Heliyon

Relations between economic development, violence and corruption: A nonparametric approach with DEA and data panel

Alexander Cotte Poveda[*], Jorge Enrique Martínez Carvajal, Nicolas Ronderos Pulido

Faculty of Economics, University Santo Tomas, Carrera 9 No 51-11, Bogotá, Colombia

[*] Corresponding author.

E-mail address: alexandercotte@usantotomas.edu.co (A.C. Poveda).

Abstract

This research analyses the connection between homicides, corruption, and economic development in Colombian government departments. This empirical research explores the trends of homicides, corruption, and economic development utilizing different estimation techniques: DEA and econometric analysis with panel data. The DEA is applied to assess socioeconomic performance and interactions of homicides, corruption, and economic progress in Colombian, according to the rank and uncertainty of corruption and violence. Econometric models are Generalized Method of Moments (GMM) estimates to determine the incidence of some institutional and socioeconomic variables on the score range of uncertainty and risk generated by DEA in terms of the level of corruption and homicides. Estimates with DEA data envelopment analysis shows that the risk score associated with homicides and corruption has different tendencies, socioeconomic and political instability are causes that explain the behaviour of this variable over time. The results of the panel data estimation show that there are several hypotheses and theories that explain the effects of corruption and violence on the economic development of countries. This finding indicates the importance of developing effective policies that strengthen public administration,

the judicial structure, and public social spending and thus rupture the cycles of corruption and homicides that prevent the creation of sustained economic growth and development.

Keyword: Economics

1. Introduction

In this complex world, corruption, or the overreach of public power for personal profit, has become a problem that affects most of the political, social and economic actions of a society, Morales and Finke (2015). This event slows economic growth and development, debilitate democratic institutions, and produces governmental uncertainty and instability, which can lead to crime and homicides, Cotte and Martinez (2019). Moreover, poverty and corruption is likely to increase because of the lack of opportunities and the decrease in social investments and economic growth, Cieślik and Goczek (2018).

Poverty is more likely to increase because of the lack of opportunities and the decrease of social investments. Economic growth is debilitated because investment decline due to the increase transaction costs. Within the country, small and median businesses are often affected by the consequences of corruption, (Cotte, 2017b) including higher costs (Cotte, 2017a; Shao et al., 2007).

Le Billon (2003) has analysed the role of corruption in armed conflict with various conceptual interrelations and shows that corruption extends war through two interrelated mechanisms associated with the benefits associated with the armed conflict. First, armed conflict offers a productive ground for corruption and unlawful enrichment. Second, corruption can break the efficiency and dedication of the armed forces, especially government forces. Neapolitan (1999) has compared nations with low and high levels of crime using a model of cross-national crime variation and shows that countries with high levels of crime are characterised by a high degree of corruption and inefficiency within the criminal justice system. Hodgson and Jiang (2016) have analysed corruption as an instability event that influence at the same time private and public spheres. The erosion of social rules by organisational corruption produces big social costs that may lead to social, violence political and institutional uncertainty.

Vaal and Ebben (2011) have explored the incidence of public corruption on economic development using a two-layer model that showed that an institutional lack produces corruption, which causes a decline in development due to lower growth of public goods and labour. Shao et al. (2007) have analysed quantitative relations between the level of corruption and its economic causes utilizing a time series analysis. They found that less corrupt countries show important economic development,

whereas more corrupt countries show minor development. Moreover, Gyimah and Munoz (2006) have used panel data methods to research regional discrepancy in the effect of corruption on economic development and income inequality. Their research found that low-income countries are characterised by high rates of corruption and low rates of economic development.

Blackman et al. (2006) have study corruption using the Colombian environmental authorities and found that corruption was a dilemma at both the country and state levels. Thoumi (1999) has considered the connection between corruption and the drug trade and showed both that this relationship is cyclic and that both are the consequence of the deterioration of institutions accompanied by the de-legitimation of the government.

The empirical investigations on the dynamic relationships between economic growth, homicides and corruption have been focused at most in two of these variables. In this article two contributions to literature are proposed. First the relative efficiency of the Colombian economy is estimated in terms of homicides rates, corruption measures and economic growth using data envelope analysis (DEA); this allows evaluating the social conduct of the Colombian departments. On the other hand, the main drivers of the social performance are identified using dynamic panel estimation; this gives lights on the factors that cause this type of social dynamics. The relationships between income growth, violence and corruption are analysed for the period 2001−2015. The question in this investigation is: how economic growth affects violence and corruption? And which are the main drivers of violence and corruption in Colombia?

This document has five sections including this introduction. A revision of the data sets and the estimation methodology is presented in section 2. The estimates of the relative efficiency if terms of homicides rates, corruption measures and economic growth are presented in section 3, the DEA and clustering techniques are shown in detail. The estimations of the dynamic panel model are presented in section 4. In section 5 the conclusions and recommendations are given.

2. Materials & methods

This paper uses the political and geographical division of the Colombian departments. We use data published by the National Directorate of Taxes and Customs, Colombian Department of Statistics, Electronic system of Public Contracting, the Ministry of Finance and Public Credit of Colombia, The National Center for Historical Memory, Conflict Analysis Resource Center, the Illicit Crop Monitoring System in Colombia of the United Nations Office on Drugs and Crime and National Planning Department. The selection of every variable used in the various techniques and time

periods was established by the availability and reliability of detailed data for the Colombian departments from 2001 to 2015.

In this research, cluster analysis is used. Colombian departments are separated among departments with a moderate level of corruption and violence, and a low level of corruption and violence using k-means clustering, Cotte (2012, 2014). In mathematical terms, we seek to minimise (Types, 2000),

$$SSE = \sum_{i=1}^{K} \sum_{\overrightarrow{x} \in C_i} \| \overrightarrow{x} - \overrightarrow{C}_i \|^2 = \sum_{i=1}^{K} \sum_{\overrightarrow{x} \in C_i} \sum_{j=1}^{d} (x_j - c_{ij})^2. \tag{1}$$

Data envelopment analysis (DEA) is a method applies linear programming to design a non-parametric boundary and allow comparison of relative efficiencies. The CCR DEA structure was applied by Charnes et al. (1978) with the following relationships:

$$\max \lambda_0 (\gamma, \delta) = \frac{\sum_{j=1}^{n} \gamma_j w_{j0}}{\sum_{i=1}^{m} \delta_i h_{i0},} \tag{2}$$

Restricted to:

$$\frac{\sum_{j=1}^{n} \gamma_j w_{if}}{\sum_{i=1}^{m} \delta_i h_{if}} \leq 1; f = 1, \ldots, n, \tag{3}$$

$$\gamma_j \delta_i \geq 0; j = 1, \ldots, n; \ i = 1, \ldots, m, \tag{4}$$

The data envelope analysis is a linear programming model, in line with Charnes − Cooper the maximization can be expressed as:

$$\max z = \sum_{j=1}^{n} \gamma_j w_{j0},$$

subject to,

$$\sum_{j=1}^{n} \delta_i w_{jf} - \sum_{i=1}^{m} \delta_i h_{if} \leq 0 \tag{5}$$

$$\sum_{i=1}^{m} \delta_i h_{i0} = 1$$

$$\gamma_j \delta_i \geq 0, \quad i = 1, \ldots, m; \ j = 1, \ldots, n$$

The number of decision making units (DMUs) increase with the number of degrees of freedom and and decrease with the number of inputs and outputs. Cooper et al. (2007) propose a rule to count the DMUs number.

$$\xi \geq \max\{\gamma \ x \phi , 3(\gamma + \phi)\} \tag{6}$$

Where $\xi = DMUs$, $\gamma = inputs$ and $\phi = outputs$.

In this research, following, Cotte (2014), the inputs are delimited as a desired characteristic and the outputs are delimited as a non-desirable characteristic. The model of Data Envelopment Analysis for this investigation is based on three desired characteristics (inputs) for the variables: level of education, captures of criminals and number of police officers for each department and period. The outputs of the estimation are based on: the violence that is measured by the homicide rate and a variable of corruption that is measured according to international literature, Cotte (2014:377).

To compare the results of the DEA estimates and other corruption and violence indicators we use the nonparametric Wilcoxon signed ranks test. The test does not depend on distributional assumptions of the dataset. With the test the hypothesis that the distribution of X-measurement in population A is the same as in population B can be proved, Shahroudi (2009). In this hypothesis, the sample of observations is denominated A (the effectiveness index of the control of homicides in Colombian departments (ICV) or the transparency index by department (ITD)) and B (the DEA), also the scores containing η_A and η_B observations, respectively. The null hypothesis is as follows:

H0: *The DEA and the ICV or ITD have the same probability distribution.*

To calculate the statistical the sum of the ranking of group A is performed. Using the central limit theorem the statistical follows a normal distribution with mean $m(m + n + 1)/2$ and variance $mn(m + n + 1)/12$. Therefore the standardized statistic is given by:

$$T = \frac{S - m(m+n+1)/2}{\sqrt{mn(m+n+1)/12}}, \tag{7}$$

Where S is the sum of the rankings for group A. The number of DMUs is m, and n is the number of DMUs in the other group. The statistical $T \sim N(0, 1)$, see Cooper et al. (2007).

The panel present a time dimension T relatively close to the number of departments, therefore the possibility of cointegrated panels was analysed using the Pedroni (2001) methodology. Nevertheless the panels used in the model do not exhibit a unit root. The null hypothesis of unit root was tested using the individual unit root test of Im et al. (2003) and the common unit root test proposed by Levin et al. (2002).

The dynamic structure of the dataset is modelled with a dynamic panel. To estimate the parameters in the model the generalized method of moments (GMM) is used, Arellano and Bover (1995) y Blundell and Bond (1998). The method uses lagged

differences as instruments. It is most likely that simultaneity and measurement errors are present in our data set. This methodology can resolve both problems, and also by includes lags of the dependent variable the omitted variables bias can be attenuated, Cotte (2012).

The regression model for violence and corruption is:

$$y_{i,t} = \beta_1 y_{i,t-1} + \beta_2 X_{i,t} + \eta_i + \varepsilon_{i,t}. \tag{8}$$

Equation (8) and a GMM method are employed to obtain consistent results of the variables relevant and to adjust for bias originated by endogenous explanatory variables. The models estimated in this research are.

$$\widehat{\Omega}_{i,t} = \alpha_1 \widehat{\Omega}_{i,t-1} + \alpha_2 GINI_{i,t} + \alpha_3 UBN_{i,t} \, \alpha_4 \varphi_{i,t} + \xi_i + \varepsilon_{i,t,} \tag{9}$$

where $\widehat{\Omega}_{i,t}$ is the DEA index of the measure of violence and corruption for each department in time t for department i, $\widehat{\Omega}_{i,\,t-1}$ is the lagged index measuring corruption and homicides, inequality measure and a poverty indicator. On the other hand $\varphi_{i,\,t}$ is a vector that contains the following variables: budget execution, GDP per capita, hectares hectares of cultivated drugs, confiscated drugs, hectares of eradicated drugs, mineral extraction, political participation, oil extraction, extraction of metallic minerals, extraction of other non-metallic minerals and criminal actions for department i in period t.

Recently other panel data estimators were proposed by Bruno (2005), Everaert and Pozzi (2007) and Gouriéroux et al. (2010). Using Monte Carlo simulations this authors show that their estimators outperform, in terms of bias reduction, the Arellano and Bover (1995) and Blundell and Bond (1998) estimators. The result is based in certain conditions; one is that the autoregressive parameter α_1 presents a large magnitude. In the fourth section of this study it is observed that this is not the case here. Actually the Blundell and Bond (1998) estimator were developed to reduce the bias generated by large α_1 in the usual level model and first difference variables as instruments. When α_1 is moderately small and a stationary panel the Arellano and Bover (1995) has good properties in finite samples.

3. Results & discussion

The Figs. 1 and 2 and Table 1 shows the results of the classification of the Colombian government departments by corruption and violence levels using cluster analysis. There are clusters of mid-level corruption and violent activities around a number of departments in different Colombian regions. The economic activities in these departments are somewhat varied, but they predominantly consist of the mining, agriculture and livestock industries. Finally, the departments

Fig. 1. Results of DEA analysis for the period 2001−2015. Middle level risk of violence and corruption. (a) Atlántico (b) Antioquia (c) Boyacá (d) Córdoba (e) Caldas (f) Cundinamarca (g) Andrés (h) Quindio (i) Valle.

with a moderate level of corruption and homicides are mainly in charge of the west and centre regions. Several of these departments, which manage large populations, have the highest levels of development, and their primary economic activities include agriculture, livestock, and industry.
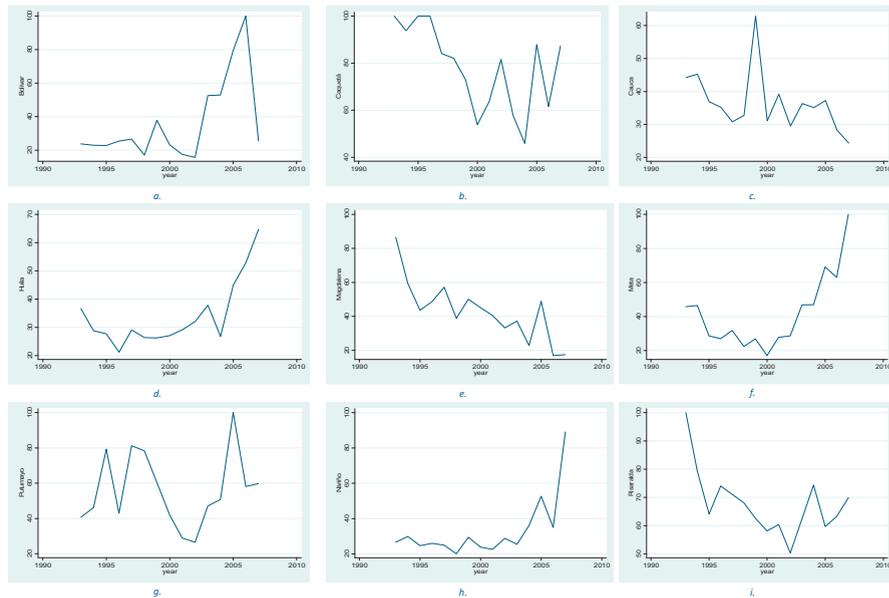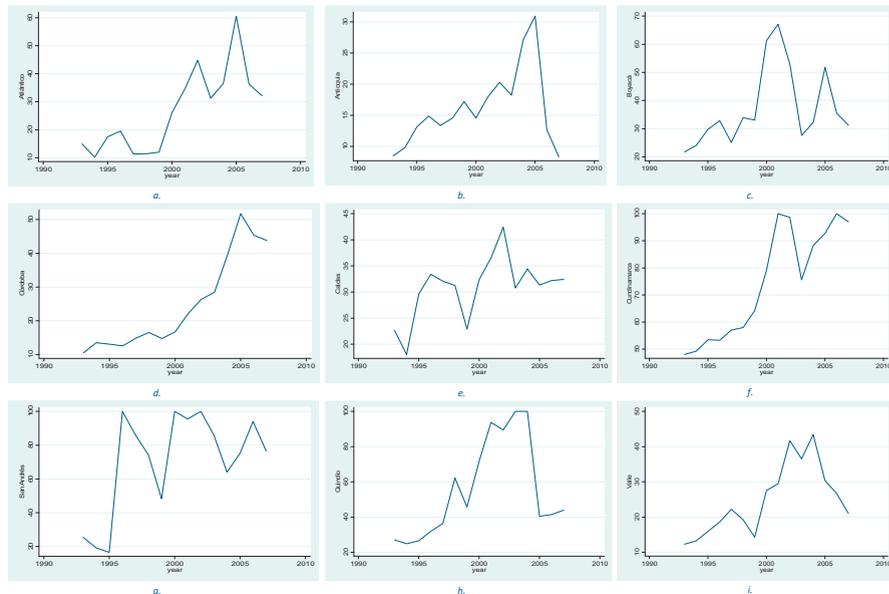

Fig. 2. Results of DEA analysis for the period 2001−2015. Moderate level risk of violence and corruption. (a) Atlántico (b) Antioquia (c) Boyacá (d) Córdoba (e) Caldas (f) Cundinamarca (g) Andrés (h) Quindio (i) Valle.

Table 1. Scores of the Data Envelopment Analysis model for Colombian departments by risk level of corruption-violence.

Departments	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Mean annual	Rank
Middle-Level Risk of Corruption and Violence																	
Bolivar	23.73	22.91	22.76	25.43	26.57	17.13	37.75	23.15	17.47	15.67	52.53	52.89	79.36	100.0	25.51	36.19	8
Caquetá	100.0	93.76	100.0	100.0	84.01	82.12	73.07	53.88	63.62	81.58	57.82	45.93	87.90	61.61	87.29	78.17	1
Cauca	44.20	45.22	36.91	35.20	30.79	32.74	62.87	31.10	39.16	29.52	36.36	35.12	37.24	28.23	24.36	36.60	7
Huila	36.61	28.80	27.71	21.22	29.07	26.38	26.25	27.07	29.12	32.07	37.86	26.82	45.01	52.86	64.70	34.10	10
Magdalena	86.56	59.50	43.58	48.79	57.15	38.85	50.10	45.04	40.58	33.27	37.22	22.85	48.82	16.93	17.44	43.11	4
Meta	45.78	46.47	28.60	26.94	31.78	22.36	26.88	17.11	27.79	28.61	46.83	46.93	69.13	62.97	100.0	41.88	5
Nariño	26.60	29.82	24.67	25.96	24.92	20.12	29.46	23.78	22.55	28.87	25.41	36.08	52.64	34.95	89.10	33.00	11
Putumayo	40.77	46.20	79.25	42.94	81.23	78.40	60.29	41.84	28.90	26.50	47.11	50.73	100.0	58.14	59.73	56.14	3
Risaralda	100.0	79.28	64.13	74.05	71.06	68.06	62.58	58.13	60.42	50.32	62.38	74.39	59.68	63.27	69.93	67.85	2
Santander	51.69	31.31	25.39	29.44	44.13	38.86	90.39	34.67	27.09	19.21	26.49	24.39	38.43	18.47	27.90	35.19	9
Tolima	42.96	28.81	25.61	24.74	23.90	21.67	34.60	26.05	21.20	18.75	83.97	97.79	55.65	48.40	25.76	38.66	6
Moderate-Level Risk of Corruption and Violence																	
Antioquia	8.49	9.82	13.14	14.87	13.38	14.54	17.18	14.58	17.90	20.29	18.23	27.10	30.93	12.67	8.33	16.10	9
Atlántico	14.96	10.16	17.48	19.52	11.34	11.40	11.98	26.10	34.40	44.78	31.24	36.45	60.55	36.30	32.13	26.59	6
Boyacá	21.77	24.05	29.78	32.86	25.08	33.93	33.04	61.33	67.09	52.83	27.61	32.27	51.73	35.52	31.26	37.34	4
Caldas	22.64	18.03	29.61	33.40	32.08	31.26	22.90	32.39	36.56	42.44	30.78	34.45	31.36	32.22	32.43	30.84	5
Córdoba	10.48	13.52	13.04	12.55	14.82	16.53	14.73	16.69	22.08	26.36	28.43	39.52	51.72	45.42	43.82	24.65	8
Cundinamarca	48.02	49.22	53.43	53.26	57.04	57.97	64.24	78.96	100.0	98.69	75.56	88.28	92.72	100.0	97.05	74.30	1
Quindío	27.05	24.86	26.58	31.87	36.39	62.22	45.76	71.73	93.83	89.47	100.0	100.0	40.45	41.38	43.94	55.70	3
San Andrés	25.46	19.19	16.55	100.0	86.21	74.05	48.33	100.0	95.47	100.0	85.95	64.09	75.33	94.01	76.54	70.75	2
Valle	12.28	13.21	15.92	18.64	22.21	19.25	14.29	27.55	29.46	41.69	36.55	43.39	30.39	26.68	21.04	24.84	7

These results show that corruption and violence have different trends within the Colombian departments and that issues such as economic growth and development, economic activities, localisation, natural resources, and political instability may determine higher or lower levels of corruption and violence. Various studies have demonstrated that a culture of impunity, political instability, and low economic growth and development are integral factors of corruption and homicides (Pellegrini and Gerlagh, 2008; Zaum and Cheng, 2008; World Bank, 2003).

The estimates of the data envelopment analysis are shown in Figs. 1 and 2, Tables 1 and 2. The average indicator for all Colombian departments during the sample period is 47.04. The departments with the best results are Arauca, Caquetá, Casanare, Cesar, and Cundinamarca, whereas Antioquia, Sucre, Córdoba, Valle, and Atlántico display the worst performances. The scores of the DEA model are similar for the Colombian regions.

Figs. 1 and 2 and Tables 1 and 2 show the results of the DEA model by the level of risk for the Colombian departments. The departments with middle levels of risk for corruption and violence, the average score is 45.54. Caquetá, Risaralda, and Putumayo have the best performance, whereas Nariño, Huila, and Santander show the worst performance. The departments with moderate-to-high levels of risk for corruption and violence have an average score of 40.12. Cundinamarca, San Andrés, and Quindío have the best scores, whereas Antioquia, Atlántico, and Valle show the worst performance. Comparing the two levels of risks for corruption and violence, the majority of the departments with a high level of risk for corruption and homicides are above average, whereas the departments with middle and moderate levels of risk for corruption and homicides are below average (see Figs. 1 and 2). In other words, these departments may be more inclined towards an increase in the level of risk for corruption and homicides.

The results of the DEA model by region show that regions vary in their patterns of the level of risk for corruption and violence. Caribbean and Orinoquía regions have more departments with higher levels of risk for corruption and violence. The middle level of risk for corruption and violence predominates in the Centre-East, Caribbean, and Amazonian regions. Finally, the moderate level of risk for corruption and violence is concentrated in the West, Caribbean, and Centre-East regions. The average scores by region range from 64.83 to 40.76.

The Wilconxon test supports the null hypothesis. The indexes present the same probability distribution. In Table 3 the results of the test are presented, the DEA model applied in this study is adequate to measure violence, corruption, and economic development.

The estimates with the technique of DEA evidence fluctuation in the DEA index for Colombian departments. To interpret these fluctuations, the DEA model applies

Table 2. Scores of the Data Envelopment Analysis by Colombian regions.

Departments	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Mean annual	Rank	Risk
Amazonian Region																		
Amazonas	18.16	10.99	10.99	4.39	8.86	3.14	99.42	5.51	0.51	2.29	47.84	99.23	36.55	70.64	100.0	34.57	7	H
Caquetá	100.0	93.76	100.0	100.0	84.01	82.12	73.07	53.88	63.62	81.58	57.82	45.93	87.90	61.61	87.29	78.17	1	Mid
Putumayo	40.77	46.20	79.25	42.94	81.23	78.40	60.29	41.84	28.90	26.50	47.11	50.73	100.0	58.14	59.73	56.14	3	Mid
Caribbean Region																		
Atlántico	14.96	10.16	17.48	19.52	11.34	11.40	11.98	26.10	34.40	44.78	31.24	36.45	60.55	36.30	32.13	26.59	6	Mod
Córdoba	10.48	13.52	13.04	12.55	14.82	16.53	14.73	16.69	22.08	26.36	28.43	39.52	51.72	45.42	43.82	24.65	8	Mod
Magdalena	86.56	59.50	43.58	48.79	57.15	38.85	50.10	45.04	40.58	33.27	37.22	22.85	48.82	16.93	17.44	43.11	4	Mid
Bolivar	23.73	22.91	22.76	25.43	26.57	17.13	37.75	23.15	17.47	15.67	52.53	52.89	79.36	100.0	25.51	36.19	8	Mid
Sucre	23.07	27.02	27.02	34.71	30.95	19.95	13.17	19.90	15.04	13.92	14.63	11.32	49.00	7.00	8.80	21.03	9	H
San Andrés	25.46	19.19	16.55	100.0	86.21	74.05	48.33	100.0	95.47	100.0	85.95	64.09	75.33	94.01	76.54	70.75	2	Mod
Guajira	100.0	95.93	95.93	60.43	73.29	60.82	73.35	78.26	80.23	92.21	100.0	100.0	100.0	75.97	100.0	58.32	5	H
Cesar	82.66	72.81	72.81	64.32	62.73	34.58	40.41	48.89	52.99	56.24	65.80	52.46	75.68	35.34	57.07	74.99	3	H
Centre-East Region																		
N. Santander	83.69	71.11	71.11	61.88	54.41	50.50	100.0	71.61	71.82	91.17	84.05	59.17	63.20	47.56	47.51	27.22	8	H
Santander	51.69	31.31	25.39	29.44	44.13	38.86	90.39	34.67	27.09	19.21	26.49	24.39	38.43	18.47	27.90	35.19	9	Mid
Boyacá	21.77	24.05	29.78	32.86	25.08	33.93	33.04	61.33	67.09	52.83	27.61	32.27	51.73	35.52	31.26	37.34	4	Mod
Cundinamarca	48.02	49.22	53.43	53.26	57.04	57.97	64.24	78.96	100.0	98.69	75.56	88.28	92.72	100.0	97.05	74.30	1	Mod
Tolima	42.96	28.81	25.61	24.74	23.90	21.67	34.60	26.05	21.20	18.75	83.97	97.79	55.65	48.40	25.76	38.66	6	Mid

Heliyon

Article No~e01496

Table 2. (*Continued*)

Departments	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Mean annual	Rank	Risk
Huila	36.61	28.80	27.71	21.22	29.07	26.38	26.25	27.07	29.12	32.07	37.86	26.82	45.01	52.86	64.70	34.10	10	Mid
West Region																		
Caldas	22.64	18.03	29.61	33.40	32.08	31.26	22.90	32.39	36.56	42.44	30.78	34.45	31.36	32.22	32.43	30.84	5	Mod
Risaralda	100.0	79.28	64.13	74.05	71.06	68.06	62.58	58.13	60.42	50.32	62.38	74.39	59.68	63.27	69.93	67.85	2	Mid
Quindío	27.05	24.86	26.58	31.87	36.39	62.22	45.76	71.73	93.83	89.47	100.0	100.0	40.45	41.38	43.94	55.70	3	Mod
Antioquia	8.49	9.82	13.14	14.87	13.38	14.54	17.18	14.58	17.90	20.29	18.23	27.10	30.93	12.67	8.33	16.10	9	Mod
Pacific Region																		
Nariño	26.60	29.82	24.67	25.96	24.92	20.12	29.46	23.78	22.55	28.87	25.41	36.08	52.64	34.95	89.10	33.00	11	Mid
Valle	12.28	13.21	15.92	18.64	22.21	19.25	14.29	27.55	29.46	41.69	36.55	43.39	30.39	26.68	21.04	24.84	7	Mod
Cauca	44.20	45.22	36.91	35.20	30.79	32.74	62.87	31.10	39.16	29.52	36.36	35.12	37.24	28.23	24.36	36.60	7	Mid
Chocó	35.86	32.27	32.27	41.61	64.98	40.37	22.22	31.19	18.81	31.42	9.40	12.42	19.41	8.84	7.30	68.59	4	H
Orinoquia Region																		
Arauca	89.20	58.96	58.96	66.49	92.40	63.87	62.73	44.57	67.85	94.40	78.33	65.57	100.0	99.47	82.00	85.76	1	H
Meta	45.78	46.47	28.60	26.94	31.78	22.36	26.88	17.11	27.79	28.61	46.83	46.93	69.13	62.97	100.0	41.88	5	Mid
Casanare	74.84	62.81	62.81	60.61	57.34	67.77	51.40	44.62	57.07	49.03	46.28	44.72	48.98	40.85	45.55	77.38	2	H
Guaviare	77.08	74.02	74.02	100.0	90.25	97.00	38.51	58.13	87.49	73.02	68.66	61.72	93.33	67.44	100.0	54.31	6	H

Table 3. The compared efficiency scores from the Wilcoxon signed ranks test.

Pairs	Wilcoxon signed ranks test	
	Z	**P-value**
All Colombian departments		
DEA vs. ICV	-3.903	0.0001
DEA vs. ITD	-3.362	0.0008
High-Level Risk of Corruption-Violence		
DEA vs. ICV	-2.666	0.0077
DEA vs. ITD	-2.666	0.0077
Middle-Level Risk of Corruption-Violence		
DEA vs. ICV	-2.756	0.0058
DEA vs. ITD	-2.490	0.0128
Moderate-Level Risk of Corruption-Violence		
DEA vs. ICV	-2.666	0.0077
DEA vs. ITD	-2.310	0.0209

Notes: ICV: Effectiveness index of the control of violence.
ITD: Transparency index by department.

Table 4. Dependent variable: Violence-Corruption DEA score. All Colombian departments.

Variables	[1]	[2]	[3]	[4]
Constant	4.046 [a] (1.019)	3.989 [a] (1.019)	3.933 [a] (1.020)	4.171 [a] (1.048)
Lagged homicides- corruption score	0.165 [b] (0.070)	0.173 [b] (0.069)	0.162 [b] (0.070)	0.159 [b] (0.068)
Budget execution	-0.160 [a] (0.056)	-0.156 [a] (0.055)	-0.149 [a] (0.055)	-0.159 [a] (0.056)
GDP per capita	0.121 [a] (0.039)	0.120 [a] (0.039)	0.121 [a] (0.039)	0.120 [a] (0.039)
Hectares under drug cultivation	-0.009 (0.026)	-0.005 (0.026)	-0.007 (0.027)	-0.004 (0.027)
Drugs seized	0.006 (0.014)	0.005 (0.014)	0.005 (0.014)	0.006 (0.014)
Hectares under drug cultivation eradicated	0.003 (0.006)	0.002 (0.006)	0.002 (0.006)	0.003 (0.006)
GINI	-2.495 [a] (0.719)	-2.540 [a] (0.722)	-2.505 [a] (0.723)	-2.459 [a] (0.723)
Unsatisfied basic needs	-0.012 [b] (0.006)	-0.014 [b] (0.006)	-0.012 [b] (0.006)	-0.013 [b] (0.006)
Mining production	-0.074 [c] (0.041)	-0.064 (0.042)	-0.077 [c] (0.041)	-0.078 [c] (0.041)
Political participation	-0.338 (0.461)	-0.373 (0.462)	-0.318 (0.472)	-0.364 (0.463)
Armed actions	-0.000 (0.001)			
Actions National Liberation Army (ELN)		-0.002 (0.001)		
Actions Popular Liberation Army (EPL)			-0.001 (0.002)	
Actions Common Crime and criminal organisations				-0.001 (0.001)
Specification test (p-values)				
Sargan test	0.056	0.071	0.060	0.058
Second-order Correlation	0.229	0.179	0.240	0.231
No. Obs	170	170	170	170

Notes: All models are estimated using the Arellano-Bover/Blundell-Bond linear dynamic panel-data system GMM estimations. Figures in parentheses are standard errors. [a] Significant at the 1% level, [b] Significant at the 5% level, [c] Significant at the 10% level.

Table 5. Dependent variable: Violence and Corruption Data Envelopment Analysis results. Departments with middle-level risk of violence and corruption.

Variables	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Constant	1.419 (1.719)	4.518 [a] (1.604)	1.261 (1.375)	3.048 [c] (1.707)	3.301 [b] (1.676)	2.832 [c] (1.641)	3.159 [c] (1.705)
Lagged homicides-Corruption score	0.328 [a] (0.099)	0.298 [a] (0.100)	0.331 [a] (0.100)	0.377 [a] (0.112)	0.368 [a] (0.104)	0.358 [a] (0.104)	0.337 [a] (0.105)
Drugs seized	0.019 (0.023)	0.021 (0.024)	0.019 (0.023)	0.025 (0.026)	0.027 (0.025)	0.027 (0.025)	0.033 (0.025)
Hectares under drug cultivation eradicated	0.011 (0.009)	0.009 (0.008)	0.011 (0.009)	0.008 (0.009)	0.009 (0.009)	-0.008 (0.009)	0.009 (0.009)
GINI	-3.310 [b] (1.317)	-0.184 (0.737)	-3.259 [b] (1.339)	-0.434 (0.725)	-0.418 (0.708)	-0.375 (0.728)	-0.343 (0.743)
Unsatisfied basic needs	-0.059 (0.309)	-0.376 (0.459)	-0.051 (0.303)	-0.307 (0.481)	-0.370 (0.479)	-0.236 (0.473)	-0.237 (0.478)
Budget execution	-0.016 (0.068)						
Production of coal, lignite and peat.		-0.105 [a] (0.032)					
Production of Metallic minerals		-0.000 (0.000)					
Production of other non-metallic minerals		-0.087 (0.061)					
Armed actions			-0.019 (0.063)				
Actions Revolutionary Armed Forces of Colombia (FARC)				-0.001 (0.002)			
Actions National Liberation Army (ELN)				-0.001 (0.003)			
Actions Popular Liberation Army (EPL)				-0.004 (0.006)			
Actions United Self-Defence Forces of Colombia (AUC) − Paramilitary					-0.014 [c] (0.008)		
Actions Common Crime and criminal organisations						0.001 (0.001)	
Political Participation							-0.681 (0.862)
Specification test (p-values)							
Sargan test	0.129	0.152	0.127	0.101	0.149	0.085	0.111
Second-order Correlation	0.573	0.643	0.576	0.776	0.657	0.826	0.566
No. Obs	99	99	99	99	99	99	99

Notes: All models are estimated using the Arellano-Bover/Blundell-Bond linear dynamic panel-data system GMM estimations. Figures in parentheses are standard errors. [a] Significant at the 1% level, [b] Significant at the 5% level, [c] Significant at the 10% level.

Table 6. Dependent variable: Violence and Corruption Data Envelopment Analysis results. Departments with a moderate level of violence-corruption.

Variables	[1]	[2]	[3]	[4]	[5]
Constant	0.969 [c] (0.588)	5.921 [a] (1.265)	5.541 [a] (1.448)	5.518 [a] (1.458)	5.546 [a] (1.437)
Lagged homicides-corruption score	0.721 [a] (0.072)	0.630 [a] (0.071)	0.625 [a] (0.072)	0.624 [a] (0.072)	0.604 [a] (0.073)
Budget execution	-0.030 (0.040)	-0.035 (0.038)	-0.013 (0.053)	-0.013 (0.054)	-0.017 (0.053)
Cocaine seized	0.032 [b] (0.015)	0.031 [b] (0.014)	0.029 [b] (0.014)	0.029 [b] (0.014)	0.028 [b] (0.014)
Cocaine paste seized	0.030 (0.040)	0.071 (0.029)	0.074 [b] (0.029)	0.013 (0.054)	0.080 [a] (0.029)
GINI	-0.166 (1.227)	-0.626 (1.172)	-0.583 (1.184)	-0.581 (1.190)	-0.507 (1.177)
Unsatisfied basic needs		-1.325 [a] (0.303)	-1.230 [a] (0.367)	-1.221 [a] (0.372)	-1.165 [a] (0.367)
Mining production			-0.019 (0.039)	-0.019 (0.039)	-0.026 (0.039)
Armed actions				-0.000 (0.001)	
Actions Common Crime and criminal organisations					-0.001 (0.001)
Specification test (p-values)					
Sargan test	0.110	0.243	0.195	0.201	0.201
Second-order Correlation	0.479	0.452	0.505	0.563	0.561
No. Obs	123	123	123	123	123

Notes: All models are estimated using the Arellano-Bover/Blundell-Bond linear dynamic panel-data system GMM estimations. Figures in parentheses are standard errors. [a] Significant at the 1% level, [b] Significant at the 5% level, [c] Significant at the 10% level.

Generalised Method of Moment estimations for panel data. Tables 4, 5, and 6, illustrate the estimates of the econometric models with dynamic data panel, including those with middle-level risk, and moderate-level risk of corruption and homicides.

Table 4 shows the results for all Colombian departments. The lagged homicide-corruption score has a significant impact on the corruption-violence score, which suggests that corruption and homicides persist over time. Several studies have discussed various causes for this persistence of corruption and violence. The main reasons are as follows: (*i*) corruption and violent activities may become more beneficial to criminals and corrupt individuals because these groups gain more expertise, and, especially for criminal individuals, legal labour market opportunities decrease as their criminal records increase; (*ii*) the reduction in the social cost of criminal and corrupt behaviour generates more criminal and corruption activities because of the lack of a proper response from the legal system in the use of appropriate sanctions, penalties and sentences that would discourage criminal and corrupt activities; and (*iii*) the persistence of corruption and violence may reveal links between violence, corruption and other socio-economic conditions that are persistent over time (Glaeser et al., 1996; Fajnzylber et al., 2000; Levinson, 2002; Mocan et al., 2005).

Both the GINI coefficients and the Unsatisfied Basic Needs measurement show that there is a negative and significant relationship between a higher corruption and

violence score and departments with higher income inequality and poverty. Various studies have demonstrated that the primary cause of poverty, inequality, and violence is corruption, which is illustrative of poor governance and mismanagement. Indeed, corruption and violence increase transaction costs, making financial aspects more difficult for the poor, and they corrode the development of societies. Furthermore, corruption generates and deepens social rupture while increasing social discrimination and societal segmentation (Gupta et al., 1998; Narayan et al., 2000; Eberlei and Führmann, 2004).

Variables representing economic development show that departments with lower budget execution and mining extraction have higher levels of corruption and homicides, whereas departments with higher GDP per capita generate lower corruption and violence. These results are consistent with various studies in the Colombian context that argue that budget execution is low in departments with higher mining exploitation. Therefore, criminal and corrupt individuals have more opportunities to pursue criminal activities because these departments receive substantial royalties from the exploitation of mineral resources (Gamarra, 2006; Fisher, 2007). Likewise, as illustrated in the results, the presence of armed groups and illegal drug trade in these zones generates a higher level of corruption and violence, although these variables are not significant in the model.

Table 5 shows the results for departments with a middle-level risk of corruption and homicides. In these departments, the lagged homicide-corruption score, the GINI coefficient, the production of coal, lignite, and peat, and the actions of paramilitaries are significantly correlated with the corruption-violence score. This indicates that corruption and homicides persist over time and that higher inequality, production of coal lignite and peat and actions of paramilitaries generate higher corruption and violence.

This result illustrates the close relationship between corruption, violence and the illegal drug trade. Because Colombian illegal arms groups principally finance their activities using narcotics trafficking, they become a cause of corruption. Moreover, in Colombia, the corruption that is usually linked to violence and the narcotics trade has implicated powerful legislators, judges, and military officials (Charry, 2002; Rodriguez and Seligson, 2008; Acemoglu et al., 2010), supporting the results of this study.

The variable of political participation shows that an increase in this variable generates a lower corruption-violence score. Thus, in departments with active, effective, and democratic institutions, an effective and independent judicial system, and active political participation, there is an increase in the probability of detection and punishment of corrupt and criminal activities, thereby reducing corruption and violence over time, in accordance with Sandholtz and Koetzle (2000), Bohara et al. (2004), and Saha and Campbell (2007), among others.

The estimations of the econometric model for departments with a moderate level of risk for corruption and homicides are described in Table 6. A lagged homicide-corruption score, the estimates for cocaine and cocaine paste seized and the unsatisfied basic needs are variables with significant effects on the corruption-violence score. Therefore, departments with higher cocaine and cocaine paste trafficking have lower levels of corruption and homicides, whereas departments with higher unsatisfied basic needs have higher levels of corruption and homicides, which tends to remain for an extended period of time.

Furthermore, the results indicate direct relationships between poverty and inequality and the corruption-violence score, which is characterised by low income, poor health and education status, lack of opportunities in the labour market, insecurity, poor government and public management, and other features that decrease economic growth and development. In the literature, the relationship between poverty, corruption, and violence can be explained by two models. (*i*) The *economic model* argues that corruption and violence affect poverty and inequality by altering and discouraging economic growth and development factors, such as foreign and domestic investments, taxing and dampening entrepreneurship, lowering the quality of public infrastructure, decreasing tax revenue, distorting the composition of public expenditure and budget execution, and forcing households and businesses to pay a higher proportion of their income in bribes, thus lowering the income of both households and businesses. (*ii*) The *governance model* argues that corruption and violence affect poverty because they affect governance factors, leading to a reduction in governance capacity and generating weak political institutions, lower citizen participation, a decrease in productivity, and a lower quality of government management, services, security and infrastructure (World Bank, 2000; Mauro, 2002; Kaufmann and Kraay, 2002; Chetwynd et al., 2003; Goel and Nelson, 2010).

The estimations of this research illustrate that Colombian departments that have low economic growth, and socioeconomics circumstances and extraction of mineral, illegal drug traffic, and the existence of armed groups are susceptible to higher corruption and homicides. This finding illustrates This investigation explains the importance of framework legal and strong, reasonable and efficient institutions, and governance and public management systems that contribute necessary attributes, all of which are indispensable to interrupt the vicious circle of corruption and homicides in Colombia.

4. Conclusions

In this research the different dynamic interactions between institutional variables, instability and economic development taking as a case study to Colombia during

the 2001−2015 period given the availability of data is displayed. Several measurement techniques are used to contrast the main findings of the work, also the different estimates were presented using different empirical methodologies and consistency tests, including cluster analysis, the DEA, dynamic panel data models, these models are accompanied by evidence of robustness and reliability with the application of the test data envelopment analysis DEA degrees of freedom for DMUs, the Wilcoxon analysis and dynamic panel data with the Sargan test. The techniques used in this research show that models generate consistent estimates applied in the institutional economic analysis of homicides, corruption and economic growth.

The main findings of the study show consistent estimates with empirical evidence showing how corruption and homicides over time have adverse effects on economic development. The results indicate that by not fighting corruption, productivity, investment, capital and, therefore, economic growth and development decreases over time. From this perspective, the regression analysis using panel data techniques showed that poverty, inequality, drug trafficking, the actions of armed agents affect violence. It was also established that corruption negatively affects business growth. From the methodology and techniques employed, it was determined that these variables are suitable to analyze the incidence of corruption and violence in the growth and economic development.

Our framework suggests that appropriate institutional policy is to strengthen the interactions between different economic agents, transparent participation in decision-making adequate and strengthened governance, strengthening the judicial system and adequate efficient resource allocation system. This would greatly decrease the vicious cycle that hampers development and economic growth of countries, Cotte (2011).

Declarations

Author contribution statement

Alexander Cotte Poveda, Jorge Enrique Martínez Carvajal, Nicolas Ronderos Pulido: Conceived and designed the analysis; Analyzed and interpreted the data; Contributed analysis tools or data; Wrote the paper.

Funding statement

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

References

Acemoglu, D., Robinson, J., Santos, R., 2010. The Monopoly of Violence: Evidence from Colombia. NBER Working Paper No. 15578. http://econ-www.mit.edu/files/5561.

Arellano, M., Bover, O., 1995. Another look at the instrumental variable estimation of error-components models. J. Econom. 68, 29−51.

Blackman, A., Morgenstern, R., Topping, E., 2006. Institutional Analysis of Colombia's Autonomous Regional Corporations (Cars). Resources for the future. http://www.rff.org/rff/documents/rff-rpt-colombiacars.pdf.

Blundell, R., Bond, S., 1998. Initial conditions and moment restrictions in dynamic panel data models. J. Econom. 87, 115−143.

Bohara, A., Mitchell, N., Mittendorff, C., 2004. Compound democracy and the control of corruption: a cross-country investigation. Pol. Stud. J. 32, 481−499.

Bruno, G.S., 2005. Estimation and inference in dynamic unbalanced panel-data models with a small number of individuals. STATA J. 5 (4), 473−500.

Cieślik, A., Goczek, Ł., 2018. Control of corruption, international investment, and economic growth−Evidence from panel data. World Dev. 103, 323−335.

Charnes, A., Cooper, W., Rhodes, E., 1978. Measuring efficiency of decision making units. Eur. J. Oper. Res. 2, 429−444.

Charry, H., 2002. For a global approach to fighting corruption: Colombia's steps towards transparency. Forum Crime Soc. 2, 147−151.

Chetwynd, E., Chetwynd, F., Spector, B., 2003. Corruption and poverty: a review of recent literature. Management Systems International. Final Report.

Cooper, W., Seiford, L., Tone, K., 2007. Data Envelopment Analysis. A Comprehensive Text with Models, Applications, References and DEA-Solver Software, second ed. Springer.

Cotte, A., 2011. Economic development and growth in Colombia: an empirical analysis with super-efficiency DEA and panel data models. J. Soc. Econ. Plan. Sci. 45 (4), 154−164.

Cotte, A., 2012. Estimating effectiveness of the control of violence and socioeconomic development in Colombia: an application of dynamic data envelopment analysis and data panel approach. Soc. Indicat. Res. 105, 343−366.

Cotte, A., 2014. Corruption, economic development and insecurity in Colombia: evidence from data envelopment analysis (DEA) and dynamic panel data model (DPDM). In: Osman I, Latef A and Emrouznejad (Ed.), Handbook of Research on Strategic Performance Management and Measurement Using Data Envelopment Analysis. IGI Global: International Publisher of Science and Technology.

Cotte, A., 2017a. Corruption and ethics in the professions: the case of the economy. Revista CIFE: Lecturas de Economía Social 19 (30), 17−22.

Cotte, A., 2017b. Economic development, violence and corruption. Revista CIFE: Lecturas de Economía Social 19 (31), 17−21.

Cotte, A., Martinez, J., 2019. Economic development, political violence and socio-political instability in Colombia: an econometric analysis using panel data. Eur. Res. Stud. J. XXII (1), 237−253.

Eberlei, W., Führmann, B., 2004. Fighting Poverty and Corruption. Integrating the Fight against Corruption into the PRS Process −Analysis and Recommendations for Development Cooperation. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). http://www.u4.no/document/literature/gtzfightingpoverty.pdf.

Everaert, G., Pozzi, L., 2007. Bootstrap-based bias correction for dynamic panels. J. Econ. Dyn. Control 31 (4), 1160−1184.

Fajnzylber, P., Lederman, D., Loayza, N., 2000. Crime and victimization: an economic perspective. Economia, fall 2000. J. Latin Am. Caribb. Econ. Assoc. 1, 219−248.

Fisher, C., 2007. International Experience with Benefit-Sharing Instruments for Extractive Resources. Resources for the future. http://www.rff.org/rff/Documents/RFF-Rpt-Benefit Sharing.pdf.

Gamarra, J., 2006. Poverty, corruption and political participation: a review for the Colombian case. Serie Documentos de Trabajo Sobre Economía Regional No. 70. http://www.banrep.gov.co/documen tos/publicaciones/regional/documentos/DTSER-70%20(VE).pdf.

Glaeser, E., Sacerdote, B., Scheinkman, J., 1996. Crime and social interactions. Q. J. Econ. CXI, 507−548.

Goel, R., Nelson, M., 2010. Causes of corruption: history, geography and government. J. Policy Model. 32, 433−447.

Gouriéroux, C., Phillips, P.C., Yu, J., 2010. Indirect inference for dynamic panel models. J. Econom. 157 (1), 68−77.

Gupta, S., Davoodi, H., Alonso, R., 1998. Does Corruption Affect Income Equality and Poverty? (IMF Working Paper 98-76). World Bank (1998): Corruption and Development, Washington D.C. 1998. PREM Notes No. 4. May 1998.

Gyimah, K., Munoz, S., 2006. Corruption, growth, and income distribution: are there regional differences? Econ. Govern. 7, 245−269.

Hodgson, G., Jiang, S., 2016. The economics of corruption and the corruption of economics: an institutionalist perspective. J. Econ. Iss. XLI, 1043−1061.

Im, K.S., Pesaran, M.H., Shin, Y., 2003. Testing for unit roots in heterogeneous panels. J. Econom. 115 (1), 53−74.

Kaufmann, D., Kraay, A., 2002. Growth without Governance. http://siteresources. worldbank.org/INTWBIGOVANTCOR/Resources/growthgov.pdf.

Le Billon, P., 2003. Buying peace or fuelling war: the role of corruption in armed conflicts. J. Int. Dev. 15, 413−426.

Levin, A., Lin, C.F., Chu, C.S.J., 2002. Unit root tests in panel data: asymptotic and finite-sample properties. J. Econom. 108 (1), 1−24.

Levinson, D., 2002. Encyclopedia of Crime and Punishment. In: Crime and Violence in Latin America, 3. Sage Publications.

Mauro, P., 2002. The Effects of Corruption on Growth and Public Expenditure: A Cross Country Analysis. Chapter 4 in Institute for International Economics. www. iie.com.

Mocan, H., Billups, S., Overland, J., 2005. A dynamic model of differential human capital and criminal activity. Economica 72, 655−681.

Morales, P., Finke, 2015. Small-world networks of corruption. Revista CIFE: Lecturas de Economía Social 17 (26), 17−33.

Narayan, D., Patel, R., Schafft, K., Rademacher, A., Koch-Schulte, S., 2000. Voices of the Poor. Can Anyone Hear Us? Poverty Group. PREM World Bank.

Neapolitan, J., 1999. A comparative analysis of nations with low and high levels of violent crime. J. Crim. Justice 27, 259−274.

Pedroni, P., 2001. Fully modified OLS for heterogeneous cointegrated panels. In: Nonstationary Panels, Panel Cointegration, and Dynamic Panels. Emerald Group Publishing Limited, pp. 93−130.

Pellegrini, L., Gerlagh, R., 2008. Causes of corruption: a survey of cross-country analyses and extended results. Econ. Govern. 9, 245−263.

Rodriguez, J., Seligson, M., 2008. Cultura política de la democracia en Colombia, 2008. El impacto de la gobernabilidad. Observatorio de la democracia. http://www.vanderbilt.edu/lapop/ab2008/colombia-es.pdf.

Saha, S., Campbell, N., 2007. Studies of the effect of democracy on corruption. In: Prepared for the 36th Australian Conference of Economists. http://www.ecosoc.org.au/files/File/TAS/ACE07/presentations%20(pdf)/Saha.pdf.

Sandholtz, W., Koetzle, W., 2000. Accounting for corruption: economic structure, democracy, and trade. Int. Stud. Q. 44, 31−50.

Shahroudi, I., 2009. The application of data envelopment analysis methodology to improve the benchmarking process in the EFQM business model. Iran. J. Optim. 1, 243−265.

Shao, J., Ivanov, P., Podobnik, B., Stanley, E., 2007. Quantitative relations between corruption and economic factors. Eur. Phys. J. B 56, 157−166.

Thoumi, F., 1999. The relationship between corruption and drug trafficking: an general analysis and some references for Colombia. Rev. Econ. Univ. del Rosario 2, 11−33. www.urosario.edu.co/urosario_files/be/be30d307-e2eb-4459-8b3d-a14a748ebb62.pdf.

Types, P., 2000. An Introduction to Cluster Analysis for Data Mining. Analysis. Birkhäuser Verlag AG, pp. 1−75. Retrieved from. http://www-users.cs.umn.edu/~han/dmclass/.

Vaal, A., Ebben, W., 2011. Institutions and the relation between corruption and economic growth. Rev. Dev. Econ. 15, 108−123.

World Bank, 2000. Helping Countries Combat Corruption: Progress at the World Bank since 1977. Report number 21571.

World Bank, 2003. Corruption, Poverty, and Inequality. http://web.worldbank.org.

Zaum, D., Cheng, C., 2008. Key themes in peacebuilding and corruption. Int. Peacekeeping 15 (3), 301−309.