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Causality Analysis between Electricity Consumption, Real Gross Domestic Product, Foreign Direct Investment, Human Development and Remittances in Colombia, Ecuador and Mexico

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ABSTRACT

This paper examines the relationship between electricity consumption (EC), gross domestic product (GDP), foreign direct investment (FDI), human development index (HDI) and remittances (RMT) for Colombia, Ecuador and Mexico using annual data from 1980 to 2012. Previous literature oversees the relevance of RMT in Latin America and the urgent need to improve HDI levels when analyzing EC and GDP linkages. Time series techniques test the causal relationships direction and its interaction sign. In Colombia there are two unidirectional causalities running from HDI to EC and GDP to FDI generating a positive effect, and bidirectional causality between HDI and RMT reflecting an enhancing feedback in the long-run. In Ecuador, a unidirectional direct causality from EC to GDP and a negative impact from RMT to GDP characterize for the long-run interaction. In Mexico, EC causes FDI in the short-run within a positive interaction, and FDI and HDI sustain short-run unidirectional causalities affecting RMT negatively exerted from FDI and positively from HDI. After reviewing the results, the author suggests policies to each country.

Keywords: Electricity Consumption, Gross Domestic Product, Foreign Direct Investment, Human Development Index, Remittances
JEL Classifications: C3, O4, Q43

1. INTRODUCTION

Energy plays a vital role in any economy, it is a key factor of production, in addition to capital, labor and materials; and, it is closely associated to economic and social development of nations, growth and living standards (Conejo et al., 2005). However, the threat of climate change driven by energy consumption (hereafter EC) has motivated research on the relationship among EC, economic growth and other variables considered on welfare economics (Nordhaus and Radetzki, 1994). For the purposes of environmental sustainability and development, embedded in the human development index (HDI), there is a dilemma because EC is needed to improve the HDI through development projects to stimulate gross domestic product (GDP), though the current energy mix increases pollution and affects climate change in the long run (Apergis and Payne, 2012).

The Latin American region is abundant in natural resources where agriculture, energy, and other commodity sectors lead much of the region's exports (ECLAC, 2011). The increasing attention on global energy issues and international policies expands the academic scope to identify the linkages between the energy sector and economic performance, where the emphasis is on the potential energy efficiency gains generated through foreign direct investments (FDI) furthermore, Latin American characterizes for a great number of migrant workers who send remittances (RMT) back home. Thus, there is a potential impact of those flows on economic growth and human development. This explains the interest on the exponential increase, in real terms, of the remittance flows in the last two decades (Martinez and Ebenhack, 2008; The World Bank, 2013).

Despite the high growth rates in the last years, Latin America still holds high levels of poverty, inequality and corruption (Portes and Walton, 2014). Regarding the energy mix for electricity generation, the region is highly dependent on fossil fuels, and it is expected this pattern will remain in the next decades (Cremonez et al., 2015). Thus, this study explores how a set of variables closely associated with human welfare (e.g., GDP, RMT, FDI, and HDI) dynamically interact with the EC. For this we apply time series analysis and Granger causality tests where results may serve as guidelines for policy makers and future researchers.

We select countries from the Latin American region by setting an ordering with respect to the real GDP per capita. The calculated quartiles are \$3843-\$7192, \$7193-\$11243, and \$11244-\$15410 (Table 1). We choose Colombia, Ecuador and Mexico. Regarding energy mix (reported in the US Energy Information Administration) in Colombia 30% of electricity generation comes from fossil fuels combustion, whereas for Ecuador it is 70% and Mexico 85%.

The HDI of Ecuador (0.711) and Colombia (0.711) are below the regional average (0.74). Thus policy prescriptions would suggest promoting GDP growth, on non-oil sectors to attract FDI to local initiatives; and, to sustain RMT inflows for households (United Nations Development Program, 2014). However, in order to achieve these goals, large EC will be required which, consequently, would produce oil combustion and pollution. Hence, there is the need to investigate the causal relationship among the GDP, EC, FDI, HDI and RMT to take the proper decisions in development policies.

2. LITERATURE REVIEW

In a study for 30 OECD and 26 non-OECD countries, it was found that in the short and long-run, the causality link is predominantly from income to EC (Joyeux and Ripple, 2011). Therefore, energy conservation programs to constrain CO_2 emissions, by reducing use of fossil fuels, should have a negative effect on economic activity, both in developed or developing countries. Campo and Sarmiento (2011) mention that the long-run relationship between GDP and EC has a positive but inelastic slope. Consequently, in the long run, EC generates GDP, allowing the country to implement energy conservation policies in the short run. In Mexico, Gomez-Lopez (2011) confirms that Granger causality agrees with previous works that found that increases in EC cause EG. The impulse-response functions show that the EC of the industry and transportation sectors change the aggregate EC and EG. Likewise, an important result is that increases in CO_2 emissions effect changes in EG and EC.

Hussain and Othman (2011) analyze the causal relationship among EC, CPI, total consumption expenditure, GDP and FDI in Malaysia. The cointegration analysis reported a significant long-run causality from EC to FDI, EC to inflation, and EC to EG. Regarding EC, Cerdeira (2012) found for Portugal a strong positive impact of EG on the EC, and an energy reducing effect from aggregate FDI. Ouedraogo (2013) investigated the long-run relationship between the EC and HDI for a panel of 15 African countries. They used panel data unit root tests and Pedroni cointegration techniques. The results showed a long-run relationship between HDI, EC and EC. In particular, EC has a positive and significant effect on HDI for Western African countries. In a study for South Asian countries, Hossain (2012) examined the dynamic causal relationship among economic growth, EC, export values and RMT

Table 1: Latin American countries real GDP ranking

Country	GDP 2012	Country	GDP 2012
Chile	15,410.12	Peru	6530.33
Uruguay	14,614.15	D. Republic	5762.98
Venezuela	12,956.08	Ecuador	5310.63
Brazil	12,078.83	Paraguay	3903.26
Argentina	11,576.21	El Salvador	3823.49
Mexico	10,247.18	Guatemala	3302.25
Panama	9918.73	Bolivia	2532.48
Costa Rica	9672.91	Honduras	2242.23
Colombia	7854.84	Nicaragua	1756.52

Real GDP per capita in constant USD for 2012, Source: World Bank Data 2014.
GDP: Gross domestic product

and found a bidirectional short-run causal relationship between EG and export values, and a long-run causality from economic growth to EC and RMT (Table 2).

3. METHODOLOGY

The objective of this paper is to investigate the dynamic relationship between EC, GDP, FDI, HDI and RMT in Colombia, Ecuador and Mexico. For this we use annual data between 1980 and 2012. EC is in billions of kilowatts per hour and is used as the proxy for EC. Data come from the US Energy Information Administration. RMT (in millions of US dollars) represents the remittances from migrants to their families, and FDI (in millions of US dollars) represents the currency inflows to finance enterprises. Data for FDI are obtained from the UN Trade Database, and for HDI data come from the UN Development Program Database. HDI measures the living standards, health and education of the national population. Real GDP is in millions of constant US dollars. Data come from the IMF World Outlook database. All the variables, except HDI, are transformed applying natural logarithms to mitigate heteroscedasticity.

Based on Campo and Sarmiento (2011); Gomez-Lopez (2011), this study sets the Ozturk growth hypothesis of a positive unidirectional causality running from EC to GDP (Ozturk, 2010). Results from Pao and Tsai (2011) included a unidirectional causality from EC to FDI in Brazil, which suggests a positive unidirectional causality from EC to FDI. Regarding HDI causalities, Ouedraogo (2013) found a positive cointegration relationship between EC and HDI in developing countries. This also suggests a positive unidirectional causality from HDI to EC. Finally, regarding RMT, Hossain (2012) found a positive unidirectional causality between RMT and GDP in developing countries. This leads to the hypothesis of a positive unidirectional causality from RMT to GDP.

The empirical strategy for this study is as follows: (1) Unit root tests for stationarity, (2) lag length selection, (3) cointegration analysis, and (4) Granger causality tests (Granger, 1988; Greene, 2011; Johansen, 1988; Johansen, 1992; Kwiatkowski et al., 1992; Lütkepohl, 2007; Phillips and Perron, 1988; Schwarz, 1978; Verbeek, 2008). All variables included were stationary, either in levels or in first differences, so that models and lag order were properly specified to observe the likelihood for short and long-run relationships. Then we determined the direction of causalities. In addition, every model was examined for goodness of fit, through

Table 2: Summary of recent studies concerning EC and welfare variables

Author(s)	Country	Period	Variables	Method	Results
Joyeux and Ripple (2011)	30 OECD and 26 non-OECD	1973-2007	GDP, EC, ELC, REC	JC, VECM, GR	Short run GDP→EC GDP→ELC GDP→REC
Campo and Sarmiento (2011)	10 LAC	1971-2007	GDP, EC	PC, WC	Ecuador, Colombia EC→GDP
Gomez-Lopez (2011)	Mexico	1980-2005	GDP, EC, CO_2	VAR, GR, IRF	EC→GDP CO_2→GDP CO_2→EC
Hussain and Othman (2011)	Malaysia	1971-2009	ELC, CPI, C, GDP, FDI	VECM, GR	ELC→FDI ELCGGDP
Cerdeira (2012)	Portugal	1980-2007	EG, FDI, EC	ARDL, VECM, GR	EG→FDI FDI→EC
Ouedraogo (2013)	15 ECOWAS countries	1988-2008	HDI, EC, ELC	PC	Co-integrated HDI, EC ELC-HDI(+)
Hossain (2012)	Bangladesh, India, Pakistan	1976-2009	GDP, ELC, X, RMT	JC, GR	Short Run GDP↔X Long Run ELC→GDP RMT→GDP

→ (Unidirectional causality), ↔ (Bidirectional causality), A-B(+) (Positive relationship). ARDL: Autoregressive distributed lag, C: Total consumption, CO_2: CO_2 emissions, CPI: Price index, ECOWAS: Economic Commission of West African States, ELC: Electricity consumption, GR: Granger causality, IRF: Impulse-response function, JC: Johansen cointegration, LAC: Latin American Country, OECD: Organization for Economic Co–operation and Development, PC: Pedroni cointegration, REC: Residential electricity consumption, VECM: Vector error correction model, X: Exports, WC: Westerlund cointegration, VAR: Vector autoregressive model

information criteria; stability of the inverse roots of the AR characteristic polynomial; autocorrelation; and, residual normality.

4. RESULTS

Step 1: Unit root test. These tests were performed following Enders (1995) methodology. For Colombia and Ecuador, EC, GDP, FDI, HDI and RMT were non-stationary at levels, then first-differences were applied so that all variables were integrated of order 1. Then cointegration was tested before building a definitive model to detect causalities. Johansen cointegration test requires a lag parameter, thus, protempore stable vector autoregressive (VARs) were built. For Mexico, the linear transformation was enough for stationarity at levels for EC, GDP and FDI. In turn, HDI and RMT were non-stationary at levels and required first-differences. Mexico had 3 variables integrated of order 0, and 2 variables integrated of order 1. Consequently, the Granger tests were applied on a VAR model (Appendix A).

Step 2: The lag selection results are portrayed in Table 3. For Ecuador and Mexico, Schwartz information criteria (SIC) and Akaike information criteria (AIC) set the VAR lag length on one. For Colombia, there is a discrepancy between the SIC and the AIC. Thus, we choose lag 1 using the Hannan Quinn criterion following Lütkepohl (2007). Then we tested the stability and residuals of the model. This optimal-lag model passed the stability, autocorrelation, and normality specifications (Appendix B).

Step 3: After differencing, the sample size is reduced to 32 periods. Based on Lutkepohl et al. (2001), the results from the trace test may be distorted in small samples. Thus, we determine the number

Table 3: VAR optimal lag selection criterion

Country	Lags	SIC	AIC	HQ
Colombia	1*	−14.86818*	−16.25591	−17.01707*
	2	−14.74541	−17.31427	−16.75703
	3	−13.68341	−17.45526*	−16.27397
Ecuador	1*	−15.08375*	−16.47148*	N/A
	2	−13.68189	−16.25075	N/A
	3	−12.58173	−16.35358	N/A
Mexico	1*	−18.55423*	−19.94196*	N/A
	2	−16.82196	−19.39083	N/A
	3	−15.18763	−18.95948	N/A

*Optimal lag concerning to the information criterions. SIC: Schwartz information criterion, AIC: Akaike information criterion HQ: Hannan-Quinn Information Criterion, VAR: Vector autoregressive model

of cointegration equations through the maximum eigenvalue test. The vector error correction model (VECM) for Colombia presents two cointegration equations for Ecuador there is only one, as in Table 4. Other tests for lag structure, stability, autocorrelation and normality are shown in Appendix C.

Step 4: The Granger causality test is in Table 5. For Colombia there are two unidirectional Granger causalities running from HDI to EC and from GDP to FDI; whereas a bidirectional Granger causality exists between HDI and RMT. For Ecuador, there exist two unidirectional Granger causalities targeting GDP which originate from EC and RMT. For Mexico, the test detects three Granger causalities flowing from EC to FDI and from HDI and FDI to RMT.

We follow Pesaran and Shin (1998) to interpret the significant causalities between the variables through impulse-response functions. For Colombia's VECM, as in Figure 1, a HDI shock

Table 4: Johansen cointegration test

Country	Null H_0	Eigen value	Max Eigen value statistic	Critical value (α=5%)	*P*
Colombia	None*	0.762039	43.06942	33.87687	0.0031
	At most 1*	0.708654	36.9973	27.58434	0.0023
	At most 2	0.479619	19.59579	21.13162	0.0808
	At most 3	0.368509	13.79014	14.2646	0.0593
Ecuador	None*	0.805792	49.16477	33.87687	0.0004
	At most 1	0.496747	20.59984	27.58434	0.3011
	At most 2	0.402514	15.45073	21.13162	0.2586
	At most 3	0.294965	10.48525	14.2646	0.182

[a]Null H_0 is the presence of n cointegration equations, [b]The probability is computed by Mackinnon, Haug, and Michelis (1999) method, *denotes rejection at 5% of significance

Table 5: Granger causality test

Countries	Causalities	Chi-square	df	Prob.
Colombia	HDI→EC*	5.55566	1	0.0184
	GDP→FDI	2.86214	1	0.0907
	HDI→RMT	3.52479	1	0.0605
	RMT→HDI	3.32269	1	0.0683
Ecuador	EC→GDP**	25.5702	1	0.0000
	RMT→GDP**	61.5705	1	0.0000
Mexico	EC→FDI**	6.36809	1	0.0116
	HDI→RMT**	11.6623	1	0.0006
	FDI→RMT**	7.49642	1	0.0062

[a]Null H_0 is A does not Granger cause B, [b]All causalities are significant at 10%, *Significance at 5%, **significance at 1. FDI: Foreign direct investment, HDI: Human development index, RMT: Remittances, EC: Electricity consumption

Figure 1: Impulse-response functions for Colombia vector error correction model

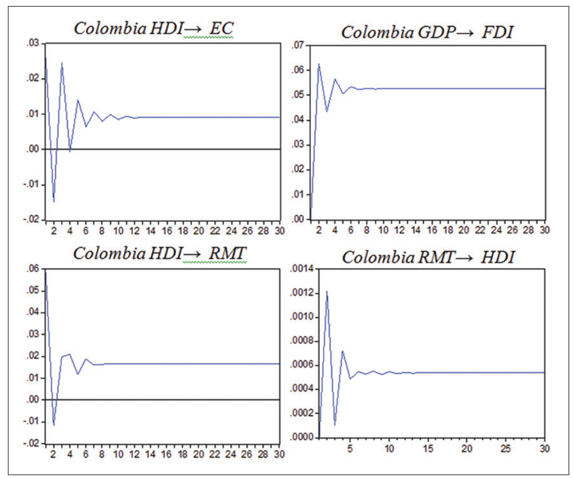
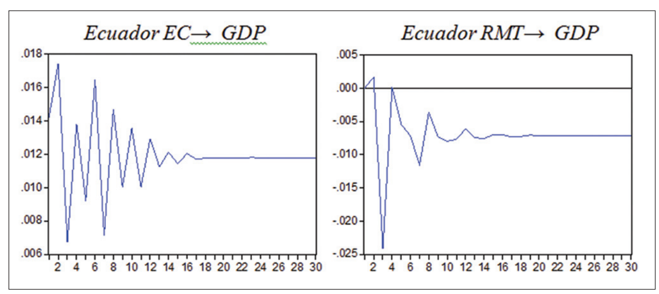


Figure 2: Impulse-response functions for Ecuador vector error correction model



is followed by a significant increase of EC in the short-run until stabilizing at a significant positive level in the long-run. A GDP shock brings up an increase of FDI after one period. The positive effect holds in the long-run. Furthermore, the HDI shock does not generate a positive impact on RMT in the short-run, and RMT cause an immediate significant increase on HDI. Hence, the relationship holds as a significant positive feedback.

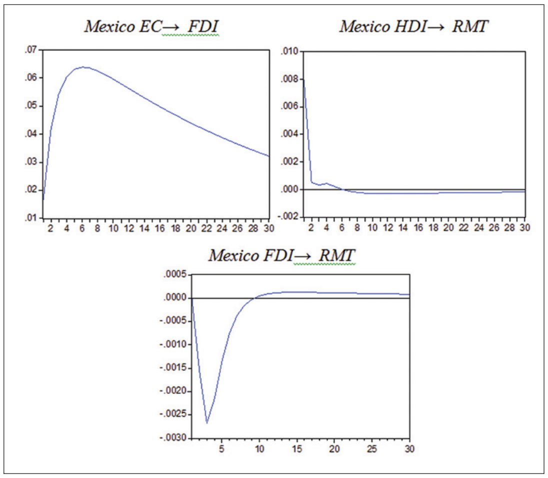
Regarding Ecuador's VECM impulse-response functions, as in Figure 2, an EC shock is accounted in the function as a sudden growth of the GDP. The positive effect holds in the long-run. Moreover, an RMT shock implies a slightly positive impact in the short-run, followed by a mean reverting process two periods after the shock, setting the overall effect as negative.

Reviewing Mexico's VAR, the impulse-response functions (Figure 3) interpretation is limited to the short-run, including the immediate effect and one period after the shock (Masih and Masih, 1997). An EC shock induces a positive but decreasing reaction to the FDI. Furthermore, a HDI shock implies an instant positive impact on RMT (i.e. better trained migrant workers); and, a FDI shock generates a sudden negative effect on RMT.

5. CONCLUSIONS AND POLICY IMPLICATIONS

This study investigates, within a multivariate Granger analysis, the causal relationships between EC, GDP, FDI, HDI and remittances. Three Latin American countries were chosen to review the interaction of these variables. Previous literature is limited to study output, energy and foreign investment linkages without accounting the importance of remittances in the local economies and the imperious need of improving human development in the region. The VECM is used to examine long-run causalities for Colombia and Ecuador, and the VAR model is applied for short-run causalities for Mexico. In addition, impulse-response functions were conducted to confirm the sign and robustness of the significant causalities. The empirical results show a unidirectional long-run causality running from EC to GDP sustaining the growth hypotheses for Ecuador, and the neutrality hypothesis for the other countries. Likewise, Ecuadorians' remittances Granger-cause a negative impact on GDP in the long-run. Furthermore, a unidirectional causality from EC to FDI is identified only for Mexico. Finally, a unidirectional causality from human development to EC is accounted in Colombia.

Figure 3: Impulse-response functions for Mexico vector error correction model



We mention some policy implications. For Colombia, as human development improvements demand a greater amount of electricity, policies should measure its energy capacity and consider a wider diversification of its energy sources since the economy requires increasing availability of electricity as they reach better health, education and income levels. For Ecuador, as EC Granger-causes GDP, energy shortages could lessen economic performance. Thus, policies should focus on pollution mitigation and technological development to increase the availability of cleaner forms of energy. Additionally, policies should encourage repatriation of its nationals not to hinder economic growth in the long-run. For Mexico, where foreign funds are attracted by increasing EC, balance of payments deficit may reduce and policies should fixate on drawing the attention of cleaner energy projects to prevent a pollution haven.

This research is limited to its data range since there are no official HDI measurements before 1980. A greater scope would allow us to perform forecasting techniques of the studied variables. Furthermore, the data of Mexico did not favor a VECM long-run equilibrium. Future research should look forward to apply ARIMA transfer functions for the sustained causalities to quantify elasticity; take our results as a starting point to write essays reviewing the current energy policy for each country; and, deeply analyze the causalities which did not interact with EC.

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APPENDIX A

Appendix Table A1: Unit root test results

Variable	ADF model	ADF statistic	PP model	PP statistic	Result
LNEC_COL	Int	−2.07 (0.2565)	Int	−2.21 (0.2075)	I(1)
ΔLNEC_COL	Int	−6.57 (0.0000)*	Int	−6.55 (0.0000)*	
LNGDP_COL	Tr, Int	−1.89 (0.6353)	Trend, Int	−2.15 (0.5001)	I(1)
ΔLNGDP_COL	Int	−3.61 (0.0113)*	Int	−3.63 (0.0107)*	
LNFDI_COL	Int	0.08 (0.9584)	Int	0.95 (0.9949)	I(1)
ΔLNFDI_COL	Int	−4.51 (0.0012)*	Int	−3.92 (0.0053)*	
HDI_COL	Trend, Int	−3.04 (0.1376)	Trend, Int	−2.94 (0.1652)	I(1)
ΔHDI_COL	Int	−6.66 (0.0000)*	Int	−6.70 (0.0000)*	
LNRMT_COL	Int	−1.16 (0.6794)	Int	−1.14 (0.6869)	I(1)
ΔLNRMT_COL	Int	−3.29 (0.0261)*	Int	−5.36 (0.0001)*	
LNEC_ECU	Int	−0.58 (0.8611)	Int	−0.60 (0.8577)	I(1)
ΔLNEC_ECU	Int	−6.66 (0.0000)*	Int	−6.77 (0.0000)*	
LNGDP_ECU	Int	−0.29 (0.9155)	Int	−0.29 (0.9164)	I(1)
ΔLNGDP_ECU	Int	−6.41 (0.0000)*	Int	−6.45 (0.0000)*	
LNFDI_ECU	Trend, Int	0.01 (0.9946)	Trend, Int	−0.88 (0.9462)	I(1)
ΔLNFDI_ECU	Int	−3.26 (0.0256)*	Int	−3.24 (0.0271)*	
HDI_ECU	Int	0.33 (0.9763)	Int	1.01 (0.9957)	I(1)
ΔHDI_ECU	Int	−6.63 (0.0000)*	Int	−6.83 (0.0000)*	
LNRMT_ECU	Trend, Int	−0.42 (0.9821)	Trend, Int	−1.697 (0.7288)	I(1)
ΔLNRMT_ECU	Int	−9.50 (0.0000)*	Int	−9.18 (0.0000)*	
LNEC_MEX	Int	−3.91 (0.0053)*	Int	−3.93 (0.0049)*	I(0)
ΔLNEC_MEX	N/A				
LNGDP_MEX	Trend, Int	−3.64 (0.0419)*	Trend, Int	−3.64 (0.0419)*	I(0)
ΔLNGDP_MEX	N/A				
LNFDI_MEX	Trend, Int	−7.29 (0.0000)*	Trend, Int	−7.15 (0.0000)*	I(0)
ΔLNFDI_MEX	N/A				
HDI_MEX	Int	−1.07 (0.7146)	Int	−1.40 (0.5700)	I(1)
ΔHDI_MEX	Int	−7.75 (0.0000)*	Int	−7.79 (0.0000)*	
LNRMT_MEX	Trend, Int	−2.95 (0.1617)	Trend, Int	−1.76 (0.7001)	I(1)
ΔLNRMT_MEX	Int	−3.95 (0.0049)*	Int	−4.07 (0.0036)*	

[a]Null Ho is the non-stationarity of the series, [b]LN is the logarithm of the series, [c]Δ is the 1st difference of the series, [d]ADF and PP critical value at 5% of significance is 2.96, [e]*P* values are on parenthesis and * represents significant values. [f]I(x) indicates integrated of order x, [g]Int is intercept or drift. [h]ADF: Augmented dickey fuller

APPENDIX B

Appendix Table B1: VAR residual autocorrelation test

Lags	Colombia		Ecuador		Mexico	
	Q-statistics	*P*	*Q*-statistics	*P*	*Q*-statistics	*P*
1	13.28545	NA	8.767362	NA	18.91682	NA
2	35.55457	0.0786*	30.67995	0.1998*	39.71184	0.0312
3	58.48558	0.192*	57.50848	0.2171*	59.63877	0.1651*
4	82.98422	0.247*	79.05914	0.352*	86.60136	0.1695*
5	99.99055	0.4815*	108.8718	0.2557*	108.0825	0.273*
6	112.6538	0.778*	124.8146	0.4879*	128.834	0.3889*
7	121.4755	0.9578*	132.7914	0.8402*	159.9453	0.2742*
8	138.1379	0.9818*	155.2323	0.8562*	175.6921	0.4711*
9	153.4701	0.9938*	167.7377	0.9531*	192.6777	0.632*
10	180.9805	0.986*	176.633	0.9926*	212.9818	0.7073*
11	198.913	0.9925*	197.7043	0.9937*	228.4342	0.8324*
12	216.8897	0.996*	211.5384	0.9982*	239.4097	0.9406*

[a]Null H_0 is no residual autocorrelation up to lag n, [b]The test applied is only valid for lags larger than the VAR lag order, [c]*indicates significance at 10%, **at 5%, ***at 1%.

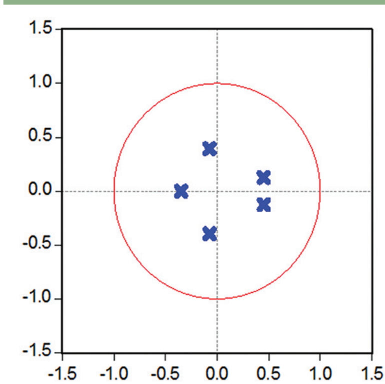
Appendix Table B2: VAR residual normality test

Component	Colombia		Ecuador		Mexico	
	Jarque-Bera	*P*	Jarque-Bera	*P*	Jarque-Bera	*P*
1	0.634063	0.7283*	84.10025	0.0000	3.473114	0.1761*
2	12.60827	0.0018	2.078244	0.3538*	2.23985	0.3263*
3	0.044184	0.9782*	11.30434	0.0035	2.387447	0.3031*
4	1.915149	0.3838*	1.164993	0.5585*	2.438197	0.2955*
5	1.885319	0.3896*	22.64382	0.0000	0.777889	0.6778*
Joint	17.08698	0.0725*	121.2916	0.0000	11.3165	0.3334*

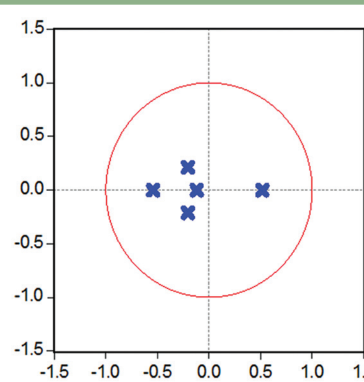
[a]Null H_0 is multivariate normal residuals, [b]The test applied Cholesky orthogonalization, [c]*indicates significance at 10%, **at 5%, ***at 1%.

Appendix Table B3: Vector autoregressive inverse roots of AR characteristic polynomial

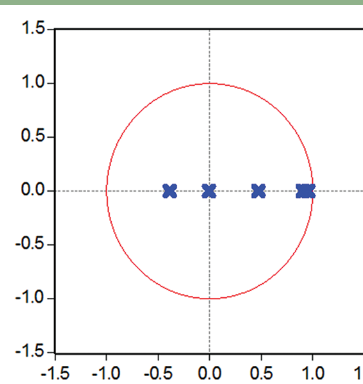
Colombia



Ecuador



Mexico



APPENDIX C

Appendix Table C1: VECM residual autocorrelation test

Lags	Colombia		Ecuador	
	Q-statistics	*P*	*Q*-statistics	*P*
1	11.79794	NA*	12.59972	NA*
2	40.0272	0.029	35.7806	0.0476
3	62.65551	0.1079*	54.0495	0.1999*
4	94.15324	0.0667*	80.14552	0.1401*
5	111.3043	0.2067*	100.5589	0.1803*
6	133.1457	0.2924*	117.6287	0.2726*
7	147.1327	0.5509*	126.1793	0.5939*
8	168.2564	0.6291*	144.2747	0.5938*
9	187.7334	0.7233*	165.2012	0.4899*
10	213.4853	0.6987*	189.2858	0.2946*
11	234.4047	0.7525*	212.3715	0.1578*
12	254.9355	0.802*	228.6669	0.1477*

[a]Null H_0 is no residual autocorrelation up to lag n, [b]The test applied is only valid for lags larger than the VAR lag order, [c]*indicates significance at 10%, **at 5%, ***at 1%

Appendix Table C2: VECM residual normality test

Component	Colombia		Ecuador	
	Jarque-Bera	*P*	Jarque-Bera	*P*
1	2.675515	0.2624*	6.230561	0.0444*
2	4.118727	0.1275*	3.161544	0.2058*
3	2.973775	0.2261*	1.639952	0.4404*
4	2.011725	0.3657*	1.233708	0.5396*
5	2.024578	0.3634*	2.996223	0.2236*
Joint	13.80432	0.1821*	15.26199	0.1228*

[a]Null H_0 is multivariate normal residuals, [b]The test applied Cholesky orthogonalization, [c]*indicates significance at 10%, **at 5%, ***at 1%.

Figure C1: Vector error correction model inverse roots of autoregressive characteristic polynomial