The Long-run Impact of Energy Use, Income and Trade on Carbon Dioxide Emissions in Mercosur Member States: A Panel Cointegration Analysis

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Abstract
Using a panel cointegration regression technique, this study examines the long-run impacts of income, energy consumption, and trade on carbon dioxide emissions (CO_2), in Mercosur members, over the period 1970-2008. The potential influence of the regional free trade agreement in 1991 on the long-run CO_2 emission impact is also explored. The empirical results show that CO_2 emissions are affected by energy use, income, and trade during the post-Mercosur period (1991-2008). In addition, the long-run impacts of those factors on CO_2 emissions changed after the establishment of Mercosur. There is great potential to reduce CO_2 emissions in the region by promoting the use of less polluting transportation modes for the trade between the member states. Economic development, energy, and the environment should not be treated in isolation but jointly pursued in a comprehensive regional effort by the Mercosur members.

Keywords: Energy consumption, economic growth, carbon dioxide emissions, Mercosur region.
JEL: F_1, O_{13}, Q_4

1. Introduction

The Southern Common Market (Mercosur), founded in 1991, is designed to create a political and economic agreement between Argentina, Brazil, Paraguay, and Uruguay. Those four member states in Mercosur have experienced rapid increases in income, energy consumption, and trade since the establishment.[2] Over the period 1991-2008, 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, 2012). Meanwhile, the compounded average annual growth rate in the consumption of petroleum and

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[2] Venezuela is not included in this study since its entry in 2012 is beyond the time period in this study (1970–2008).

natural gas in Mercosur was 2.8 percent and 5.6 percent, respectively, which were considerably above the world average growth rate over the same period (1.4 and 2.1 percent). In addition, this regional free trade agreement (FTA) stimulated the intra-Mercosur trade up by a compounded average annual rate of 13.4 percent between 1991 and 2008, while world merchandise exports grew at a compounded average annual rate of 9.3 percent.

The quick growth in energy use, national output and trade in Mercosur consequently generates the concern of environmental degradation in the region (Villegas, 1999). As all four member states in Mercosur are developing countries, the potential environmental consequences from expanding economic activities is important to evaluate since, relatively, little is known about the relationship between environmental politics and regional FTA in which all the participants are developing countries (Hochstetler, 2003). Expansions in economic activities have more potential to induce more environmental pollutions in developing countries since developing countries generally have less restricted environmental policy and environmental awareness when comparing to the postindustrial countries (Steel et al., 2003). In addition, natural resources that typically have accounted for a main portion of developing countries' exports, such as agriculture, mining, etc., may generate more negative impacts when comparing to industrial production (Tussie, 2000). Thus, understanding the impact of increasing energy use, income, and trade on regional environmental quality in Mercosur 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 (Grossman and Krueger, 1991). Stern (2004) and Dinda (2004) provided extensive review surveys of these studies, while more recent studies include Dinda and

Coondoo (2006), Lee and Lee (2009) among others. The second strand of research focuses on the economic growth and energy use nexus, initiated by Kraft and Kraft (1978). A detailed summary of this research area can be found in Ozturk (2010) literature survey. 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 et al., 2007; Ang, 2007; Soytas et al., 2009; Apergis and Payne, 2009; Akbostanci et al., 2009; Narayan and Narayan, 2010). 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; Andersson et al., 2009; Al-mulali, 2012). Specifically, Sadorsky (2012) indicated that neglecting the effect of trade on energy use might underestimate the demand for energy.

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, Pao et al. (2011a) and Hossain (2011) studies revealed positive and statistically significant impacts of energy consumption and income on CO_2 emissions in Brazil for the periods 1971-2005 and 1971-2007, respectively. Pao et al. (2011b) 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. Their findings also suggested that energy intensity decreased in Argentina and Brazil during the period 1990-2006. Apergis and Payne (2010) concluded that energy use Granger-cause economic growth in nine South American countries in both the short and long runs. Sadorsky (2012) found that trade expansions in South American nations, including Argentina, Brazil, Chile, Ecuador, Paraguay, Peru, and Uruguay will increase energy consumption. Those aforementioned studies; however, did not consider the potential changes in the effect of economic activities on the environmental quality attributed to the development of regional FTAs.

As managing climate change through reducing CO_2 emissions has become a global focus, studying the potential impact of economic growth, energy, and trade on the environment is crucial to developing effective energy and environmental policies for the Mercosur region. This study aims to answer two research questions: 1) whether the energy use, income and trade in Mercosur member states have a long-run impact on the CO_2 emissions, and 2) whether the CO_2 emission impact of those variables, particularly trade, altered after the implementation of Mercosur by member states. We hypothesize that (1) energy use, income and trade in Mercosur member states have a long-run impact on their CO_2 emissions, and (2) the impact of those variables does not alter after the introduction of Mercosur. This study applies a panel cointegration regression model to the annual data of income, energy use, and trade on CO_2 emissions for the period 1970-2008.

A distinguishing feature in the present study apart from the aforementioned studies is to incorporate the potential influence of a FTA on the long-run CO_2 emissions impact of income, energy use, and trade in developing countries. Specifically, this paper includes the intra-Mercosur trade and trade with the rest of the world (ROW) to better understand the implications of a regional FTA to the effect of economic activities on CO_2 emissions. Exploring the environmental impact of expanding economic activities from regional agreements made up entirely of developing countries can help better understand the openness-environmental tradeoff (Hochstetler, 2003). Environmental choices in these economically less-developed regions are likely to be important harbingers of what could be attained through broader international trade agreements like the incoming South American Union.[3]

2. Expanding and integrating economy of the study area

The importance of Mercosur to the global economy is evident by the expansion in its energy consumption and economic activities. 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. The vast majority of transportation emissions, around 90 percent, were produced by road transport (IEA Statistics, 2012). Similarly, natural gas experienced a significant upsurge, increasing from 23.1 to 62.2 Mtoe. The upsurge of natural gas has modified the fossil fuel use matrix of the region. The region possesses 8.4 percent of the world proven reserves of natural gas and world technically recoverable shale gas resources combined (EIA Database, 2010).

Between 1991 and 2008 Mercosur exports to the ROW grew at a compounded average annual rate of 11.2 percent and intra-Mercosur trade increased from 5 billion in 1991 to nearly 42 billion dollars in 2008 with a compounded average annual rate of 13.4 percent (UN Comtrade, 2012). 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 increases in energy use and economic activities in the region can be partially attributed to the improvement of weak transportation links within the region (Tussie and

[3] The Union of South American Nations Treaty, UNASUR, was signed in 2008. Tariff elimination for non-sensitive products will begin in 2014 and for sensitive products in 2019.

Vásquez, 1997). One of the major transportation infrastructure projects, Hidrovía, is a coordinated dredging of the Paraguay-Paraná waterway to improve navigation in 1995. 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 utilized 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 energy savings in the intra-trade given its highly favorable fuel/kilometer per ton and consequent 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 17.3 percent over that period. The ratio of waterway use to intra-regional trade increased from less than 7 percent in 1991 to approximately 14 percent in 2008.[6] Despite the waterway having the potential to become the greatest axis for freight movement in the Mercosur region, progress is yet to be made in its two main sections (World Bank, 2010).

3. 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

[4] Typical vessels sailing in the waterway are called "convoys" formations which are shallow draft barges, propelled by a pusher tug. Typical convoys of "4x5 barges" can carry up to 30,000 tons which is equivalent to 600 50-ton rail cars or 1,112 semi-trailers of 27 tons of capacity each (Monserrat Llairo M., 2009).
[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 consequently lowering CO_2 emissions and other pollution emissions (Monserrat Llairo M., 2009). Also, barge transport can halve CO_2 emissions from rail transport and reduce road-based CO_2 emissions by 90 percent (World Bank, 2010).
[6] According to Koutoudjian (2007), IIRSA (Iniciativa para la integración Regional Sudamericana) forecasted about 38.2 million tons of merchandise transported through the waterway in 2020.

of total trade (exports and imports) to GDP, and the ratio of intra-Mercosur trade and inter-Mercosur trade representing the relative level of member state's 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 ratio of intra-inter trade is designed to illustrate the changes in a member state's trade pattern with partners 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:

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

where CO_{2it} represents the greenhouse gases emissions per capita in a member state, i, at time t; y represents the per capita real income; e represents total energy use per capita; o represents trade openness; tr represents the intra-inter trade ratio, and ε is the error term. All variables are in natural logarithm form, thus the parameters of α_i, β_i, γ_i, δ_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 utilized 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 were measured in thousand tons of carbon equivalents, and obtained from Emission Database for Global Atmospheric Research (EDGAR) collected by the European Commission Joint Research Center/Netherlands Environmental Agency. Per capital real income (y) was measured at constant 2,000 US$, while total energy consumption per capita (e) was 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) were 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 state 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 income 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.

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 1990 encourages 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-inter trade ratio variable is also volatile, which explains why the variation of this variable is the highest when comparing to other variables in Table 1.

4. Analytical methods

This study uses panel cointegration techniques that have higher power over single equation techniques and should provide more reliable long-run estimates of income, energy consumption, and trade on the environment. Following the recent development of panel data analysis, 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. Based on the output in those two tests, the heterogeneous long-run impact of those variables on GHG emissions was conducted. The details of each procedure are presented in the following subsections.

4.1 Panel unit root tests

The presence of a unit root in panel data makes the data series non-stationary or integrated, which can lead to 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:

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

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:

$$\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_{iT} \quad (3)$$

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 2*N* degrees of freedom:

$$-2 \ln \pi_i \sim \chi^2_{2N} \quad (4)$$

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 employed 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).

4.2 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 adopted 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.

4.3 Panel cointegration estimation

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). Thus, this study adopted the fully modified OLS (FMOLS) approach developed by 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 (1970-1990) and post-Mercosur period (1991–2008). A Wald test was then conducted to evaluate if the estimated long-run impacts varied between the two periods.

5. Results and Discussion

Table 2 presents the results of the LLC, IPS and the 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 other 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. 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, all other five statistics reject the null hypothesis of no cointegration among evaluated variables at the 5% level. Therefore, the long-run cointegrated relationship between GHG emissions and explanatory variables are suggested.

The FMOLS estimators for equation (3) of individual states and the panel during the study period (1970–2008) are presented in Table 5. As expected, per capita energy use was the major factor to CO_2 emissions in Mercosur with an elasticity of 1.39 at the 1% significance level in the panel estimate. The long-run impact was also significant for individual members except for Argentina. The growth of the trade between the members over trade with the rest of the world also induced more CO_2 emissions in the region; however, the impact was relatively modest with the elasticity of 0.07 at the 10% significance level. Also, the increases in the intra-trade produced more CO_2 emissions in Brazil and Paraguay but lowered the emissions in Argentina. Per capita income and trade openness were not found to be significant to the emissions in the panel estimate, however, the estimated long-run impacts of those two factors were found statistically significant in some individual member states (see Table 5). The statistical significance of those variables along with the panel cointegration test output suggest that we fail to reject the first hypothesis in the study that assumes those four economic activities have long-run impact on CO_2 emissions in the Mercosur member states.

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 (1970–1990) and the post-Mercosur time period (1991–2008) are summarized in Table 6. The panel results suggest that, prior to Mercosur, one percent increases in both energy use (*e*) and trade openness (*o*) in the region create 1.20 percent and 0.11 percent of CO_2 emissions, respectively. After the implementation of Mercosur, increases in income, energy use, and the ratio of intra-inter Mercosur trade create more CO_2 emissions; while a one percent expansion in trade openness mitigates CO_2 emissions by 0.17 percent. After the formation of Mercosur, all four selected variables are found to have statistical significant impact at the 5% level. The Wald test statistics of 29.95 suggests that the long-run impact of evaluated economic factors on CO_2 emissions was significantly different at the 1% level between the two periods. The test result suggests that the hypothesis (2) in the study assuming the long-run CO_2 emissions effects of evaluated economic variables did not vary after the Mercosur is rejected.

The slight reduction in the elasticity of energy use from 1.20 percent to 1.02 percent is likely due to variations in the fossil fuel consumption matrix from petroleum and coal to natural gas.[7] Mercosur's share of petroleum consumption to total fossil fuel use declined from 71 percent in 1991 to 63 percent in 2008 as the share of coal consumption dropped from 10 to 7 percent. In contrast, consumption of natural gas has grown from 19 percent in 1991 to 30 percent of total fossil fuel use in 2008 (IEA, 2010).[8] The growth in demand for this cleaner burning fossil fuel in Mercosur was driven primarily by its higher efficiency in power generation, and its

[7] Adopting policies that accommodate a rise in energy consumption by increasing the relative share of renewables in the energy matrix may show more effective reducing CO_2 emissions in the Mercosur region.
[8] Since methane has a shorter atmospheric lifetime of 12 ± 3 years than CO_2 (IPCC, Climate Change 2007: the 4th Assessment Report), switching from CO_2 to methane will allow cooling to follow within a decade and not centuries.

environmental benefits relative to other fossil fuels.[9] In addition, decrease in their demand for energy caused by an economic downturn in both Paraguay and Uruguay had likely contributed less CO_2 emissions in those two countries after Mercosur. Both countries showed stagnation in their consumption of oil and its derivatives between 2001 and 2008 (EIA, 2010). Meanwhile, the development in Argentina and Brazil have encouraged more energy consumption and increased the long-run impact of energy use on their CO_2 emissions.

Post-Mercosur individual income elasticity coefficients are larger compared to those prior to the formation of Mercosur, implying that over time income contributes to more CO_2 emissions, except for Argentina. In Argentina, the country with the highest per capita income in the region (see Table 1), economic growth appears to gradually reduce emissions.[10] This finding gives support to the EKC hypothesis which indicates that environmental pressure rises faster than income in the early stage of development and slows down relative to GDP growth at the higher income levels. On the other hand, Paraguay, the country with the lowest per capita GDP in the region, experiences the largest increase in pollution levels in relation to income.

The change in the long-run impact of the trade variables on CO_2 emissions after the establishment of Mercosur is likely linked to the utilization and enhancement of inland waterway systems.[11] For instance, with trade liberalization under the FTA, a one percent increase in the ratio of intra-inter Mercosur trade and trade openness in Argentina reduces CO_2 emissions by 0.15 percent and 0.11 percent, respectively. Dredging the waterway provided an energy efficient way to move domestic dry bulk for manufacturing from its northern regions and for

[9] Natural gas produces fewer CO_2 emissions than petroleum (1.4oil/natural gas) and coal (1.7coal/natural gas). See the International Panel on Climate Change (IPCC, 4th Assessment Report).
[10] Narayan and Narayan (2010) found similar results in terms of sign, magnitude, and statistical significance for the period 1980-2004. They concluded that CO_2 emissions in Argentina have been falling over time.
[11] According to World Bank (2010) projections, the existing use of the waterway will avoid on average 1.12 million tons of carbon emissions in Mercosur region per year for the period 2010-2020.

transshipment to the ROW, and to receive freight from upstream countries (Brazil and Paraguay).[12] It also facilitated upstream exports (fuel, wheat, containers) to Paraguay and Bolivia. Argentina benefited from the increase in the flow of transfer freight to oceangoing vessels for overseas trade, since the lower section of the waterway attracts foreign freight for processing or transshipment.

For the particular case of landlocked Paraguay, a one percent increase in trade openness lowered CO_2 emissions by 0.16 percent during the post-Mercosur period. That mitigation on CO_2 emissions, in contrast to a positive elasticity before Mercosur (0.13 percent), is likely to be attributed to the expanded use of the waterway. Deepening the channel of the river system by dredging and installing navigation aids provided a crucial improvement to the access of their production to overseas ports through the Paraná Delta. Paraguay trade with ROW turned massively to river transportation in terms of bulk solids and liquids and containerized freight (World Bank, 2010). On the other hand, expansion in intra-Mercosur trade creates more CO_2 emissions after Mercosur: a one percent increase in regional trade increased CO_2 emissions by 0.39 percent (see Table 5). This is mostly due to commercial transport between Paraguay and its neighbors being almost exclusively conducted by truck transport (World Bank, 2009) and the difficulties in domestic surface transportation (USAID, 2006).

For Brazil, it is found that trade openness had a significant and negative elasticity of 0.41 percent during the post-Mercosur period. The Brazilian government's ambitious investments in the modernization and expansion of their national transportation and logistics infrastructure are likely to generate long-lasting positive effects on reducing CO_2 emissions. Its vigorous National Plan for Transportation and Logistics (NPTL) and the Growth and Acceleration Program (PAC)

[12] Each additional foot of draft enables the load of extra cargo; decreasing energy consumption and consequently CO_2 emissions (Ordoñez et al., 2001).

call for a reduction in the use of road transport from roughly 60 to 30 percent of total cargo transported by 2023, through improvement of the nation's waterways and railway transportation infrastructure.[13] However, investments in transportation infrastructure are relatively concentrated within specific regions with some investments directly targeting commodity exports to ocean ports alone (USITC, 2012). Increases in the ratio of intra-inter Mercosur trade lead to more CO_2 emissions in Brazil during both the pre- and post- Mercosur formation although the impact increased after the Mercosur formation (0.12 percent vs. 0.22 percent). The increasing influence is most likely due to Brazil's overreliance on road transport for intra-regional commerce. Improvements in this issue will be made once the navigation system of locks at the Itaipú Dam on the Paraná River at the Brazil-Argentina border is built. The connection of the Tietê-Paraná down to the Paraná and Paraguay rivers can form an efficient bulk-cargo highway through the heart of Mercosur, decreasing Mercosur's heavy reliance on road transport (World Bank, 2010).

For Uruguay, intra-Mercosur trade mostly captures the positive effect of dredging the waterway and the coordinated enhancement of the transportation infrastructure of the Paraguay-Paraná River on the environment. A one percent increase in intra-regional trade lowered emissions by 0.07 percent in the post-Mercosur period. Since most of Uruguay's trade with ROW is via major port facilities strategically located along the Atlantic Ocean, enhancing the use of the waterway also intensified Uruguay's transshipment of merchandise coming in and out of the waterway.

[13] The plan calls for an increase in the ratio of railway use to total cargo transported from 25 to 35 percent and an increase in the use of waterways from 13 to 29 percent (Brazilian Ministry of Transport, 2010).

6. Conclusions

Using a panel cointegration regression technique, this study provides an empirical analysis of the long-run impact of income, energy consumption, and trade on the environment in Mercosur member states over the period 1970-2008. Our results suggest that income, energy use, and trade are important factors to CO_2 emissions in the Mercosur region. Also, the implementation of Mercosur alters the long-run impact of those variables; particularly trade, on CO_2 emissions in the region. The panel results in the pre- and post-Mercosur periods illustrate that emissions are income and trade inelastic while energy use is elastic. Despite high emission responsiveness of energy consumption elasticities, results suggest decreases in the impact of energy use panel estimates from pre- to post-Mercosur period. This is likely due to changes in the fossil fuel consumption mix. With respect to trade openness, we found environmental quality to be a normal good in the post-Mercosur period. The changes in the impact of trade on CO_2 emissions after establishing Mercosur are likely to be attributable to changes in transportation infrastructure investments.

Additional investments in the freight transportation sector can have increasingly positive impacts in mitigating CO_2 emissions. For instance, the Tietê-Paraná section of the waterway can potentially become the backbone of a regional inter-modal transport system once the Itaipú Dam system of connecting locks, the last obstacle to navigation on the Rio de la Plata, is built (United Nations WWDR 3, 2009). In addition, enhancing the depth of the northern part of the Paraguay-Paraná section of the waterway could improve its navigability and attract more freight through the waterway consequently reducing fuel use. The stretch between Asunción (Paraguay) and the Apa River at the Brazil-Paraguay border is crucial to ensure traffic circulation that originates in or is destined to Bolivia, Brazil, and the zone continuing on to Concepción city (World Bank, 2010).

There is great potential to decrease CO_2 emissions in the region by further reducing Mercosur's overreliance on road transport (World Bank, 2010). Policies like the NPTL and PAC that promote the extension of railways and development of viable waterways will encourage shifting from road transport to alternative economical and less polluting transportation options (Brazilian Ministry of Transport, 2010). Such initiatives, particularly those that benefit the development of multi-modal networks capable of connecting waterways with railways and highways, will most likely create long-lasting positive effects in CO_2 emissions reduction without jeopardizing economic growth in the Mercosur region. These initiatives' positive effects can occur with the coexistence of the environmental policies that aim at reducing energy consumption and GHG emissions and trade policies targeting regional economic integration and expansion. As suggested by Hochstetler (2003), economic development, energy, and the environment should not be treated in isolation but jointly pursued as key components in the success of the Mercosur.

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Table 1. Descriptive Statistics for the Individuals and the Panel

Member State		*GHG* (metric ton)	*y* (2000 US$)	*e* (gram of oil equivalent)	*o* (%)	*tr* (%)
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: *GHG* is greenhouse gases emissions, *y* represents per capita income, *e* represents total energy use per capita, *o* represents trade openness, and *tr* is the intra-inter trade ratio.

Table 2. Panel Unit Root Tests without Considering Cross-sectional Dependence, 1970-2008

		LLC	IPS	Fisher-ADF	Fisher-PP
		Levels			
Intercept	GHG	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	GHG	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	GHG	-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	GHG	-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: LLC and IPS represent the panel unit root tests of Levin et al. (2002) and Im et al. (2003), respectively. Fisher-ADF and Fisher-PP refer to the unit root tests in Maddala and Wu (1999). 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* is the intra-inter trade ratio.

Table 3. Panel Unit Root Tests Considering Cross-sectional Dependence, 1970-2008

		q=0	q=1	q=2	q=3
			Levels		
Intercept	*GHG*	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)*	-0.75(0.23)
	tr	-2.16(0.02)**	-1.32(0.09)*	-1.70(0.05)**	-0.31(0.38)
Intercept &Trend	*GHG*	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(0.79)
	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	*GHG*	-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	*GHG*	-8.02(0.00)***	-6.26(0.00)***	-2.79(0.00)***	-1.02(0.15)
	y	-6.01(0.00)***	-2.55(0.01)***	-2.52(0.01)***	-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* is the intra-inter trade ratio.

Table 4. Panel Cointegration Test, 1970-2008

	Intercept	Intercept & Trend
Panel ν-statistic	-1.34(0.91)	-1.80(0.96)
Panel ρ-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 ρ-statistics	-0.27(0.39)	-0.55(0.29)
Group PP-statistics	-1.99(0.02)**	-3.42(0.00)***
Group ADF-statistic	-2.72(0.00)***	-3.58(0.00)***

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

Table 5. Fully Modified OLS Estimates of the Long-run Impact on CO_2 emissions in the Mercosur Member States, 1970-2008

	y	*e*	*o*	*tr*
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. *y* represents per capita income, *e* represents total energy use per capita, *o* represents trade openness, and *tr* is the intra-inter trade ratio.

Table 6. Fully Modified OLS Estimates of the Long-run Impact on CO_2 emissions before and after the formation of Mercosur

	1970-1990 (Pre-Mercosur)			
	y	*e*	*o*	*tr*
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)

	1991-2008 (Post-Mercosur)			
	y	*e*	*o*	*tr*
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. *y* represents per capita income, *e* represents total energy use per capita, *o* represents trade openness, and *tr* is the intra-inter trade ratio.

Figure 1. The Paraguay-Paraná Waterway

Source: Iniciativa para la integración Regional Sudamericana (IIRSA)

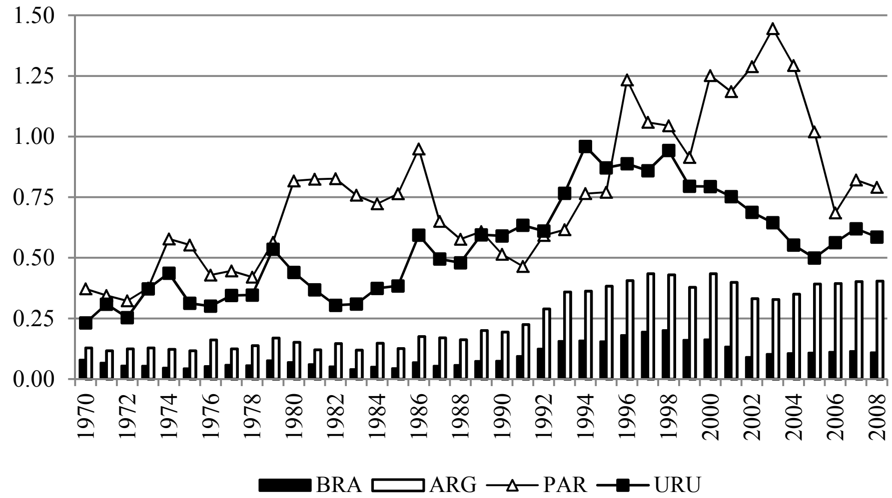

Figure 2. Intra-inter trade ratios for four Mercosur members, 1970-2008