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THE LONG-RUN IMPACT OF ENERGY USE, INCOME AND TRADE ON CARBON DIOXIDE EMISSIONS IN MERCOSUR MEMBER STATES

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ABSTRACT

Using a heterogeneous panel cointegration approach and annual data, this study examines the long-run impacts of income, trade, and energy use on carbon dioxide emissions (CO_2) in Argentina, Brazil, Paraguay and Uruguay between 1970 – 2008. Results show that the long-run impact of those factors on CO_2 emissions, particularly trade, changed after the establishment of the Mercosur regional free trade agreement in 1991. The results also suggest that increasing the level of openness created positive effects in the reduction of CO_2 emissions post-Mercosur. In addition, our findings suggest that intra-region trade expansion within Mercosur lowered region's CO_2 emissions, likely due to increasing utilization of and investment in the region's inland waterway system. Our study implies that developing multi-modal networks connecting waterways with railways and highways could be a means to create long-run effects on CO_2 emissions reduction without jeopardizing economic growth in the Mercosur region.

Keywords: Heterogeneous Panel Data; Economic Growth; CO_2 Emissions; Trade; Mercosur.

RESUMO

Utilizando uma abordagem heterogênea de co-integração em painel e dados anuais, este estudo examina os impactos de longo prazo da renda, do comércio e do uso de energia nas emissões de dióxido de carbono (CO2) na Argentina, Brasil, Paraguai e Uruguai entre 1970 e 2008. Os resultados mostram que o impacto a longo prazo desses fatores nas emissões de CO2, particularmente no comércio, mudou após o estabelecimento do acordo regional de livre comércio do Mercosul (1991). Os resultados também sugerem que o aumento do nível de abertura criou efeitos positivos na redução das emissões de CO2 pós-Mercosul. As análises também sugerem que a expansão do comércio intra-região no Mercosul reduziu as emissões de CO2, provavelmente devido à crescente utilização e investimento no sistema de hidrovias na região. Nosso estudo implica que o desenvolvimento de redes multimodais que conectam hidrovias com ferrovias e rodovias poderia ser meio de criar efeitos de longo prazo na redução de emissões de CO2 sem comprometer o crescimento econômico na região do Mercosul.

Palavras-chave: Painel Heterogêneo de Dados; Crescimento econômico; Emissões de CO2; Comércio; Mercosul.

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INTRODUCTION

The Southern Common Market (Mercosur), established in 1991, was designed to create a political and economic agreement between Argentina, Brazil, Paraguay, and Uruguay. Those four member states have experienced rapid increases in income, trade, and energy use since the establishment of Mercosur. During the period of 1991-2008,[1] real GDP in Mercosur countries grew at a fast compounded average annual rate of 3.3 percent compared to the compounded world real GDP average annual rate of 2.9 percent (World Bank, 2015). Similarly, Mercosur countries' exports grew at a compounded average annual rate of 11.2 percent, while world merchandise exports grew at a compounded average annual rate of 9.3 percent.

Meanwhile, the compounded average annual growth rate of petroleum consumption in Mercosur was 2.8 percent, which was considerably higher than the world average growth rate of 1.4 percent. Emissions produced from burning petroleum cause air pollution (carbon monoxide, nitrogen oxide, particular matter, and unburned hydrocarbons) and contain carbon dioxide, a major contributor to global warming. The resulting higher global temperatures, more severe flooding and droughts, and more frequent heat waves can negatively affect livestock, agriculture, and fisheries both directly and indirectly (IPCC, 2014).

The rapid expansions in real per capita income, trade, and energy use in Mercosur generate concerns of environmental degradation in the region as less stringent environmental policies are expected in those developing countries relative to postindustrial nations. Little is known about the relationship between environmental politics and regional free trade agreements (FTA), like the Mercosur agreement, in which all the participants are developing countries. Quick growth in FTAs where all member states are developing countries has the potential to induce more environmental pollution. Thus, understanding the impact of increasing income, energy use, and trade on regional environmental quality in the Mercosur region is essential and warranted.

Studies on the effect of economic activities on the environment can be divided into three strands of research. The first concentrates on the relationship between economic growth and the environment, which is mainly devoted to testing the validity of the Environmental Kuznets Curve (EKC) hypothesis.[2] Lee and Lee (2009) among others provided extensive review surveys of these studies. The second strand of research focuses on the economic growth and energy use nexus. A detailed summary of this research can be found in the literature survey in Ozturk's (2010) and Omri

[1] We used data up to 2008 in this study due to potential distortions from other factors other than Mercosur, such as the global Great Recession in 2009-10, Venezuela's enrollment in 2012, and suspension of Paraguay in Mercosur in 2012-14.

[2] The EKC illustrates an inverted U-shape relationship between economic condition and the environment of an economy (Grossman and Krueger, 1995). The EKC presumes that economic growth leads to environment deterioration in the early stages of the economy development; however, the environment quality improves once the economy reaches a level of output (which varies for different economic indicators).

(2014). The third strand integrates the first two areas in a multivariate model that facilitates the examination of the impact of economic growth and energy use on the environment (e.g. Soytas and Sari, 2009; Narayan and Narayan, 2010; Yuan et al., 2014; Gokmenoglu and Taspinar, 2016; Destek et al., 2017; Tiba and Omri, 2017).

Recent studies have also considered trade in the literature of the growth-energy-environment nexus given the importance of incorporating trade in determining pollution emissions (e.g. Halicioglu, 2009; Al-mulali, 2012; Ozturk and Acaravci, 2016). Specifically, Sadorsky (2011; 2012) indicated that neglecting the effect of trade on energy use might underestimate the demand for energy. Theoretically, an increase in trade can affect energy use given that an increase in the number of goods for export leads to an increase in the demand for energy in order to produce and transport those goods (Adewuyi et al., 2015). However, trade could enhance energy efficiency and reduce energy use through importing innovative and sustainable technology or equipment. On the other hand, as an important input for transportation and production of goods for international trade, energy can potentially influence the trade amount and distribution.

Among the studies of the nexus of growth, energy use and the environment in various countries and regions, a group of researchers have focused on some South American countries, given their rapid expanding economy. For instance, Apergis and Payne (2010) concluded that energy use Granger-causes economic growth in nine South American countries in both the short and long runs. Hossain (2011) revealed positive and statistically significant impacts of income and energy use on CO_2 emissions in Brazil for the period 1971-2007. Pao and Tsai (2011) found energy as a more important determinant of CO_2 emissions than income in Brazil. Similar results were found by Sheinbaum et al. (2011) for Argentina and Brazil despite varying magnitudes of their impacts. Sadorsky (2012) found that trade expansions in South American countries increase energy consumption. Rosado and Sánchez (2017) showed that GDP growth and electricity use leads to more CO_2 emissions in 10 selected South America both short- and long-run. Those aforementioned studies, however, did not consider the potential changes in the effect of economic activities on the environment attributed to the development of regional FTAs.

This present article has several distinguishing features. First, our attention is focused on the effect of the creation of the Mercosur trade agreement on income, trade, and energy use, and its consequences on the environment. Earlier studies searching for evidence of the effect of income, trade, and energy on CO_2 emissions in that region did not explore the potential consequences of establishing the Mercosur FTA on the environment. Second, to better understand the effect of this regional FTA, this paper also explores the environmental consequences of the post Mercosur intra-region trade expansion. Previous studies did not investigate the effects on the environment of the additional intra-region trade caused by the formation of the Mercosur FTA. Finally, this paper further disaggregates the impact of Mercosur on the environment for each individual nation. Mercosur countries are expected to display different economic activity-CO_2 pollution relationships as they become more economically integrated.

The findings in this paper are potentially of large practical importance to developing effective environmental policies. As managing climate change through reducing CO_2 emissions has become a global focus, a better understanding of the impact of economic growth, trade, and energy use on the environment is crucial to supporting the formulation of more effective policies to reduce emissions in the Mercosur region.

EXPANDING AND INTEGRATING ECONOMY OF THE STUDY AREA

The impact of the development of the Mercosur is evident by the significant expansion in its energy use, level of economic integration, and economic activity. Mercosur's energy consumption from petroleum increased from 84.1 to 132.6 million tons of oil equivalent (Mtoe) during the period 1991−2008. Petroleum remained the region's dominant energy source post-Mercosur period with the transport sector amounting up to 60 percent of total petroleum CO_2 emissions in 2008 (IEA Statistics, 2012).[3] This regional FTA also increased intra-Mercosur trade from 5 billion in 1991 to nearly 42 billion dollars in 2008, or by a compounded average annual rate of 13.4 percent, while Mercosur exports to the ROW grew at a compounded average annual rate of 11.2 percent during the same period (UN Comtrade, 2015). Moreover, the ratio of intra-Mercosur trade to total exports increased from 12.5 percent in 1991 to almost 17.7 percent in 2008, with Argentina, Paraguay and Uruguay becoming increasingly more dependent on their Mercosur partners.

The rapid expansion of intra-region economic activities can be partially attributed to the improvement of weak transportation links within the region after Mercosur. One of the major transportation infrastructure projects, Hidrovía, is a coordinated dredging, rock removal, and structural channeling of the Paraguay-Paraná waterway to improve navigation. The Paraguay-Paraná waterway stretches from near Sao Paulo (Brazil), for its Tietê-Paraná portion, and near Cáceres (Brazil), for its Paraguay-Paraná portion, to the Rio de la Plata basin (see Figure 1). Mercosur countries utilize the Paraguay-Paraná waterway system for intra-region trade given the advantage of inland waterways for transporting large amounts of goods over long distances.[4]

The use of the waterway allows significant intra-trade energy savings given its highly favorable fuel/kilometer per ton ratio and consequent

[3] Around 90 percent of transportation emissions were produced by road transport (EIA, 2010).

[4] Typical convoy formations, which are shallow draft barges propelled by a pusher tug, of "4×5 barges" can carry the equivalent of 600 50-ton rail cars or 1,112 semi-trailers of 27 tons of capacity each (Monserrat Llairo, 2009).

environmental advantage.[5] Mercosur's waterway use increased from almost 1 million tons in 1991 to nearly 15 million tons in 2008, a compounded average annual rate of 17.2 percent over that period (IIRSA, 2008). The ratio of waterway use to intra-region trade increased from less than 7 percent in 1991 to approximately 14 percent in 2008.[6]

Figure 1. The Paraguay-Paraná waterway

Source: La hidrovía acrecienta el comercio y la integración en el Mercosur (Caceres C.A., 2009)

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[5] With one liter of fuel, a truck could travel 25.1 kilometers, on average, against 85.9 kilometers per rail car, and 218.5 kilometers per barge, hence lowering energy use and pollution (Monserrat Llairo, 2009).

[6] Freight transport using the waterway generated an estimated 5.66 grams of CO_2 per ton per kilometer, half that of using railways, and one tenth that of using trucks (59.14 grams of CO_2 per ton per kilometer) (World Bank, 2010).

EMPIRICAL MODEL AND DATA

Similar to Halicioglu (2009), this study defines CO_2 emissions as a function of income, energy use, and trade. Two trade proxies are considered in the analysis: trade openness as a ratio of total trade (exports and imports) to GDP, and the ratio of intra-region to inter-region trade, representing the relative level of member states' trade, within Mercosur members over its trade with the ROW. The first trade proxy captures a country's openness to the international market over time, while the intra-region to inter-region trade ratio is designed to illustrate the changes in intra-region trade pre- and post-implementation of the Mercosur agreement.

The relationship between CO_2 and those variables in the panel of Mercosur member states, therefore, is specified as follows:

$$CO_{2_{it}} = \alpha_i + \beta_i y_{it} + \gamma_i e_{it} + \delta_i o_{it} + \vartheta_i tr_{it} + \varepsilon_{it};\ i = 1,\ldots,N;\ t = 1,\ldots,T \quad (1)$$

Where CO_{2it} represents per capita carbon dioxide emissions in a member state, i, at time t; y represents the per capita real income; e represents energy use in per capita values; o represents trade openness; tr represents the intra-region to inter-region trade ratio, and ε is the error term. All variables are in natural logarithm form, thus the parameters of $\alpha_i, \beta_i, \gamma_i, \delta_i$, and ϑ_i represent the long-run elasticities of CO_2 emissions with respect to each explanatory variable in individual member states.

This study utilizes an annual panel data set of four Mercosur member states, including Argentina, Brazil, Paraguay and Uruguay, over the period of 1970−2008. Per capita CO_2 emissions are measured in thousand tons of carbon equivalents, and obtained from Emission Database for Global Atmospheric Research (EDGAR). Per capital real income (y) is measured at constant 2000 US$, while energy consumption per capita (e) is measured in grams of oil equivalent. Both income and energy use data were obtained from the World Bank Development Indicators. The data for trade openness (o) and intra-inter trade ratio (tr) are calculated from each country's exports and imports that were extracted from the UN Comtrade using the Standard International Trade Classification (SITC) Rev. 3.

Table 1 summarizes the descriptive statistics of the variables by individual member states and the panel over the study period. Among the four member states, Uruguay has the highest average CO_2 emissions per capital (CO_2), followed by Argentina. The variability of average CO_2 emissions in Paraguay is relatively higher than other member states. In terms of per capita real income (y), Argentina tops the group with an average per capita income of more than $7,000 while Paraguay's income ranks the lowest in Mercosur. The variation of per capita energy use among the four members is similar. Argentina also has the highest energy use per capita (e) and Paraguay consumes the least energy within the group.

Table 1. Descriptive statistics for the individuals and the panel

Member State		CO_2 (metric ton)	income (2000 US$)	energy (gram of oil equivalent)	openness (%)	intra (%)
Argentina	Mean	8.20	7,171.92	1.52	13.54	24.99
	Std. dev.	0.44	871.62	0.14	5.01	12.17
	CV	0.05	0.12	0.10	0.37	0.49
Brazil	Mean	4.85	3,385.20	0.97	16.52	9.53
	Std. dev.	0.41	514.54	0.14	5.06	4.67
	CV	0.08	0.15	0.14	0.31	0.49
Paraguay	Mean	6.01	1,279.53	0.68	42.06	76.03
	Std. dev.	0.73	211.20	0.09	18.55	29.76
	CV	0.12	0.17	0.13	0.44	0.39
Uruguay	Mean	9.77	5,689.26	0.84	22.58	54.88
	Std. dev.	0.65	1,093.42	0.10	6.45	20.64
	CV	0.07	0.19	0.12	0.29	0.38
Panel	Mean	7.21	4,381.48	1.00	23.67	41.36
	Std. dev.	2.00	2,369.71	0.34	15.20	32.16
	CV	0.28	0.54	0.34	0.64	0.78

Notes: CO_2 represents carbon dioxide emissions, income represents per capita income, energy represents energy use in per capita values, openness represents trade openness, and intra represents the intra-region to inter-region trade ratio. Source: Calculated by authors based on the databases of the UNComtrade and the World Bank.

Regarding the two indicators of trade, Paraguay ranks the highest in both trade openness (*o*) and the intra-inter trade ratio (*tr*), suggesting that Paraguay takes advantage of the free trade agreement and primarily keeps business within the Mercosur. Similarly, the average ratio of international trade to GDP is substantial in Uruguay. In addition, the high intra-inter trade ratio (about 55 percent) shows a stronger trade relationship between Uruguay with Mercosur members than with the ROW. The lower intra-inter trade ratio in Brazil compared to other member states suggests that Brazil has more diverse trade matrices. Intra-inter trade ratio patterns of Mercosur member states during the study period are presented in Figure 2, which shows that the formation of Mercosur in 1991 encouraged member states' trade with each other. Moreover, the upward ratio suggests that growth in trade with Mercosur members outpaces the change in trade with the ROW. The intra-region trade variable is also volatile, which explains why the variation of this variable is the highest when compared to other variables in Table 1.

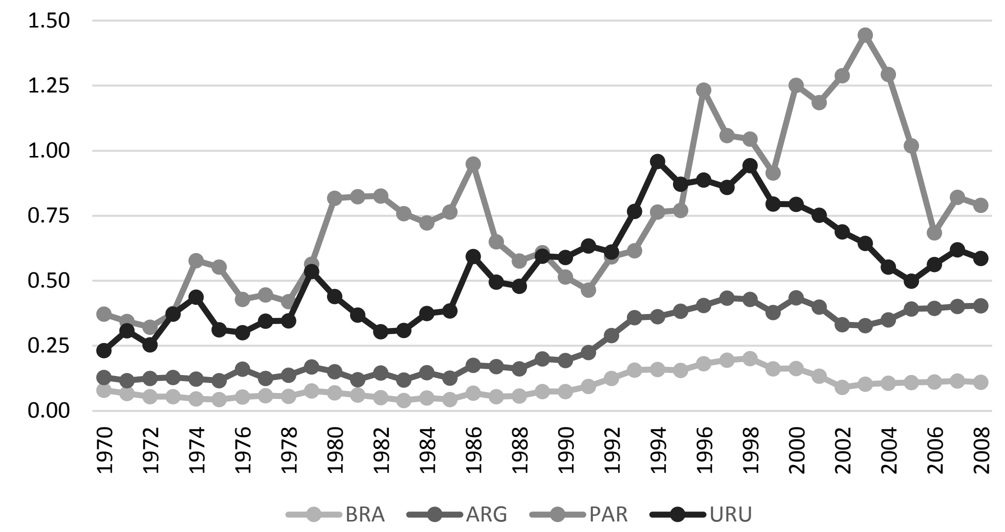

Figure 2. Intra-inter trade ratios for four Mercosur members, 1970-2008.

Source: Compiled by authors based on the database of UNComtrade.

ANALYTICAL METHODS

This study uses heterogeneous panel cointegration approach to identify the long-run relationship between income, energy use, trade, and the environment. Using the panel data approach can overcome the small sample size issue encountered in the cross-sectional or time-series data (four counties and 39 years in this study) and improve the consistency of the estimates (Al-mulali, 2012). In addition, the panel cointegration approach outperforms the single equation cointegration setup given its ability to control for the unobserved heterogeneity across individuals (Mark and Sul, 2003). Thus, this study first conducted panel unit root tests for each data series, followed by a panel cointegration test to examine if the long-run relationship among data series existed. The heterogeneous long-run impact of those variables on CO_2 emissions was then conducted. The details of each procedure are presented in the following subsections.

As the time dimension of this panel data is relatively long (1970-2008), this analysis also considers the possibility of a break point using the Chow test (1960) and for robustness purposes includes the Bai and Perron (2003) test. The Chow test (1960) result indicates the presence of a structural break in 1992, after the formation of Mercosur. When testing for a single structural break at unknown points of time, the breaking point also appears in 1992. When checking for multiple structural changes (up to five) two structural breaks appears in the sample, one in 1982 and the other in 1992. The structural change in 1982 was likely caused by the financial crisis in Brazil (1982-1983) and the war between Argentina and England (1982). The break in 1992 can be likely attributed to the establishment of the Mercosur in 1991.

Panel unit root tests

The presence of a unit root in panel data makes the data series non-stationary or integrated, which can cause a spurious regression and biased estimates when the ordinary least square (OLS) is used. Thus, this study first applied the panel unit root test developed by Levin et al. (2002) (hereafter referred to as the "LLC") and Im et al. (2003) (hereafter referred to as the "IPS") to test the non-stationarity of the data series. In addition, two nonparametric Fisher-type unit root tests by Maddala and Wu (1999) were also conducted. The LLC test assumes a common unit root process across the industries using an augmented Dickey-Fuller (ADF) test:

$$\Delta y_{it} = \alpha y_{it-1} + X_{it}'\theta + \sum_{j=1}^{p_i} \beta_{it} \Delta y_{it-j} + \epsilon_t \tag{2}$$

where Δ is the operation of first difference. The parameter α is considered identical for all panels whereas the lag order, p, can be different. The null hypothesis of the LLC unit root test is $\alpha = 0$, implying the existence of unit root.

Alternatively, the IPS and the two Fisher-type tests (Fisher-ADF and Fisher-PP) allow for heterogeneity in the autoregressive coefficient. The IPS test statistics can be written as follows:

$$\bar{\mathrm{t}} = \frac{1}{\mathrm{N}} \sum_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{t}_{\mathrm{iT}} \tag{3}$$

where t_{iT} is the ADF t-statistic for member state i based on the individual-specific ADF regression. The Fisher-ADF and Fisher-PP statistics combine the p-value of individual unit root tests with a chi-squared distribution with 2N degrees of freedom:

$$-2 \ln \pi_i \sim \chi_{2N}^2 \tag{4}$$

where π_i is the p-value of the individual unit root test.

The above-mentioned panel unit root tests generally neglect the potential cross-section dependence among member states, which may result in lowering the power of the tests. Thus, this study also employs the cross-sectionally augmented IPS (CIPS) test by Pesaran (2007). The CIPS test uses the cross-section averages of lagged levels and first-differences of the individual series in augmented ADF test as the test statistics (Pesaran, 2007).

Table 2 presents the results of the LLC, IPS, and two Fisher-type panel unit root tests of each variable in the full sample. The unit roots are found in all variables in levels, except for y, while the null hypothesis of unit roots is rejected in first difference at the 1% level, suggesting that all four variables are *I(1)*. The result of the panel unit root test, considering cross-section dependence, is presented in Table 3. Given a lag order from one through three, all variables in levels are generally non-stationary regardless of the number of lags. After taking the first difference, the existence of a unit root is rejected in all cases at the 5% level. Since structural breaks are present in the series, the Zivot and Andrews (1992) test is added for robustness check. The test results validates the previous findings, suggesting that all four variables are *I(1)*.

Table 2. Panel unit root tests without considering cross-sectional dependence, 1970-2008

		LLC	IPS	Fisher-ADF	Fisher-PP
		Levels			
Intercept	CO_2	0.34 (0.63)	0.68 (0.75)	7.85 (0.45)	9.49 (0.30)
	y	-2.50 (0.01)***	-1.20 (0.12)	15.22 (0.05)*	13.41 (0.10)*
	e	0.67 (0.75)	1.70 (0.96)	2.81 (0.95)	3.06 (0.93)
	o	1.20 (0.89)	0.99 (0.84)	4.03 (0.85)	1.90 (0.98)
	tr	-0.77 (0.22)	-0.01 (0.49)	6.79 (0.56)	6.65 (0.58)
Intercept & Trend	CO_2	0.32 (0.63)	0.53 (0.70)	8.88 (0.35)	15.33 (0.05)*
	y	-1.41 (0.08)*	-1.93 (0.03)**	16.84 (0.03)**	9.34(0.31)
	e	0.91 (0.82)	0.40 (0.66)	7.10 (0.53)	4.97 (0.76)
	o	0.98 (0.84)	-0.77 (0.22)	10.80 (0.21)	4.15 (0.84)
	tr	-0.13 (0.45)	-0.05 (0.48)	5.96 (0.65)	6.87 (0.55)
		First Difference			
Intercept	CO_2	-16.29 (0.00)***	-14.85 (0.00)***	105.02 (0.00)***	103.53 (0.00)***
	y	-6.10 (0.00)***	-4.82 (0.00)***	38.31 (0.00)***	34.86 (0.00)***
	e	-6.98 (0.00)***	-6.41 (0.00)***	53.18 (0.00)***	52.61 (0.00)***
	o	-7.05 (0.00)***	-6.90 (0.00)***	57.32 (0.00)***	57.65 (0.00)***
	tr	-12.52 (0.00)***	-12.21 (0.00)***	108.98 (0.00)***	110.60 (0.00)***
Intercept & Trend	CO_2	-10.12 (0.00)***	-10.28 (0.00)***	88.68 (0.00)***	336.72 (0.00)***
	y	-5.87 (0.00)***	-3.63 (0.00)***	27.20 (0.00)***	25.00 (0.00) ***
	e	-6.32 (0.00)***	-5.11 (0.00)***	38.75 (0.00)***	48.00 (0.00)***
	o	-6.47 (0.00)***	-5.77 (0.00)***	43.11 (0.00)***	43.08 (0.00)***
	tr	-11.54 (0.00)***	-11.49 (0.00)***	100.38 (0.00)***	104.75 (0.00)***

Notes: The null hypothesis of all four unit root tests is the nonstationarity of the evaluated series. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively. *y* represents per capita income, *e* represents total energy use per capita, *o* represents trade openness, and *tr* represents the intra-region to inter-region trade ratio.

Table 3. Panel unit root tests considering cross-sectional dependence, 1970-2008

		q = 0	q = 1	q = 2	q = 3
		Levels			
Intercept	CO_2	1.72 (0.96)	2.15 (0.98)	3.81 (1.00)	3.59 (1.00)
	y	-1.91 (0.03)**	-1.13 (0.13)	-1.32 (0.09)*	-0.10 (0.46)
	e	0.85 (0.80)	1.04 (0.85)	1.41 (0.92)	2.01 (0.98)
	o	-0.45 (0.33)	-0.98 (0.16)	-1.45 (0.07)*	-1.75 (0.23)
	tr	-2.16 (0.02)**	-1.32 (0.09)*	-1.70 (0.05) **	-0.31 (0.38)
Intercept & Trend	CO_2	1.30 (0.90)	2.87 (1.00)	4.82 (1.00)	5.05 (1.00)
	y	-0.95 (0.17)	-0.58 (0.28)	-0.87 (0.19)	0.80 (0.78)
	e	0.81 (0.79)	0.86 (0.81)	1.33 (0.91)	2.55 (1.00)
	o	0.83 (0.80)	0.51 (0.70)	-0.02 (0.49)	0.51 (0.70)
	tr	-0.70 (0.24)	0.15 (0.56)	-0.10 (0.46)	1.84 (0.97)
		First Difference			
Intercept	CO_2	-8.17 (0.00)***	-6.03 (0.00)***	-2.48 (0.01)***	-0.56 (0.29)
	y	-6.05 (0.00)***	-2.95 (0.00)***	-3.13 (0.00)***	-1.90 (0.03)**
	e	-6.54 (0.00)***	-4.39 (0.00)***	-3.14 (0.00)***	-1.96 (0.03)**
	o	-8.59 (0.00)***	-5.45 (0.00)***	-3.97 (0.00)***	-3.38 (0.00)***
	tr	-7.71 (0.00)***	-5.17 (0.00)***	-4.64 (0.00)***	-3.68 (0.00)***
Intercept & Trend	CO_2	-8.02 (0.00)***	-6.26 (0.00)***	-2.79 (0.00)***	-1.02 (0.15)
	y	-6.01 (0.00)***	-2.55 (0.00)***	-2.52 (0.00)***	-1.16 (0.12)
	e	-6.27 (0.00)***	-4.13 (0.00)***	-2.68 (0.00)***	-1.89 (0.03)***
	o	-7.92 (0.00)***	-4.87 (0.00)***	-3.17 (0.00)***	-3.31 (0.00)***
	tr	-7.17 (0.00)***	-4.29 (0.00)***	-3.67 (0.00)***	-2.17 (0.02)***

Notes: The cross-sectional panel unit root tests (Pesaran et al. 2007) has a null hypothesis of nonstationarity of the evaluated series. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively. *y* represents per capita income, *e* represents total energy use per capita, *o* represents trade openness, and *tr* represents the intra-region to inter-region trade ratio.

Panel cointegration test

Based on the unit root test, a panel cointegration test was conducted to determine if the linear combination of those variables is stationary. This study adopts the panel cointegration technique from Pedroni (1999), which takes heterogeneity into account by using specific parameters varied across the sample industries, since all of the evaluated variables are integrated of order one (*I(1)*). According to Pedroni (1999), pooling the data across panels can provide more information about the long-run relationship. Therefore, panel cointegration techniques allow researchers to selectively pool information across panels to get long-run relationships while allowing heterogeneity across different panel members.

The null hypothesis of the Pedroni cointegration test is that there is no cointegrated relationship. Seven different statistics to test the null hypothesis of no panel cointegration are proposed in Pedroni (1999). Four of those statistics consider the cointegration within dimensions, (panel v, panel ρ, panel PP, and the panel ADF statistics). These statistics are based on estimators that effectively pool the autoregressive coefficient across different members for the unit root tests on the estimated residuals. Another three test statistics examine cointegration between dimensions, including group ρ, group PP and group ADF. These tests are based on the simple average of the individually estimated coefficients for each member state i. If the test results show evidence of cointegration, the panel cointegration method can be used to estimate the long-run relationship between the dependent and explanatory variables.

The result of the Pedroni panel cointegration test for the full sample is presented in Table 4. Except panel v-statistics and group ρ-statistic, the other five statistics reject the null hypothesis of no cointegration among evaluated variables at the 5percent level. Therefore, the long-run cointegrated relationship between CO_2 emissions and explanatory variables is suggested. For robustness, we used the Gregory and Hansen (1996) cointegration with break test. The findings from the Gregory and Hansen test suggest that the results from the Pedroni test are valid.

Table 4. Panel cointegration test, 1970-2008

	Intercept	Intercept & Trend
Panel v-statistic	-1.34 (0.91)	-1.80 (0.96)
Panel p-statistics	-1.72 (0.04)**	-3.45 (0.00)***
Panel PP-statistics	-2.92 (0.00)***	-7.01 (0.00)***
Panel ADF-statistics	-2.94 (0.00)***	-7.02 (0.00)***
Group p-statistics	-0.27 (0.39)	-0.55 (0.29)
Group PP-statistics	-1.99 (0.02)**	-3.42 (0.00)***
Group ADF-statistics	-2.72 (0.00)***	-3.58 (0.00)***

Notes: The dependent variable is CO_2 in natural logarithm.
*** and ** indicate statistical significance at the 1% and 5% level, respectively.

Panel cointegration estimation

By identifying the linear combination of the non-stationary variables in the long run, the OLS estimators of equation (1) will be biased and inconsistent (Kao and Chiang, 2000; Pedroni, 2001). As such, this study adopts the fully modified OLS (FMOLS) approach (Pedroni, 1999) that corrects for endogeneity and serial correlation issues in OLS estimators to estimate the heterogeneous long-run impact of income, energy, and trade variables on CO_2 emissions in Mercosur member states. We first estimated the long-run impact of evaluated explanatory variables on CO_2 emissions using the full sample period (1970–2008). To evaluate the potential changes in the long-run impact on CO_2 emissions in each member state after Mercosur, the

FMOLS approach was then applied to the data in two sub-periods: the pre-Mercosur period (1970-1991) and post-Mercosur period (1992–2008).

RESULTS AND DISCUSSION

The FMOLS estimators for equation (3) of individual states and the panel during the study period (1970–2008) are presented in Table 5. In the long-run equilibrium, energy use appears to be the major cause of CO_2 emissions in Mercosur, with an elasticity of 1.39 at the 1 percent significance level in the panel estimate. The long-run impact of trade openness and intra-region trade also induced more CO_2 emissions in the region with an elasticity of 0.05 and 0.07, respectively. However, the influence of trade variables to CO_2 emissions were mixed for individual Mercosur member states. A greater degree of openness and a greater ratio of intra-region to inter-region trade increased CO_2 emissions in Brazil and Paraguay but lowered emissions in Argentina and Uruguay, with most of those long-run individual estimates being statistically significant.

Table 5. Fully modified OLS estimates of the long-run impact on CO_2 emissions in the Mercosur member states, 1970-2008

	Income	Energy	Openness	Intra
Argentina	0.18(2.46)***	1.07(1.53)	-0.03(-1.15)	-0.09(-4.89)***
Brazil	0.05(0.18)	0.70(2.02)**	0.15(2.44)**	0.11(3.52)***
Paraguay	-0.07(-0.37)	1.75(7.38)***	0.18(3.17)***	0.27(4.87) ***
Uruguay	-0.50(-4.01)***	2.03(20.7)***	-0.09(-1.78)*	-0.01(-0.04)
Panel	-0.08(-0.87)	1.39(19.4)***	0.05(1.34)	0.07(1.73)*

Notes: ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively. Intra represents the intra-region to inter-region trade ratio.

To illustrate the potential variations in the emission effect of evaluated economic factors after the formation of Mercosur, the FMOLS estimators of those economic variables during the pre-Mercosur (1970–1991) and the post-Mercosur periods (1992–2008) are summarized in Table 6. Post-Mercosur panel results suggest that increases in income, energy use, and intra-region trade created more environmental damage, while trade openness helped mitigate emissions. After the formation of Mercosur, all four selected variables had statistical significant impacts at the 5 percent level.

Table 6. Fully modified OLS estimates of the long-run impact on CO_2 emissions before and after the formation of Mercosur

	1970-1991 (Pre-Mercosur)			
	Income	Energy	Openness	Intra
Argentina	0.48(4.00)***	0.53(1.53)	-0.02(-0.80)	0.06(1.06)
Brazil	-0.16(-0.39)	0.94(1.59)	0.30(3.90)**	0.12(2.00)**
Paraguay	0.56(2.19)**	1.04(3.42)***	0.13(1.69)*	-0.03(-0.28)
Uruguay	-0.57(-2.83)**	2.27(24.7)***	0.04(0.61)	-0.02(-0.52)
Panel	0.07(1.48)	1.20(15.6)***	0.11(2.70)**	0.03(1.12)
	1992-2008 (Post-Mercosur)			
	Income	Energy	Openness	Intra
Argentina	0.39(4.02)***	0.98(8.43)***	-0.11(-1.82)*	-0.15(-3.90)**
Brazil	1.05(1.26)	1.31(3.23)***	-0.41(-2.80)**	0.22(4.91)***
Paraguay	2.29(3.36)**	0.51(2.01)**	-0.16(-2.36)**	0.39(7.62)***
Uruguay	-0.00(-0.01)	1.27(13.2)***	-0.02(-0.46)	-0.07(-2.83)**
Panel	0.93(4.31)**	1.02(13.5)***	-0.17(-3.72)***	0.09(2.89)**

Notes: ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively. Intra represents the intra-region to inter-region trade ratio.

The pre- and post-Mercosur panel results also indicate that energy was a more important determinant of emissions than income, with the elasticity of energy use reducing its contribution from 1.20 percent prior to Mercosur to 1.02 percent after the implementation of the Mercosur. Alternatively, post-Mercosur income elasticity panel results appeared to be larger compared to that prior to the formation of Mercosur, implying that income contributed to more CO_2 emissions in Mercosur member states over time, except for Argentina. As the country with the highest per capita income in the region, Argentina's CO_2 emissions from economic growth appear to gradually reduce over time. In contrast, Paraguay had the lowest per capita GDP in the region and experienced the largest increase in pollution levels in relation to income. These findings are in line with the EKC hypothesis which indicates that environmental pressure rises faster than economic growth in the early stage of development and slows down relative to GDP growth at the higher income levels.

Changes in the impact of both openness to trade and intra-region trade on CO_2 emissions in post Mercosur are likely caused by variations in the composition of the transport modes for cargo freight. For instance, a one percent increase in Argentina's trade openness reduced CO_2 emissions by 0.11 percent. Dredging the waterway provides an energy efficient way to move domestic cargo freight from its northern regions and for transshipment to oceangoing vessels for overseas trade (See Fig. 1). The results also suggest that post-Mercosur, a one percent increase in Argentina's intra-region trade decreased CO_2 emissions by 0.15 percent. The enhancement and increased use of the inland waterway system also helped decrease the impact of Argentina's intra-region trade on the environment by facilitating upstream exports (fuel, wheat, containers, etc), mostly to Paraguay and Bolivia, and downstream cargo freight from Paraguay and Brazil (World Bank, 2010).[7]

For the case of Paraguay, a one percent increase in trade openness lowered CO_2 emissions by 0.16 percent during the post-Mercosur period. This could be due to Paraguay's trade with ROW turning massively to river transportation, in terms of bulk solids and liquids and containerized freight, after the establishment of Mercosur (World Bank, 2010). In contrast, expansion in intra-Mercosur trade resulted in more CO_2 emissions in Paraguay after Mercosur: a one percent increase in intraregional trade increased CO_2 emissions by 0.39 percent (see Table 5). The rising CO_2 emissions is likely resulting from the heavy reliance on truck transportation of Paraguay with its neighbors (World Bank, 2009), and the hindrances in domestic surface transportation (United States Agency for International Development (USAID), 2006). It could also be related to Paraguay's truck transportation expansion outpacing the growth of other transportation modes after Mercosur.

For Brazil, trade openness decreased CO_2 emissions by 0.41 percent post-Mercosur. This decrease in emissions is likely associated with the Brazilian government's ambitious investments in the modernization and expansion of its national transportation and logistics infrastructure, especially through the improvement of their waterways and railway infrastructure (National Plan for Transportation and Logistics (NPTL); Growth and Acceleration Program (PAC); Brazilian Ministry of Transport (2013)). These investments have been relatively concentrated within specific regions that tend to ship commodities to ocean ports (United States International Trade Commission (USITC), 2012). However, similar to Paraguay, Brazil's intra-region trade expansion after Mercosur led to more CO_2 emissions, likely attributed to increased reliance on road transport for intra-Mercosur commerce.[8]

For Uruguay, a one percent expansion in its intra-region trade lowered its emissions by 0.07 percent in the post-Mercosur period, which may capture the positive effect of dredging the waterway and the coordinated enhancement of the transportation infrastructure of the Paraguay-Paraná River. However, the impact of trade openness in Paraguay after Mercosur did not cause CO_2 emissions, likely due to the fact that most of Uruguay's trade with ROW is via major port facilities already strategically located along the Atlantic Ocean.

[7] Each additional foot of draft enables the load of extra cargo; decreasing energy use and consequently CO_2. The typical dry-bulk barge size also tended to increase from 1,500 to 2,500 tons, allowing for higher capacity in shallow waters and higher capacity per convoy (World Bank, 2010).

[8] The current sign and magnitude of Brazil's intra-regional coefficient will likely change if the proposed navigation locks of the Itaipú Dam are constructed, shifting cargo freight towards a cheaper and environmentally friendlier transportation mode. Waterway transport from Sao Paulo (Brazil) to Buenos Aires (Argentina) will take 9 days and is estimated to cost approximately 55 $/ton (Teixeira Riva J.C., 2008).

CONCLUSIONS

Using a heterogeneous panel cointegration approach and annual data, this study provides an empirical analysis of the long-run impact of income, trade, and energy use on the environment in Mercosur member states over the period 1970-2008. Our results suggest that the formation of Mercosur alter the long-run impact of those factors, particularly trade, on CO_2 emissions in the region. The panel results in the pre- and post-Mercosur periods suggest that emissions are income and trade inelastic while energy use is elastic. Energy use is identified as the dominant influence to CO2 emissions, however the adverse impact has been gradually decreased. Our findings are consistent to the results in Narayan and Narayan (2010).

With respect to trade, the impact of trade openness on CO_2 emissions decreases after the regional free trade agreement. This is likely due to the positive effect of investments in transportation, especially infrastructure, that target commodity exports to ocean ports (USITC, 2012). In contrast, increase in the intra-region trade leads to more CO_2 emissions overall, presumably due to a growth in the reliance of roadways for intra-region trade after Mercosur, although the results at a country level are mixed. The expansion in intra-region trade results in higher reliance on roadway transportation for Brazil and Paraguay, hence more CO_2 emissions (World Bank, 2010). In contrast, the intra-region transportation matrix for Argentina and Uruguay shifts towards inland waterway for intra-Mercosur cargo freight and generates less CO_2 emissions in those two countries.

There is great potential to decrease CO_2 emissions from transportation in the region by further reducing Mercosur's overreliance on road transport (World Bank, 2010). Policies like Brazil's NPTL and PAC that promote the extension of railways and the development of viable waterways will encourage shifting from road transport to alternative economical and less polluting transportation options (Brazilian Ministry of Transport, 2013). Such initiatives that promote the development of multi-modal networks connecting waterways with railways and highways will most likely create long-lasting positive effects in the reduction of CO_2 emissions without jeopardizing economic growth in the Mercosur region.

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