimah-Brempong (2006)	Corruption, growth, and income distribution	Dynamic panel data model	There were statistically significant regional differences in the growth and distributional impacts of corruption.
Rock and Bonnett (2004)	Corruption, growth and investment	Time series model	Corruption slowed growth and reduced investment in most developing countries, particularly small developing countries, but increased growth in the large East Asian newly industrializing economies.
Mauro (1995)	Corruption and growth	OLS and 2SLS	Corruption may lower economic growth by lowering investment.

Please cite this article as: Zhang, Y.-J., et al., The effect of corruption on carbon dioxide emissions in APEC countries: A panel quantile regression analysis, Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.05.027

Table 3
Variable definitions and data sources.

Variable	Definition	Unit	Variable reference	Data source
CO_2	Logarithm of per capita CO_2 emissions from the energy consumption.	Metric tons per capita	–	EIA
E	Logarithm of per capita total primary energy consumption whose unit is converted from "million BTU per person" to "metric tons of oil equivalent per capita" according to the unit conversion coefficient (1 metric ton of oil equivalent = 39,683,205.411 BTU) from EIA.	Metric tons of oil equivalent per capita	–	EIA
C	Corruption index, which is rescaled from 0 (free of corruption) to 6 (highest level of corruption).	–	–	ICRG
D	Democratic accountability.	–	Pellegrini and Gerlagh (2006a)	ICRG
GDP	Logarithm of per capita GDP (constant 2005 US$).	Constant 2005 US $	–	World Bank
P	Logarithm of the total population size.	–	–	World Bank
T	The sum of exports and imports of goods and services measured as a share of GDP. But it is notable that the data of Papua New Guinea from 2005 to 2012 are missed, and we complete the missing data by this formula: the sum of exports and imports of goods and services / GDP × 100%.	% of GDP	Biswas et al. (2012) Cole (2007)	World Bank
U	Urban population (% of total).	% of total population	Biswas et al. (2012)	World Bank
I	Rate of inflation, GDP deflator.	Annual %	Cole (2007)	World Bank
G	Rate of annual population growth.	Annual %	Leitao (2010)	World Bank

Note: The logarithm of per capita CO_2 emissions is the dependent variable, and other variables act as the independents.

Canada, Chile, Indonesia, Japan, Korea, Malaysia, Mexico, New Zealand, Peru, Papua New Guinea, China, Philippines, Russia, Singapore, Thailand, the United States and Vietnam. Based on the data availability, we select the yearly sample observations from 1992 to 2012.

The variables descriptions, data definitions and data sources are shown in Table 3. The data of per capita CO_2 emissions and primary energy consumption are from the U.S. Energy Information Administration (EIA). Meanwhile, we use the corruption index in ICRG published by the PRS Group to measure the degree of corruption. It should be noted that the original range of corruption in ICRG is from 0 to 6, and 0 refers to the highest level of corruption. In contrast, in this paper the variable C, which denotes the degree of corruption, has been rescaled from 0 (free of corruption) to 6 (highest level of corruption) such that its value now increases in line with the most corrupt situation, using 6 minus the original corruption index value. D stands for the democratic accountability, which is also provided by the ICRG and indicates the democracy degree of governance. Besides, GDP, P, T, U, I and G represent per capita GDP in constant 2005 US$, total population, trade openness, urbanization, inflation and population growth, respectively, which are all from the World Development Indicators (WDI) database of the World Bank.

Table 4 reports the descriptive statistics of the variables concerned. It should be noted that different quantiles can describe different distribution trends. For instance, comparing the 2nd quantile (i.e., the median value) with the mean value of the variables, we can find that the distributions of these variables are distinct. Therefore, the OLS regression approach may bring about biased results. Also, we find that all variables are skewed, which is another proof to support us to employ the quantile regression approach to detect the effect of corruption on CO_2 emissions in this paper.

3.2. Methodologies

3.2.1. Panel quantile regression model

In order to investigate the relationship among corruption, energy consumption, economic growth and CO_2 emissions, and check the heterogeneity of the effect of corruption on different levels of CO_2 emissions, we develop the quantile regression model as Eq. (1):

$$Q_{CO_{2_{it}}}(\tau_k|\alpha_i, x_{it}) = \alpha_i + \beta_{1\tau}C_{it} + \beta_{2\tau}GDP_{it} + \beta_{3\tau}GDP_{it}^2 + \beta_{4\tau}T_{it} + \beta_{5\tau}P_{it} + \beta_{6\tau}D_{it} + \beta_{7\tau}U_{it} \quad (1)$$

where the subscripts i and t denote country and year, respectively, and α_i stands for the unobservable individual effect. Furthermore, the estimation of the coefficients for the τ-th quantile of the conditional distribution can be obtained from Eq. (2) (Koenker and Bassett, 1978).

$$\hat{\beta}(\tau) = \arg\ \min \sum_{i=1}^{n} \rho_\tau(y_i = x_i^T\beta) \quad (2)$$

where $\rho_\tau(u) = u(\tau - I(u<0)), I(u<0) = \begin{cases} 1, u<0 \\ 0, u \geq 0 \end{cases}$ denotes the check function, and $I(\bullet)$ is an indicator function.

From Eq. (2), we can find that the quantile regression is a kind of weighted regression, by setting different weights τ and $1-\tau$ to positive and negative residuals, respectively. However, it does not take α_i, i.e., the unobserved country heterogeneity into account. For this reason, due to limited yearly observations in this paper, we apply the estimation method proposed by Koenker (2004), in which the unobservable

Table 4
Summary of descriptive statistics.

Variable	Min.	1st Qu.	2nd Qu.	3rd Qu.	Max.	Mean	Skewness	Kurtosis
CO_2	−0.5522	0.2130	0.7550	1.0968	1.5928	0.6849	−0.3504	1.923038
E	2.242	3.011	3.545	3.940	4.365	3.511	−0.3567	1.847487
C	0.000	1.667	3.000	4.000	5.000	2.810	−0.2474	2.115687
D	0.000	2.000	4.500	5.458	6.000	3.819	−0.5106	2.002337
GDP	2.524	3.277	3.830	4.430	4.657	3.817	−0.2263	1.643101
P	5.434	7.224	7.678	8.100	9.131	7.566	−0.5850	3.564350
T	15.92	48.59	63.91	104.47	439.66	89.65	2.505369	9.654440
U	12.98	46.57	73.93	81.64	100.00	65.43	−0.7429	2.405556
I	−22.091	1.720	3.807	8.136	1490.418	13.124	14.32485	221.8477
G	−1.4764	0.8798	1.2190	1.7758	5.3216	1.3058	0.415275	4.550492

The visual description can be obtained upon request.

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individual effect α_i acts as one of the regression parameters. Specifically, the parameters are estimated as Eq. (3):

$$\left(\hat{\beta}(\tau_k,\lambda),\ \{\alpha_i(\lambda)\}_{i=1}^N\right) = \arg\min \sum_{k=1}^{K}\sum_{t=1}^{T}\sum_{n=1}^{N} w_k \rho_{\tau_k}\left(y_{it}-\alpha_i-x_{it}^T\beta(\tau_k)\right) + \lambda\sum_{i=1}^{N}|\alpha_i| \quad (3)$$

where w_k is the weight of the k-th quantile. According to Alexander et al. (2011) and Lamarche (2011), we use the equal weights $w_k = 1/K$ in this paper. λ is a tuning parameter for the individual effect (Koenker, 2004), and we set $\lambda = 1$ according to Damette and Delacote (2012) and Lee et al. (2012).

Besides, if $\beta_{2\tau}>0$ and $\beta_{3\tau}<0$ in Eq. (1), the Environmental Kuznets Curve (EKC) can be proved to exist at the τ-th quantile. Then, following Koenker (2004), we can calculate the level of income at the turning point of EKC as Eq. (4):

$$\hat{\theta}_\tau = e^{-\beta_{2\tau}/2\beta_{3\tau}} \quad (4)$$

3.2.2. The estimation approach for the effect of corruption on carbon dioxide emission

In order to estimate the direct and indirect effect of corruption on CO_2 emissions in APEC countries, we develop the following emission Eq. (5) and income Eq. (6) (Cole, 2007; Leitao, 2010).

$$CO_{2_{it}} = \alpha_i + \beta_1 C_{it} + \beta_2 GDP_{it} + \beta_3 GDP_{it}^2 + \beta_4 T_{it} + \beta_5 P_{it} + \beta_6 D_{it} + \beta_7 U_{it} + \mu_{it} \quad (5)$$

$$GDP_{it} = \varphi_i + \gamma_1 C_{it} + \gamma_2 E_{it} + \gamma_3 I_{it} + \gamma_4 G_{it}\zeta_{it} \quad (6)$$

Then we apply the Two-Stage Least Squares method (Kelejian, 1971) to estimate Eqs. (5) and (6). The result of the Hausman test (Hausman, 1978) indicates that they both satisfy the fixed effect estimation. Because of the potential endogeneity problem in Eq. (6), this paper employs the instrument variables (IVs) approach, which uses the quadratic of the fitted values of per capita GDP as the instrument variable (Wooldridge, 2001). Hence, according to Cole (2007) and Leitao (2010), the total effect of corruption on CO_2 emissions can be expressed as Eq. (7):

$$\frac{dCO_2}{dC} = \frac{\delta CO_2}{\delta C} + \frac{\delta CO_2}{\delta GDP}\cdot\frac{\delta GDP}{\delta C} \quad (7)$$

where $\frac{dCO_2}{dC}$, $\frac{\delta CO_2}{\delta C}$ and $\frac{\delta CO_2}{\delta GDP}\cdot\frac{\delta GDP}{\delta C}$ denote the total, the direct and indirect effect, respectively. By combining Eqs. (5), (6) and (7), we derive Eq. (8), from which we can find that the indirect effect and the total effect may vary along with the income level.

$$\begin{aligned}\frac{dCO_2}{dC} &= \frac{\delta CO_2}{\delta C} + \frac{\delta CO_2}{\delta GDP}\cdot\frac{\delta GDP}{\delta C}\\ &= \beta_1 + \left(\beta_2\cdot\frac{\delta GDP}{\delta C} + 2\beta_3\cdot GDP\cdot\frac{\delta GDP}{\delta C}\right)\\ &= \beta_1 + (\beta_2 + 2\beta_3\cdot GDP)\frac{\delta GDP}{\delta C}\\ &= \beta_1 + (\beta_2 + 2\beta_3\cdot GDP)\gamma_1\end{aligned} \quad (8)$$

4. Empirical results and discussions

4.1. The stationary properties and co-integration for all variables

First of all, we check the stationary properties for all variables in this paper and the detailed results of ADF unit root tests, PP tests and LLC tests are shown in Table 5. We can find that the level series of inflation rate (I) and population growth rate (PG) are stationary, so are their first-order differenced series. Other variables are I(1) series at the 1% significance level during the sample period. Then, according to Pedroni (2000), we can conduct the panel co-integration test, i.e., Kao Residual Co-integration Test, and the result is shown in the last line in Table 5. We can find that the statistic value is statistically significant at the 1% level, which indicates that these variables have significant long-term equilibrium relationship during the sample period.

4.2. The heterogeneity of the effect of corruption on carbon dioxide emissions

The quantile regression results based on Eq. (1) are shown in Table 6, which indicate several important findings. First, there are significant differences in the effect of corruption on CO_2 emissions across lower and higher quantiles in the conditional distribution of CO_2 emissions. Specifically, at lower quantiles, such as 10th, 20th, 30th, 40th and 50th, which refer to those lower CO_2 emission countries, we find that the effect of corruption on CO_2 emissions is significantly negative. For instance, Philippines, Vietnam, Indonesia and Peru belong to the lower emission countries. Whenever their degree of corruption increases, the CO_2 emissions do not increase accordingly. However, at higher quantiles, the effect is not significant any more. For example, Singapore, USA, Brunei, Australia and Canada have relatively higher CO_2 emissions, and both their degree of corruption and the level of CO_2 emissions have increasing trends over time during the sample period, thus the effect of corruption on CO_2 emissions becomes not negatively correlated. We may infer that there exactly exists heterogeneity for the effect of corruption on CO_2 emissions among APEC countries with different levels of CO_2 emissions. In fact, this finding is similar to the results of Grooms (2015), who argued that the states with a long-run prevalence of corruption might see a large decrease in the violation rate, i.e., environment quality, compared to the states without corruption.

Second, the effects of per capita GDP and democracy on CO_2 emissions are both heterogeneous, unlike that of trade openness and urbanization. As shown in Table 6, the coefficients at higher quantiles of per capita GDP are not statistically significant, and the quadratic coefficient is only significant at the 10th quantile. Democracy significantly and negatively affects CO_2 emissions only at 90th and 95th quantiles, while trade openness and urbanization have positive effect at the 1% and 5% significance levels across all quantiles.

Finally, the coefficient of per capita GDP is positive but its quadratic coefficient is negative, which proves the existence of the EKC. This result is a little different from that of Leitao (2010). There are two main reasons from our viewpoints. For one thing, we focus on the APEC members in this paper and every country has different characteristics, but Leitao (2010) selected 94 countries with a wide range of levels of development and corruption from 1981 to 2000. For another, most previous related studies use the OLS approach to obtain the average estimation results, but we apply the quantile regression approach in this paper, so that we may get more complete results under different conditional distributions.

Besides, according to Eq. (4), we can find that the per capita GDP at the turning point of the EKC increases when CO_2 emissions increase among APEC countries, which can be seen from the last line in Table 6. Meanwhile, we find that during the sample period, the per capita GDP in most APEC countries is yet to peak except for Vietnam, Philippines and Indonesia.

4.3. The estimations of carbon dioxide emission equation and income equation

The regression results of Eqs. (5) and (6) are presented in Table 7, from which we can safely obtain the following two main findings. First, the statistically significant coefficients of GDP and GDP^2 show the existence of EKC. The similar result is supported by Lopez and Mitra (2000), who concluded that corruption is not likely to preclude the existence of an inverted U-shaped EKC. Second, per capita GDP may

Table 5
The stationary and co-integration test of variable.

	Level			1st difference		
Variable	ADF-statistic	PP-statistic	LLC-statistic	ADF-statistic	PP-statistic	LLC-statistic
CO_2	17.5046 (0.9982)	25.3559 (0.9422)	1.2686 (0.8977)	136.271 (0.0000)	272.097 (0.0000)	−8.7831 (0.0000)
E	9.5490 (1.0000)	9,5273 (1.0000)	2.8130 (0.9975)	150.308 (0.0000)	244.196 (0.0000)	−8.6032 (0.0000)
C	19.6076 (0.9941)	18.8353 (0.9961)	0.6398 (0.7388)	203.944 (0.0000)	262.844 (0.0000)	−12.6083 (0.0000)
D	39.6146 (0.1667)	56.9756 (0.0043)	−1.5255 (0.0636)	245.845 (0.0000)	210.117 (0.0000)	−14.2135 (0.0000)
GDP	2.8862 (1.0000)	5.7908 (1.0000)	6.5034 (1.0000)	123.258 (0.0000)	158.414 (0.0000)	−4.5744 (0.0000)
P	25.3560 (0.9422)	5.4697 (1.0000)	3.8404 (0.9999)	62.5227 (0.0073)	158.690 (0.0000)	−3.3408 (0.0004)
T	10.1291 (1.0000)	13.7735 (0.9999)	2.4116 (0.9921)	232.421 (0.0000)	331.475 (0.0000)	−14.3606 (0.0000)
U	61.4562 (0.0052)	26.6356 (0.8721)	−4.9511 (0.0000)	71.9605 (0.0003)	85.8856 (0.0000)	−8.7308 (0.0000)
I	117.354 (0.0000)	161.278 (0.0000)	−12.2578 (0.0000)	386.386 (0.0000)	375.662 (0.0000)	−22.3591 (0.0000)
G	72.3503 (0.0007)	183.940 (0.0000)	−3.3510 (0.0004)	193.247 (0.0000)	178.095 (0.0000)	−6.9225 (0.0000)

Kao Residual Co-integration Test: −3.7791 (0.0001).
Note: The significance probabilities for corresponding tests are reported in parentheses.

decrease by 6.2% with one-percentage increase of corruption. In other words, corruption may affect economic growth negatively, which is similar to Rock and Bonnett (2004) and Mauro (1995). Specifically, Rock and Bonnett (2004) argued that corruption might slow growth and reduced investment in most developing countries. Similarly, Mauro (1995) drew the conclusion that corruption would pull down economic growth by lowering investment.

4.4. The total effect of corruption on carbon dioxide emissions

The direct, indirect and total effects of corruption on CO_2 emissions are shown in Table 8. According to Eq. (8), we can recognize that the effect of corruption on CO_2 emissions may be different among APEC countries because of different levels of per capita GDP. Thus we choose ten quantiles of per capita GDP as ten different levels of income, and measure the direct, indirect and total effects of corruption on CO_2 emissions in APEC countries during 1992–2012.

We can find that, first of all, corruption may directly affect CO_2 emissions negatively at different levels of CO_2 emissions, and the degree of the direct effect will decrease along with the increased per capita GDP. For instance, according to Table 8, when it comes to the per capita GDP at the 10th quantile, CO_2 emissions will decrease by 1.89% with one-percentage increase of corruption degree; and when the 95th percentile of capita GDP is concerned, CO_2 emissions will decrease by 1.33%, which is smaller than the decline margin of CO_2 emissions when per capita GDP stays at the 10th percentile (1.89%).

Second, corruption may indirectly affect CO_2 emissions positively at different levels of CO_2 emissions, and the degree of the indirect effect will decrease along with the increased per capita GDP levels. As shown in Table 8, when per capita GDP stays at the 10th percentile, CO_2 emissions may increase by 157.13% with every one-percentage increase of corruption degree, and when the 95th percentile of per capita GDP is considered, CO_2 emissions may increase by 96.22% with one-percentage increase of corruption.

Combining the two points above, we can say that the effect of corruption on CO_2 emissions in APEC countries appears dependent on the levels of per capita GDP, which is similar to the results of Cole (2007). As for the reasons, in our opinions, economic basis determines the superstructure in a society. Specifically, in the earlier stage of economic development, the economic foundation in a country is often relatively weaker and the normal market competition order has not been well established. Under this circumstance, the prevalence of corruption may rapidly break the immature economic system, which may eventually cause CO_2 emissions to become more serious. Then, when the economic situation gradually develops, the contradiction between economic growth and environmental quality may also escalate gradually. As a result, the rapid growth may bring about increased CO_2 emissions. However, when the economy stays at the highly developed stage, the environmental regulations of government and the environmental protection recognition of citizens in the society would be improved. In this period, the lower corruption may lead to a decrease of CO_2 emissions (Jetter et al., 2015; Timmons and Garfias, 2015).

Table 6
Quantile regression results of the relation of corruption and carbon dioxide emission.

	Quantiles									
Variable	10th	20th	30th	40th	50th	60th	70th	80th	90th	95th
C	−0.0189**	−0.0160*	−0.0182**	−0.0159**	−0.0139*	−0.0118	−0.0111	−0.0111	−0.0132	−0.0133
	(0.0377)	(0.0726)	(0.0374)	(0.0453)	(0.0554)	(0.1139)	(0.1495)	(0.1577)	(0.1161)	(0.1231)
GDP	1.5199**	1.3603**	1.3567**	1.3156**	1.2221*	1.1764*	1.1421	1.0709	1.0252	0.9312
	(0.0121)	(0.0195)	(0.0249)	(0.0393)	(0.0660)	(0.0822)	(0.1033)	(0.1413)	(0.1866)	(0.2265)
GDP^2	−0.1387*	−0.1160	−0.1158	−0.1094	−0.0962	−0.0887	−0.0834	−0.0737	−0.0669	−0.0545
	(0.0674)	(0.1109)	(0.1257)	(0.1709)	(0.2479)	(0.2854)	(0.3437)	(0.4215)	(0.4947)	(0.5736)
T	0.0011***	0.0010***	0.0011***	0.0011***	0.0011***	0.0011***	0.0011***	0.0011***	0.0010***	0.0009**
	(0.0004)	(0.0015)	(0.0024)	(0.0033)	(0.0035)	(0.0022)	(0.0026)	(0.0021)	(0.0084)	(0.0197)
P	0.0804	0.0812	0.0814	0.0796	0.0673	0.0621	0.0533	0.0522	0.0471	0.0388
	(0.1206)	(0.1223)	(0.1238)	(0.1337)	(0.1945)	(0.2270)	(0.2969)	(0.3132)	(0.3660)	(0.4765)
D	−0.0035	−0.0019	−0.0027	−0.0022	−0.0032	−0.0035	−0.0049	−0.0081	−0.0198**	−0.0248**
	(0.6507)	(0.7837)	(0.6936)	(0.7369)	(0.5730)	(0.5372)	(0.3798)	(0.1762)	(0.0135)	(0.0125)
U	0.0070**	0.0070**	0.0071**	0.0071**	0.0069**	0.0065**	0.0062**	0.0062**	0.0059**	0.0060**
	(0.0138)	(0.0140)	(0.0130)	(0.0128)	(0.0168)	(0.0212)	(0.0253)	(0.0256)	(0.0377)	(0.0383)
Peak	239.5516	351.8295	349.6351	409.2805	575.3728	757.7187	940.2272	1425.834	2117.154	5173.639

Note: The significance probabilities are reported in parentheses. The peak value, i.e., the per capita GDP at the turning point of the EKC, is given in the last row.
* Statistical significance at 10%.
** Statistical significance at 5%.
*** Statistical significance at 1%.

Please cite this article as: Zhang, Y.-J., et al., The effect of corruption on carbon dioxide emissions in APEC countries: A panel quantile regression analysis, Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.05.027

Table 7
The regression results of CO_2 emission equation and income equation.

The regression result of the CO_2 emission equation				
Dependent variable: CO_2				
Balanced panel: n = 19, T = 21, N = 399				
Coefficient	Estimate	Std. Error	t-Value	Pr(>|t|)
C	−0.0075	0.0050	−1.5086	0.1323
GDP	1.4820	0.2073	7.1500	0.0000***
GDP^2	−0.1561	0.0312	−4.9991	0.0000***
T	0.0010	0.0002	5.4798	0.0000***
P	0.7896	0.1463	5.3956	0.0000***
D	−0.0043	0.0039	−1.0860	0.2782
U	0.0084	0.0012	6.9250	0.0000***
F-statistic: 54.3828				
p-Value: 0.0000				

The regression result of the income equation				
Dependent variable: GDP				
Balanced panel: n = 19, T = 21, N = 399				
Coefficient	Estimate	Std. Error	t-Value	Pr. (>|t|)
C	−0.062	0.0090	−6.906	0.0000***
E	0.9879	0.0229	43.114	0.0000***
I	−0.0006	0.0001	−5.229	0.0000***
G	0.0148	0.0130	1.134	0.258
F-statistic: 39.3023				
p-Value: 0.0000				

Note: *** indicates the significance at the 1% level.

Besides, compared to the direct effect, the indirect effect is much larger in absolute value, thus the total effect of corruption on CO_2 emissions, which is the sum of the direct and indirect effects, appears positive, and when the per capita GDP levels increase, the total effect may decrease, whose changing trend is similar to that of the indirect effect.

5. Main conclusions and policy implications

APEC countries have determined to jointly fight against corruption and climate change, but corruption may have direct and indirect effect on CO_2 emissions. In this paper, we develop a panel quantile regression model to investigate the effect of corruption on CO_2 emissions for 19 APEC countries during 1992–2012. Based on the empirical results, several important conclusions can be safely drawn as follows:

(1) There is heterogeneity regarding the effect of corruption on CO_2 emissions among APEC countries with different levels of CO_2 emissions. Specifically, in the lower emission countries in APEC, such as Philippines, Vietnam, Indonesia and Peru, the effect is statistically negative. However, in the higher emission countries, such as Singapore, the United States, Brunei, Australia and Canada, the effect becomes insignificant.
(2) There exists an inverted U-shaped EKC between corruption and CO_2 emissions among APEC countries during the sample period. Meanwhile, along with the CO_2 emissions increase, the levels of per capita GDP at the turning point of the EKC will be higher among APEC countries.
(3) The total effect of corruption on CO_2 emissions appears positive during the sample period, although corruption may directly affect CO_2 emissions negatively through environmental regulation, and may also indirectly affect CO_2 emissions positively by means of economic growth. In other words, overall, more corruption may bring more CO_2 emissions.

Table 8
The direct, indirect and total effect of corruption on CO_2 emissions.

Quantile	Direct effect	Indirect effect	Total effect
10th	−0.0189	1.5713	1.5524
20th	−0.0160	1.4050	1.3890
30th	−0.0182	1.4054	1.3872
40th	−0.0159	1.3651	1.3492
50th	−0.0139	1.2679	1.2540
60th	−0.0118	1.2224	1.2106
70th	−0.0111	1.1878	1.1767
80th	−0.0111	1.1119	1.1008
90th	−0.0132	1.0631	1.0499
95th	−0.0133	0.9622	0.9489

Besides, in the future, we still have a lot of work to do on the topic in this paper. For instance, with the development of economy and technology in APEC countries, the index of corruption may cover not only different countries but also different industries and sectors, and then we can conduct inter-industry analysis and get more detailed and interesting results. Moreover, due to the complex culture background in APEC countries, if the data is obtained, we can also take their cultural information into account and discuss its effect on the nexus of corruption and CO_2 emissions, so as to explore another candidate impacting mechanism.

Acknowledgements

We gratefully acknowledge the financial support from the National Natural Science Foundation of China (nos. 71273028, 71322103) and the National Special Support Program for High-Level Personnel from the central government of China.

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Dr. Yue-Jun Zhang is a Professor with Business School, Hunan University, PR China. He got his PhD degree in energy economics from China's Academy of Sciences (CAS) in 2009. Now Dr. Zhang works in the fields of energy economics and policy modeling, such as carbon emission reduction, oil price, econometric modeling. Dr. Zhang was a visiting scholar at Energy Studies Institute of National University of Singapore (NUS).

Ms. Yan-Lin Jin is a PhD candidate with Business School, Hunan University, PR China. Her research interests mainly cover carbon emission reduction and related welfare analysis.

Dr. Julien Chevallier is a Professor with IPAG Business Schooland Université Paris 8, France. His research interests focus on energy economics, carbon emission reduction modeling. He received his PhD in Economics from the University Paris West Nanterre La Défense in 2008. Dr. Chevallier has previously held visiting research positions at Imperial College London, London School of Economics, Georgetown University, and World Bank.

Dr. Bo Shen is a Professor with Environmental Energy Technologies Divisions, Lawrence Berkeley National Laboratory (LBNL), United States. His current work at LBNL involves the reduction of industrial energy intensity, and the implementation of demand-side management programs.

Please cite this article as: Zhang, Y.-J., et al., The effect of corruption on carbon dioxide emissions in APEC countries: A panel quantile regression analysis, Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.05.027