PORTO UNIVERSITY

FACULTY OF ECONOMICS AND MANAGEMENT

# WHICH VARIABLES BETTER EXPLAIN $CO_2$ EMISSIONS IN SOUTH AMERICAN COUNTRIES? A PANEL DATA ANALYSE

**Mercedes Beatriz Alvarez Ortega**

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**SUPERVISOR:**

**Professor Isabel Soares**

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*"Despite the amazing things that humans able to do, we continue insecure about our goals and we seem unhappy as always. Is there something more dangerous than the Gods unhappy and irresponsible, that don't know what they want?"*

*Yuval Noah Harari (Homo Deus)*

**ABSTRACT**

The main goal of this thesis is to analyse seven relevant environmental and socioeconomic indicators, determining the influence and impact of $CO_2$ emissions, through empirical evidence and panel data analyse. To accomplish this goal, annual data for the period do so 1997-2016.

South America is a region with invaluable biological diversity, therefore was chosen; Brazil, Colombia, Argentina, Ecuador, Peru, Bolivia, and Chile that represent an important part of the Biodiversity Hotspots. The literature allows an overview of the actual situation in this region, the biodiversity conservation is an essential goal for the next years, the reports show and describe socio-economic indicators as well as the agreements and programs to helps control the climate change.

The environment and social indicators were selected about non-governmental organization reports in the last years. $CO_2$ emissions are dependent variable, GDP, Forest Area, Agricultural Land, and Urban Population are independents variables, and three binary variables: GINI INDEX, corruption control, and regulatory quality.

The data were analysed by a panel data model, with fixed effects used Stata software. The regression allows defining which variables are significant and which are not significant to the $CO_2$ emissions. However urban population and the dummy variables are the exceptions, the results were not that was expected. The conclusion suggested some future studies based on the literature comparison.

**Key words:** $CO_2$ emissions, Socioeconomic factors, Panel data, South America.

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**ACRONYMS**

**APEC:** Asia Pacific Economic Cooperation.

**CEPF:** Protecting Biodiversity by Empowering people.

**EPA:** United States Environmental Protection Agency.

**ES:** Ecosystem Services.

**ECLAC:** Economic Commission for Latin America and the Caribbean.

**FAO:** Food and Agriculture Organization of the United Nations.

**GDP:** Gross Domestic Product.

**IUCN:** International Union for Nature Conservation.

**IPCC:** Intergovernmental Panel on Climate Change.

**IADB:** Banco Interamericano de Desarrollo.

**LAC:** Latin America and the Caribbean.

**OECD:** Organisation for Economic Co-operation and Development.

**REDD+:** Reducing Emissions from Deforestation and Degradation in Developing Countries.

**SDGs:** Sustainable Development Goals.

**TFP:** Total Factor Productivity.

**UNEP**: United Nations Environment Programme.

**UNFCCC:** United Nations Framework Convention on Climate Change.

# CHAPTER 1. INTRODUCTION

The initial purpose of this dissertation was to relate biodiversity with economic growth in South American countries. However, due to the lack of data, even from different data sources, for a reasonable number of countries and a significant number of years, we were forced to redirect our analyse to $CO_2$ emissions, as a proxy of environment /climate impacts.

Biodiversity is biological variability, which links the diversity of all living organisms that inhabit the planet, including genetics, populations, species, and landscapes. Globally, biodiversity is unevenly distributed, there are places on the planet more biologically diverse than others as it varies with geographical location and latitudes (UNEP- WCMC, 2007),

Biodiversity has an attributed value that is related to the resources provided by ecosystems. It is a provisional source of the basic needs of human beings such as food, housing, medicines, etc. Therefore, biological diversity allows maintaining a balance in ecosystems. These benefits provided by natural resources are normally not valued within the market economy. This is due to the lack of knowledge about the economy/ecosystem interaction studied by (Wood, 1997)

Plans and programs management by correctly allocating budgets, add a monetary value on ecosystem services can help spread their real importance, leading to more efficient, profitable, and equitable decisions (MEA, 2003). The resources available to organizations that conduct global-scale conservation are extremely limited, and building a new conservation system requires considerable amounts of time, money, and effort, reconsidering the strategies and frameworks in existing priority areas is essential (Kobayashi, 2019). On this wise there must be an integration of biodiversity within the economy and social development, requiring strategies to approach environmental aspects and also being as support to reduce poverty (MEA, 2003).

The South American region has an invaluable biological diversity, more than 40% of the biodiversity of the world variety in flora and fauna. It is important to forest resources which represent 22% worldwide forest area (UNEP, 2010). South America owns one of the largest expansions of primary forest in the world, 45% of the total area, mainly in Colombia, Peru, and Ecuador, are among the most biologically rich, while in Chile and Argentina, there is an important part of the temperate forests which remain in the world. Over the years, this region are threatened by continued biodiversity loss. The rainforest, in particular, has lost 32% of the global vegetation during 2000-2012, half of the percentage loss being in South America (Hansen, 2013).

*"The World Bank estimates that crimes affecting natural resources and the environment inflict damage on developing countries worth more than $70 billion a year. Deforestation and land conversion contribute about 25% of global greenhouse emissions, and the loss of diversity reduces the resilience of ecosystems to climate change and other disturbances." (WorldBank, 2020)*

The international community has this region in high regard, and various international agreements help develop the management of natural resources (UNEP-WCMC, 2016). For instance, the Aichi Biodiversity Targets are a plan for biodiversity conservation in Latin America helps government organizations such as Ministries of Finance, Health, Planning, and Economic Development, Agriculture, Tourism, Education, among others, to get better results, such as improving institutional quality, implementing better policies and regulation. (UNEP-WCMC, 2016).

## 1.1 $CO_2$ EMISSIONS AND BIODIVERSITY IN SOUTH AMERICA

Hotspots have been adopted as an institutional plan since 1989, Conservation International (environment organization) made the first update of these critical points, introduced quantitative criteria such as a region should contain at least 1,5000 endemic plant species (> 0.5% of the world total), and experience disproportionate rates of habitat loss ( conversion of >70% of pristine vegetation cover (Newbold, 2016). A second update was in 2004, 35 biodiversity hotspots have been defined at the moment, were verified based on the new data on the distribution of the species, and which are the most threat extinction (Mittermeier, 2004). Only a small proportion of the land surface in these hotspots is under protection. Factors driving this demand for land are acting at various spatial scales, from local, regional, country-wide to global, mainly driven by increasing demographic pressure and life standards (Habel, 2019).

Three important connecting reasons contribute to land and ecosystem degradation in biodiversity hotspots: (1) The global market and complex production chains sever consumers from local land uses. (2) The value of ecosystems (ie ecosystem services) at both local and global scales is not fully reflected in global markets (Costanza, 2014). (3) The global divergence in affluence enables citizens of wealthy nations to extend their consumption and to utilize resources beyond their limits (Lenzen, 2012); (Weinzettel 2013).

According to Chaudhary and Kastner (2016), governance should be improved to reduce the impacts of $CO_2$ emissions on global biodiversity hotspots. The authors argue that seeking to establish connections between consumption in affluent countries, industrial production, and carbon footprint, and biodiversity loss with the global supply chain is a possible solution.

**The Cerrado Region in Brazil**

It is the most extensive woodland savanna in South America, located between the Amazon, Atlantic Forests, and Pantanal. It has a large number of leafy trees, which is a characteristic of the tropical region (WWF, 2016). Only 50% of its native vegetation remains, with a small part of a protected area, (FAO, 2015). Soybeans crops, hydroelectric reserves, and expansion of urban areas are the main activities that influence biodiversity loss by (Faleiro, 2013). Brazil is currently the world's largest exporter of soybeans, and the expansion of cultivated areas has been occurring rapidly in the northern regions of the savanna (the Cerrado region) (Spera, 2016). Factors such as institutional quality is an indicator for determining that the native vegetation areas are not satisfactorily protected (SEEG, 2018). According to (Castro, 2019) the cerrado is most important for environment conservation, sociocultural biodiversity, economic growth, and international food security. Cerrado is also important to the GHG emissions owing to its land-use change dynamics. Around 45% of native vegetation has been converted into pasture and cropland, about 10,000Km2 per year in the last seven years (INPE, 2018).

**The Tropical Andes**

It is a region biologically and culturally wealthy, as it crosses 7 countries in South America: Colombia, Venezuela, Bolivia, Chile, Ecuador, Argentina and Peru (Hoorn, 2010). A sixth of the biodiversity are in 4 countries of the 7 that crosses the Andes (Tiessen, 2009). This mountain range is used as a resource for different human activities such as agriculture, livestock, but population growth (mainly in Colombia, Peru, and Chile) causes several changes in the ecosystems and native vegetation, generating negative impacts (Tiessen, 2009). The tropical forest has importance, the farming on oft marginal soils has provided many ecosystems highly degraded, with little remaining natural habitat, and where there is already a phase of land abandonment (Nanni, 2019).

**Tumbes Choco Magdalena**

This region is also known as Choco-Darién- Western Ecuador, from the year 2000 this area lost 30% of native vegetation, for human activities, mainly deforestation, livestock, and agriculture (Conservation International, 2005). According to (Newbold, 2015) several conservation projects proposed by national governments, financing agencies, international organizations, protected and conserved some parts of the region, approximately 12.5% is considered protected, however, only 6.9% of tumbles -Chocó - Magdalena is conserved under IUCN (international union for nature conservation) (Mittermeier, 2004 ).

Deforestation is real trouble in this zone, as forests are altered and used for livestock pastures. Currently only a secondary fragmented forest, mostly smaller than 100ha, meanwhile can be found, the forest has left a few dispersal corridors or even disrupted connectivity (Hermes, 2018).

**Chilean Winter Rainfall Valdivian Forests:**

This area represents more than half of the temperate forest of the southern hemisphere (Donoso, 1993); (CONAF, 2011). Although the modification and use of the natural resources of this area produced a continuous loss of this ecosystem, it has been considered one of the 35 biodiversity hotspots because it is naturally rich forest (Myers, 2000; Mittermeier, 2004). Land use for these intensive agriculture activities involves 72,000 km2 that is 16.5% of the total land area. Despite this impact on the decline and fragmentation of forests, this area still has approximately 30% of native extension (Mittermeier, 2004). Noh (2019) sustains that native forest have been fragmented and reduced by 53%, with an annual deforestation rate of 1.99% between 1979 and 2011, it is urgent to implement local or small-scale restoration projects in order to mitigate the existing extinction debt.

**Atlantic Forest**

These it is considered as one of the most important regions in Brazil, contributing to 70% of gross domestic product (GDP), 2/3 of the industrial economy, urbanization, industrialization, and agricultural expansion led to economic growth (Joly, 2014); (Martinelli and Moraes, 2013).

Some of the largest urban centers, such as São Paulo and Rio de Janeiro, and some of the most productive land in Brazil (more than half of the national lands dedicated to horticulture) are in this region. (Scarano and Ceotto, 2015). This means that only 1% of its native forests are being protected as well as, 1544 species of plants being a biodiversity hotspot, and 380 animal species while are in danger of extinction (Paglia, 2008).

**GHG / $CO_2$ EMISSIONS**

According to the Fifth Assessment Report of the (IPCC, 2014), the world starting an era of climate change. The concept of climate commitment, first introduced by Ramanathan (1988), refers to changes that are already in the pipeline, regardless of any further emissions or any future change in GHG concentrations in the atmosphere. “A large fraction of anthropogenic climate change resulting from $CO_2$ emissions is irreversible on a multi-century to the millennial time scale, except in the case of a large net removal of $CO_2$ from the atmosphere over a sustained period” (IPCC 2013, (UN environment, 2019). Index gas is shown by Hartman (2013); UN environment (2019). Over the industrial period, the increase in $CO_2$ concentration over the industrial period is on the same scale as the data for the transitions in $CO_2$ concentration between the glacial and interglacial periods over the past 20,000 years.

The impact of GHG emissions on climate change is global, even though global warming impacts are not equivalently distributed across the world. It is stronger at higher latitudes, which puts in risk the species and ecosystems (Parmesan and Yohe, 2003); (Deutsch and Tewksbury, 2008). Authors like Haustein (2017) explain the current GHG emission rate persists, which will result in a continuation of global temperature increase of ~0.2°C per decade, crossing the 1.5°C Paris Agreement target by the 2040s (Leach, 2018). This growth is despite the presence of a wide array of multilateral institutions as well as national policies aimed at mitigation (Peters, 2011).

Agriculture, forestry, and other land use contribute 25 percent to global GHG emissions (Seto, 2014). In developed countries, agriculture emissions represent about 10 percent of national GHG inventories (European Environment Agency, 2017; US EPA, 2017), while in developing countries the contribution is much higher. The effects of climate change are translated into modifications in atmospheric composition converging to land-use change, primarily deforestation, and greenhouse gas (GHG) emissions. Such as $CO_2$ emitted through fossil fuel burning and methane released from agriculture and other sources, as well as the emissions of the aerosol particle (Vaughan, 2013). The production of internationally traded goods is responsible for produce about 30 percent of all $CO_2$ emissions. The household consumption, meanwhile, of goods and services over their life cycle, accounts for about 60 percent of the total environmental impact from consumption (UNEP 2010) (UN environment, 2019).

On the another hand, the fast increase in the carbon footprint per capita of countries sitting in the middle of the demographic transition (early- and late-demographic dividend) clearly illustrates the likely effects of high population growth on $CO_2$ aggregate emissions under current circumstances (UN environment, 2019); (O'Neill, 2012); (OECD, 2016).

Some countries in the LAC (Latin America and the Caribbean) region are working to implement REDD+ mechanisms, REDD+ intends to provide incentives for countries to conserve and sustainably manage their forest resources (Mant, 2014). Efforts to create a financial value for forest carbon, while investing in low-carbon sustainable development pathways, such as REDD+, can also contribute to achieving social and environmental benefits including the conservation of biodiversity (UNEP-WCMC, 2016).

Nevertheless, assessments that emphasize the main differences across the agricultural sectors of LAC countries are lacking. This gap is relevant because agricultural, forestry, and other land-use change GHG emissions in LAC account for 42% of the region's overall GHG emissions while the global average is 18% (ECLAC, 2018). Exist a shortage of information climate policy in LAC countries may need to focus more heavily on land and agriculture than in other world regions. (UNEP-WCMC, 2016); (UN environment, 2019).

## 1.2 ENVIRONMENTAL AND SOCIAL FRAMEWORK

The impacts of climate change and social inequality are associated with poverty, these factors are really important to determine the panorama for future generations (Ahmed, 2009). Climate change will have a severe impact on the poorest populations and will endanger most species of fauna and flora on the planet. The authors (Maxwell, Fuller, Brooks, and Watson, 2017) explain the transformation of ecosystems and the rest of natural resources for agriculture has been identified as one the most important driver of biodiversity worldwide.

According to LandScan (2006), 15.9% of the population live in the 35 hotspots (31.8% of the world's population), the growth in these regions is much faster than the rest of the world. A fraction poorest population is part of the hotspots, most of these countries have challenges, such as high demographic pressure and food shortage, and the expansion of the agricultural area (Williams, 2011). Food products and beef cattle products represent the major global trade flows in regard to footprints. Authors like Weinzettel (2018) proposes to standardize agricultural impacts in the direction to biodiversity hotspots and to emphasize the appropriation should have of individuals.

The bad use of landscapes may also have an impact on the pressure onto pristine ecosystems: Soil quality is low in most tropical regions so that rapid soil nutrient depletion after land conversion creates further need for new, fertile land (Habel, 2015). Besides, a higher wealth in societies is generally accompanied by a higher caloric intake per capita, particularly in developing and newly industrialized countries (Davidson and Andrews, 2013). Economic growth and social inequality are focused on countries that play an important role in the future world economy, due to their rapid development, urban and industrial, Colombia, Chile, and Brazil (UNEP-WCMC, 2016).

The excessive consumption of goods products and services from nature causing degradation of these areas, people who live in poverty are generally those who need more good water quality, protection of natural disasters (Turner, 2007). Currently, the biodiversity hotspot areas involve approximately 17.3% of the Earth's land surface, but human activity has reduced the vegetative cover in these areas to below 27% of their original extent (Marchese, 2015); (Jantz, 2015). As the majority of biodiversity hotspots are composed of forest ecoregions, human activities are generating significant losses on original forest cover, habitats, and biodiversity.

**Inequality**

The economic inequality translates into an inequality in access to water, sanitation, and adequate housing, particularly for the most vulnerable groups, translating into low adaptive capacities to climate change. All along with the 1990s, the Human Development Index score for 21 countries declined. Water scarcity affects roughly 1–2 billion people worldwide (Tekelenburg, 2009).

The decline in poverty and the increase in human well-being were modest due inequality has increased over the past decade. During the 1990s, the Human Development Index score for 21 countries declined. An increase in poverty combined with a decrease in biodiversity exploitation leads to the degradation of the natural system and productivity declines; population growth and inequality maintain poverty.

Associations have been found between inequality and biodiversity decline in tropical regions (WWF,2014), and in the LAC ( Latin-American and Caribbean) region, over 25 percent of the urban population lives in extreme poverty, with the richest 20 percent earning 20 times more than the poorest 20 percent (UN-HABITAT, 2012). Inequality grows if people who cause biodiversity loss and profit from depleting natural resources are not the ones that suffer its consequences. Nevertheless, bad policies may increase inequality in the rural population or promote activities that lead to biodiversity loss (Contreras-Hermosilla, 2000).

**Population**

Human well-being is dependent on the local environment (including climate, topography, and human population density) and richness (ability to substitute diverse ecosystem services with technologies). There is a direct relationship between ecosystem services and biodiversity, it is, therefore, necessary to consider the full range of ecosystem services from which people benefit (UNEP-WCMC, 2007). As human demands on ecosystems increase with the growth of population and consumption and increased technology, there is greater potential for ecosystem degradation and intensification of trade-offs related to ecosystem services (Dudley and Stolton, 2003).

Most urban areas were established between 1950 and 1990 as a result of a rapid demographic increase, coupled with an intensive rural-urban migration (UN-HABITAT, 2012). According to Pauchard and Barbosa (2013), fast-paced urban expansion and consequent ecosystem invasion are a challenge that needs to be addressed by ensuring the availability of urban green spaces, and the interaction between urban planning strategies, biodiversity, and ecosystem services in the region.

The initiatives that focus on urban planning and support ecosystem maintenance are being taken as examples, for instance, initiatives where urban inhabitants actively promote stewardship of urban green areas (Pauchard and Barbosa, 2013).

**Institutional quality**

According to authors (Fernandez, 2005), the population of developing countries is demanding better performance from governments, that is the reason it has been settled new standards because they are increasingly aware of the costs of poor management and corruption. Countries are asking for help in diagnostic governance failures, agencies as the world bank, evaluate indicators that help to determine the institutional quality solutions (WorldBank, 2019).

Latin America has had the highest level of income inequality among the world's regions (Chong, 2004). The final, and most serious, the problem has been the relatively slow rate of economic growth. By international standards, GDP per capita growth in Latin America has been lower than that of the more successful developing countries (Sawyer, 2011). According to the report (UNEP-WCMC, 2016), nowadays there is considerable potential within the region to mobilize sustainable financing from different sources including national governments, regional, global funds, and private businesses, amongst others. Evidence of enhancement and implementation of biodiversity-related conventions through strategies and action plans can be seen in countries from the LAC region.

**Economic growth (GDP per capita)**

Authors like Sawyer (2011) explain that one of the main economic issues in Latin America is GDP per capita only is about 20 percent in the U.S.  Economic growth in Latin America has diminished due to the low growth of total factor productivity (TFP). The LAC (Latin American and the Caribbean) to continue economic growth and prevail in poverty reduction efforts, in general, the quality of institutions in a country affects TFP which in turn affects the rate of growth of GDP (Bovarnick, 2010). Furthermore, economic growth can have trade-off effects on biodiversity elsewhere, without matter the region or country (Lazarus, 2006).

On the other hand, the baseline causes of biodiversity losses are human intervention and human inefficiencies, not economic growth. It is possible to have both economic growth and constant or increasing biodiversity (Czech, 2008). Ecosystem services have provided valuable sectoral inputs for substantial economic growth in the region. Countries in the Latin American – Caribbean region now need to consider the balance between short-term needs and maintenance of ES (ecosystem services) to support long term economic growth (Bovarnick, 2010). Given that the focus in development policies is, still economic growth at expense of the environment (Bodegom, 2006).

**Agriculture**

The agricultural sector is essential for contribution to GDP in Latin American countries, export revenues, employment, and rural livelihoods, about 9% of the region's population is employed in agriculture, the primary source of income for rural households (Bovarnick, 2010).

Growing global demand for meat and dairy products has substantially increased agricultural activity in the region. Between 2001 and 2011, poultry production in Latin America and the Caribbean nearly doubled, and production of milk, beef, and pork rising by over one third, exceeding average global increases. In 2012, the region produced 28 percent of the world's beef and 23 percent of the world's poultry. Continued rapid growth in production is envisaged over the next decade (FAO, 2014). These agricultural extension leads to environmental pressures as deforestation occurs to grow crops, such as soybeans, as feed for livestock, and highlights the need for sustainable agricultural practices.

Another important impact on habitats of the region include land cover change (forest and savannah conversion to large scale agriculture) (Piquer- Rodríguez, 2015), land pollution, and sediment runoff from industrial agriculture and cities into major watercourses and the final destination is the ocean, infill of wetlands for urbanization, and logging of high-value timber species (Pauchard and Barbosa, 2013). Agriculture, aquaculture, and forestry are all significant threats to biodiversity across Latin America and the Caribbean, often impelled by demand for exports. The biodiversity must be valued, making aware of its existence and use-values, a part of daily decision making in LAC countries requires mainstreaming within policies, institutions, laws, regulations, and productive sectors such as, agriculture, fisheries, tourism, and forestry (UNEP-WCMC, 2016).

Authors such as Maxwell (2017) and Tilman (2017) state that new measures, national and international, are needed to find ways in which demand for land can be reduced and current agricultural practices improved. The world's governments have committed to reducing the demand for land and improved agricultural practices through the Sustainable Development Goals (SDGs) but this needs to be done in an integrated way that delivers across all SDGs including those on food security and climate change, as well as on biodiversity.

## 1.3 MAIN GOAL: RESEARCH QUESTIONS

### MAIN GOAL

Analyse through panel data model the significance of seven environment and social indicators to $CO_2$ emissions in South American region.

### GOALS

- Determine the sample selection criteria through the literature review, due the Biodiversity in this region has been a study topic in the last years.

- Explain through the literature review the environment and social indicators ($CO_2$ emissions, GDP, Forest Area, Agricultural Land, Urban population, corruption control, Gini Index, and regulatory quality) in South America, and their influence in the last 20 years.

- Define through panel data analyse which variables are statistically significant, discuss around of literature and suggest future studies.

# CHAPTER 2. METHODOLOGY

## 2.1 A BRIEF SURVEY OF LITERATURE: A FOCUS ON METHODOLOGIES

At first, the main goal was to analyse the biodiversity indicators involving the biodiversity hotspots in South America. However, due to insufficient data concerning the quantitative variables, the main goal was reformulated, and the new variables were chosen based on literature review and reports, (UNEP-WCMC, 2016); (UN environment, 2019); (UN-HABITAT, 2012); (FAO, 2014); (ECLAC, 2018); (IPCC, 2014), of the last years. The criteria for selecting the seven South American countries (i.e Colombia, Brazil, Chile, Peru, Ecuador, Bolivia and Argentina) was the Biodiversity Hotspots (Chapter 2).

The methodology model, analyse N variables for an X time, is considered as a mix between cross-sectional data and time-series, providing more information related to objective reality, and allowing control of heterogeneity of variables studied. According to Li (2018), it increases freedom and reduces multicollinearity between variables. Compared with simple time-series data and cross-section data, panel data in dynamic analyse, individual analyse, and other aspects, have unparalleled advantages.

According to Saporito (2005), even when the information is not available or insufficient, this panel data methodology could be used to analyse processes. Therefore, this explains why in the last years the panel data method has become one of the main utilized methods in the literature.

As an econometric technique, panel data methods are primarily used for inference to assess the effect that one or more (exogenous) explanatory variables may have on a response, controlling for other explanatory variables. The panel data are related to people, companies, states, countries, etc, are very heterogeneous, the estimation techniques in the panel could be considered principally specific variables.

The panel data can be related to people, companies, states, countries, etc, which is a very heterogeneity method. These are some examples of studies that have been used as panel data:

- Ren, (2018) It was selected socio-economic factors for determining the relation between China's social-economic development and the number of fire occurrences. The authors used panel data in this study to establish an econometric model that can lead to better identification and measure of influencing factors that cannot be observed when simply using cross-section data or time-series data to build a model.
- Jimenez, (2018) The main goal was to analyse the effect of internet access on the economic growth in ten countries of South America in the period 1996-2016, because of that the authors a panel data model was used in addition to some covariates (some of them instrumental variables).
- Magalhães, (2010) The main goal was to analyse regulatory experiences in the natural gas sector, specifically in the transmission and distribution activities, through empirical evidence and panel data analyse.

## 2.2 WHY PANEL DATA?

The panel data can enhance empirical analyse, so that it would be impossible to restrict and separate the data in cross-sectional or time-series. (Hsiao, 2003; Klevmarken 1989) list several benefits of using panel data. These include the following.

1) **Controlling for individual heterogeneity**: Panel data suggests that individuals, firms, states, or countries are heterogeneous. Time-series and cross-section studies not controlling this heterogeneity run the risk of obtaining biased results e.g. (Moulton, 1987). An empirical example. ( Baltagi and Levin 1992) consider cigarette demand across 46 American states for the years 1963–88. Consumption is modeled as a function of lagged consumption, prices, and income. These variables vary with states and time. However, there are a lot of other variables that may be state-invariant or time-invariant that may affect consumption as religion, education, communication media. Panel data methodology can control for these state- and time-invariant variables whereas a time-series study or a cross-section study cannot.

2) **Panel data give more informative data, more variability, less collinearity among the variables, more degrees of freedom and more efficiency*:*** Time-series studies are multicollinear, the data variation can be decomposed for different features, the first variation is high with additional data more informative robust could be produce more reliable parameter estimates.

3) **Panel data allow study better the setting dynamic*:*** Panel data are suited to study the duration of economic states like unemployment and poverty, and if the sample, and data are significant, good results can be achieved. For example, unemployment indicators, the panel data can estimate what proportion of the population is unemployed in one period of time, and which remained unemployed in another period. Important policy and institutional quality questions like determining whether family’s experiences of poverty, unemployment and well- being are transitory or chronic, can be answered with the panel data method.

4) **Panel data are able to identify and measure effects not detectable in cross-section or time-series data*:*** In a panel study, the metric used by individuals is invariant over the

observation period, this issue can be avoid by estimator difference ( fixed effects) which makes inference based only on intrapersonal, and not interpersonal comparison of satisfaction.

5) **The Panel data model allow to build and test more complicated behaviour models than cross-section or time-series data:** For example, technical efficiency is better studied with panels (Baltagi and Griffin, 1988b; Cornwell, Schmidt and Sickles, 1990; Kumbhakar and Lovell, 2000; Baltagi and Griffin, 1995; Koop and Steel, 2001). Also, there are fewer restrictions in panels on a distributed lag model than in a time- series study (Hsiao, 2003).

1) **Design and data collection issues:** Authors as Kasprzyk 1989 Bailar 1989, explain and discuss about issues that arise in the panel design surveys as well as data collection management issues.
2) **Distortions of measurement errors:** Measurement errors might arise because of answers and unclear questions, providing memory errors, deliberate distortion of responses (e.g. prestige bias), inappropriate informants, incorrect register of answers and interviewer effects (insure Kalton, Kasprzyk and McMillen,1989).
3) **Short time series dimension*:*** Time interval for each individual. This means that asymptotic arguments are based on individuals' number with infinity tending. Also increasing the time interval of the panel could be affected. In fact, this increases desertion chances, and increases the difficult computational for limited dependent variable panel data model.
4) **Cross- section dependence*:*** Macro panels on countries or regions with long time series that do not account for cross-country dependence might lead to misleading inference. Alternative panel unit root tests are suggested that account for this dependence.

## 2.3 PANEL DATA MODEL

### 2.3.1 REGRESSION MODEL:

A panel data regression differs from a regular time-series or cross-section regression in that it has a double subscript on its variables, i. e.

$$Y_{it} = \alpha + X'_{it}\beta + u_{it} \quad i = 1, \dots, N; t = 1, \dots, T \quad \textbf{(1)}$$

with *i* denoting households, individuals, firms, countries, etc. and *t* denoting time. The *i* subscript, therefore, denotes the cross-section dimension whereas *t* denotes the time-series dimension. α is a scalar, β is $K \times 1$ and $X_{it}$ is observation on $K$ explanatory variables. Most of the panel data applications utilize a one-way error component model for the disturbances, with

$$u_{it} = \mu_{it} + \nu_{it} \quad \textbf{(2)}$$

where $\mu_i$ denotes the unobservable individual-specific effect and $\nu_{it}$ denotes the remainder disturbance. For example, in an earnings equation in labour economics, $y_{it}$ will measure earnings of the head of the household, whereas $X_{it}$ may contain a set of variables like experience, education, union membership, sex, race, etc. Note that $\mu_i$ is time-invariant and it accounts for any individual-specific effect that is not included in the regression. In this case we could think of it as the individual 'sun observed ability. Their main disturbance $\nu_{it}$ varies with the number of people and time and can be thought of as the usual disturbance in the regression.

### 2.3.2 FIXED EFFECT MODEL

If individual effects are considered fixed and different across individuals, because of strict multicollinearity between the effects and other time-invariant variables, there is no way one can disentangle the individual-specific effects from the impact of other time-invariant variables.

One way of combine thriftiness with heterogeneity and interdependence is to admit that coefficients b are equals for all individuals, with the exception being of the independent term Bii that is specific to each individual, maintaining the hypothesis of homogeneity.

a: $\beta_{kit} = \beta_k, \forall i,t$ , except to for k=1, case in that $\beta_{1it} = \beta_{1i}$ **(3)**

b: $u_{it} \sim \text{i.i.d.}(0, \sigma^2)$. **(4)**

Base model:

$$y_{it} = \alpha_i^* + \mathbf{x}'_{it}\beta + u_{it}, \; i = 1, \dots, N, \; 1\times K \; K\times 1 \; t = 1,\dots,T, \quad \textbf{(5)}$$

where β is a K × 1 vector of constants and $\alpha_i^*$ is a 1 × 1 scalar constant representing the effects of those variables to the it individual in more or less the same fashion over time. The error term, $u_{it}$, represents the effects of the omitted variables that are peculiar to both the individual units and time periods. We assume that $u_{it}$ is uncorrelated with ($\mathbf{x}_{i1}$, . . ., $\mathbf{x}_{iT}$) and can be characterized by an independently identically distributed random variable with mean 0 and variance $\sigma_u^2$.

The obvious generalization of the constant-intercept-and-slope model for panel data is to introduce dummy variables to account for the effects of those omitted variables that are specific to individual cross-sectional units but stay constant over time, and the effects that are specific to each time period but are the same for all cross-sectional units.

### 2.3.3 RANDOM EFFECT MODEL

When the specific effects are treated as random, they can be considered to be either correlated or not correlated with the explanatory variables. In the case in which the effects are correlated with the explanatory variables, ignoring this correlation and simply using the covariance estimator, no longer yields the desirable properties as in the case of static regression models. Thus, a more appealing approach would be to take explicit account of the linear dependence between the effects and the exogenous variables

It is a standard practice in the regression analyse to assume that the large number of factors that affect the value of the dependent variable, but that have not been explicitly included as explanatory variables, can be appropriately summarized by a random disturbance. When numerous individual units are observed over time, it is sometimes assumed that some of the omitted variables will represent factors peculiar to both the individual units and time periods for which observations are obtained, whereas other variables will reflect individual differences that tend to affect the observations for a given individual.

This model of error components introduces individual heterogeneity in the perturbation term that can be divided into two parts: a common one, with a mean null and variance σ2 and an individual, also with mean zero, but with variance σ2 and uα who assume themselves independent.

a: $\beta_{it} = \beta$**,** $\forall i,t$, em que β é $(k\times1)$; **(6)**

b: $v_{it} = \alpha_i + u_{it}$ **(7)**

The model can be seen as a model in which the independent term is random, with.

$\beta_{1i} = \beta_1 + \alpha_i$ e $E(\alpha_i) = 0$. **(8)**

**2.3.4 FIXED EFFECTS OR RANDOM EFFECTS?**

There exists a computational advantage of assuming fixed and non-random effects, although this cannot or should not be add as a justification. It be must seek in the answer of two questions. 1) The aims of study, and 2) The context data, how it was chosen, and the environment where it was developed. (Hsiao, in Mátyás and Sevestre 1996)

The fixed-effects model is viewed as one in which investigators make inferences conditional on the effects that are in the sample. The random-effects model is viewed as one in which investigators make unconditional or marginal inferences with respect to the population of all effects. There is really no distinction in the "nature (of the effect)." It is up to the investigator to decide whether to make inference with respect to the population characteristics or only with respect to the effects that are in the sample.

The principal macro econometric studies, it is impossible to see a sample of N countries as a random selection of a population with a tendency to infinite size, especially since it will most likely represent almost the entire population under study, it becomes evident that the right choice is the specification with fixed effects.

**2.3.5 COUNTRIES SELECTION**

The biodiversity hotspots define the negative environmental impacts in the regions with a big natural richness around the world. Five biodiversity hotspots are found in South America. The sample was chosen based on the geography density, and the countries where are located the hotspots. The literature review helped to determine which of the thirteen countries are relevant to be included to study. It was chosen seven countries: Brazil, Colombia, Chile, Argentina, Bolivia, Perú, and Ecuador where are the five biodiversity hotspots. Paraguay and Uruguay were not chosen, even having a part of these natural areas in small proportion and not much like the others. Otherwise, Venezuela is a country with significant natural resources, but it was not selected because the socioeconomic and government crisis has been affected the development in the last years. How was explained before ecological richness in South America region, specifically in these seven countries, represents the main criteria to select the sample, the period between 1997 – 2016 was selected about the available data for the seven countries and each variable, using the world bank and OECD base data.

## 2.4 VARIABLES

### 2.4.1 $CO_2$ Tonne/ per capita

The $CO_2$ is the most GHG found in the atmosphere, their production derives from human activities, the principal process is the fuel combustion. In Latin America and The Caribbean, the $CO_2$ production has been increased by the industrial development, use of natural resources, population growth in urban places, land use, mining, destruction of the rainforest, is one of the main causes, existing another processes and resources that contribute to the production of these GHG. Talking specifically of the South American region one of the most biodiverse regions in the world and where natural resources are a very important element for economy and industry, the $CO_2$ emissions were chosen as the dependent variable for the analyse.

### 2.4.2 GDP / per capita

According to WorldBank (N.D)

> "One of the main economic indicators is GDP divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources".

This variable allows for the analyse of the economic behaviour of the seven chosen countries from South America and its influence in relation to $CO_2$ emissions in the last years.

### 2.4.3 URBAN POPULATION (% of total population)

According to WorldBank (N.D)

> "Urban population refers to people living in cities, defined by national statistical offices. Most cities grew without any corresponding urban planning, which, together with a fast-expanding urban population, has led to issues such as the invasion of ecosystems, increased social inequality, pollution, among others".

This has been especially the case South America, where overpopulation is a current and important issue. In that sense, urban population is a fundamental indicator for analyse the situation concerning $CO_2$ emissions in this region.

### 2.4.4 FOREST AREA

According to WorldBank (N.D)

> "Forest area is land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural production systems (for example, in fruit plantations and agroforestry systems) and trees in urban parks and gardens".

South America is a region with invaluable wealth in natural resources. Over the last 20 years, the continent has been increasingly affected by several human activities, which have resulted in many negative impacts. Deforestation, wetland drainage and other types of habitat change and degradation, have led to the emission of carbon dioxide, methane, and other greenhouse gases. Furthermore, this also represents a loss of opportunity in terms of carbon storage, which helps to control the quantity of $CO_2$ in the atmosphere. Therefore, in the context of this study it is necessary to analyse the relation between these two variables (forest area – $CO_2$ emissions).

### 2.4.5 AGRICULTURAL LAND

According to WorldBank (N.D)

> "Agricultural land refers to the share of land area that is arable, under permanent crops, and under permanent pastures. Arable land includes land defined by the FAO as land under

temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow”.

The South America region has a productive agricultural land. Through the years, agriculture has become one of the regions´s principal economic activities, while also contributing to pollution and threating natural resources. Furthermore, in the last years the governments and law, have exploited many of these lands without limits, even encroaching natural conservation areas, therefore this indicator allows for the analyse of the influence of the agricultural land in the $CO_2$ emissions.

### 2.4.6 GINI INDEX

According to WorldBank (N.D)

“Gini index measures the extent to which the distribution of income (or, in some cases, consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution. The Gini index measures the area between the Lorenz curve and a hypothetical line of absolute equality, expressed as a percentage of the maximum area under the line. Thus, a Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality. “

It was intended evaluating the seven South America countries knowing the inequality conditions that exist between them. The dummy variable was determined by calculating the average of the seven countries in two periods of 10 years: 1997-2006 and 2007-2016.

**Institutional Quality (Worldwide Governance Indicators, Variables Dummies)**

### 2.4.7 CONTROL CORRUPTION ESTIMATE

According to WorldBank (N.D)

**“**Control of Corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. Estimate gives the country's score on the aggregate indicator, in units of a standard normal distribution, i.e. ranging from approximately -2.5 to 2.5".

It was intended evaluating the seven South America countries knowing the inequality conditions that exist between them. The dummy variable was determined by calculating the average of the seven countries in two periods of 10 years: 1997-2006 and 2007-2016.

### 2.4.8 REGULATORY QUALITY ESTIMATE

According to WorldBank (N.D)

"Regulatory Quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. Estimate gives the country's score on the aggregate indicator, in units of a standard normal distribution, i.e. ranging from approximately -2.5 to 2.5".

It was intended evaluating the seven South America countries knowing the inequality conditions that exist between them. The dummy variable was determined by calculating the average of the seven countries in two periods of 10 years: 1997-2006 and 2007-2016.

## 2.5 TIME RANGE AND DATA BASE:

It is was incorporated to analyse a period of 20 years between 1997 - 2016, the base data show enough information for each year in relation with the indicators, is a robust sample that allowed a complete analyse, some years did not have data, therefore these values in that years were assumed taking the previous year. The sample got an analyse the behaviour of each of the socioeconomic variables about $CO_2$ emission over the years, how it has evolved, and how it has affected or benefited the chosen countries of South America.

**BASE DATA**

| Variable | Mean | Type | Unit | Data Source |
|---|---|---|---|---|
| $CO_2$ | $CO_2$ emissions | Dependent | Per capita | OECD |
| GDP | Gross domestic product | Independent | Per capita | Wold Bank |
| UPO | Urban population | Independent | Per capita | Wold Bank |
| FA | Forest area | Independent | Per capita | Wold Bank |
| AL | Agricultural land | Independent | Per capita | Wold Bank |
| GIX | GINI Index | Dummy | - | Wold Bank |
| CC | Control of Corruption | Dummy | - | Wold Bank |
| RQ | Regulatory Quality | Dummy | - | Wold Bank |

**Table 1:** Variable type, data source, period: 1997-2016 Countries: Brazil, Colombia, Chile, Bolivia, Perú, Argentina and Ecuador

**SOURCES:**

- www.data.oecd.org.
- www.data.worldbank.org/indicators

## CHAPTER 3. MODELISATION AND EMPIRICAL RESULTS

### 3.1. A CRITICAL ANALYSE: RESULTS, AND COMPARISON TO THE LITERATURE

### REGRESSION MODEL

The sample was organized and adjusted to the linear regression model using the EXCEL tool, five variables had a specific unit: $CO_2$ emissions Ton/per capita GDP per capita (current US$), Urban population (% of the total population), Forest area, Agricultural land, because of that was necessary unify the variables, and adapt the sample to have all variables with the same units, therefore was divided each data on total population, got per capita units for this five variables. Regression models are very restrictive to the analyse of panel data, the results presented were estimated using the fixed effects model and the STATA software.

As described, the fixed-effect model aims to control the effect of the selected variables that change between individuals and remain constant over time, the intercept changes from individuals

(Country) to another, being constant over time, while the response parameters are constant for all individuals and in all periods..

The fixed-effects model was represented as:

$$CO_{2_{it}} = \alpha + \beta_1 GDP_{it} + \beta_2 UPO_{it} + \beta_3 FA_{it} + \beta_4 AL_{it} + \beta_5 GIX_{it} + \beta_6 CC_{it} + \beta_7 RQ_{it} \quad \textbf{(9)}$$

In the equation, $\alpha$ showed the intercepts that are estimated, one for each individual. As the response parameters do not influence between individuals, and neither over time, all the differences in behavior between individuals are captured by the intercept, thus α a is the effect of the variables omitted in the model. Another important characteristic of the fixed effects is the intercept, which is a fixed and unknown parameter that get the differences between individuals that are in the sample, the interferences made about the model are only on the individuals within the data. The first regression estimated yielded the following results (figure 4) with 140 observations, the panel data model with fixed effects has $CO_2$ emissions as a dependent variable analysed by 7 independent variables, GDP, UPO, FA, AL, GIX, CC, and RQ.

**HAUSMAN TEST**

The robust sample shows heterogeneity between countries, in the independent term, it was expected that be facing a fixed-effects model. The Hausman test was performed to confirm and validate the fixed effects in the studied variables (Figure 3)**.** The p-value = < 0,05 shows the null hypothesis of equality at 95% confidence rejected and the estimates of fixed effects must be assumed. How p-value = <0.05 the null hypothesis is rejected of equality at 95% confidence and the hypothesis of independence or relevance of the variables should be rejected.

## GENERAL REGRESSION

| $CO_2$ | Coef | Std. Err | t | P>\|t\| | [95% Conf | Interval] |
|---|---|---|---|---|---|---|
| GDP | .0000484 | 9.69e-06 | 4.99 | 0.000 | .0000292 | .0000676 |
| UPO | -1.169.930 | 122663 | -9.54 | 0.000 | -1413095 | -926764.6 |
| FA | -40.816 | 1.405.113 | -2.90 | 0.004 | -68.671 | -1.296.211 |
| AL | 150.920 | 3.250.464 | 4.64 | 0.000 | 86.484 | 2.153.576 |
| GIX | -.0120044 | .006935 | -1.73 | 0.086 | -.0257523 | .0017434 |
| CC | -.2507119 | .1000758 | -2.51 | 0.014 | -.4491006 | -.0523233 |
| RQ | -.0051709 | .0508805 | -0.10 | 0.919 | -1060355 | .0956938 |
| | F(6, 107) = 58.49 | | Prob > F = 0.0000 | | | |

**Table 2:** fixed effect model - continuous quantitative variables

The results of this regression show all the variables as continuous quantitative, in table 2 Prob> F = 0.0000 means that the model is globally significant. In the same way the variables GDP, UPO, FA, AL with a p-value < 0.05 shows that every variable has a significant influence on $CO_2$ emissions, due to the response of each variable the next values are assumed:

- GDP the variable is understood as value "1" increasing with positive impact in $CO_2$ emission of 0,000484 unit per capita.
- UPO the variable is understood as value "1" increasing with negative impact in $CO_2$ emission of -1.169.930 unit per capita.
- FA the variable is understood as value "1" increasing with negative impact in $CO_2$ emission of -40.816 unit per capita.
- AL the variable is understood as value "1" increasing with positive impact in $CO_2$ emission of 150.920 unit per capita.

**DUMMY VARIABLES ESTIMATE**

| $CO_2$ | Coef | Std. Err | t | P>\|t\| | [95% Conf | Interval] |
|---|---|---|---|---|---|---|
| GDP | .0000494 | 9.75e-06 | 5.07 | 0.000 | .0000301 | .0000688 |
| UPO | -1.162.008 | 128154.6 | -9.07 | 0.000 | -1416059 | -907956.3 |
| FA | -47.327 | 1.388.556 | -3.41 | 0.001 | -74.854 | -1.980.124 |
| AL | 156.590 | 3.328.048 | 4.71 | 0.000 | 90.615 | 222.565 |
| dummy_gix | -.0018264 | .0388595 | -0.05 | 0.963 | -.0788609 | .075208 |
| dummy_cc | -.0915712 | .063763 | -1.44 | 0.154 | -.2179738 | .0348314 |
| dummy_rq | -.0588954 | .0418562 | -1.41 | 0.162 | -.1418704 | .0240796 |
| | F(6, 107) = 88.32 | | Prob > F = 0.0000 | | | |

**Table 3:** fixed effect model - nominal qualitative variables

The sample was divided into 2 periods (1997-2006 and 2007 -2016). The average was calculated for each variable: GIX, CC, and RQ in each period, and the regression were evaluated in Stata software (figure 6).

The regression shows the variables GDP, UPO, FA, AL as continuous quantitative and the GIX, RQ, and CC as nominal variables. In table 3 Prob> F = 0.0000 which means that the model is globally significant. The variables GDP, UPO, FA, AL has p-value < 0.05 which means a significant influence on $CO_2$ emissions, Otherwise the variables GIX, RQ, and CC has p-value > 0.05 which means is not significant influence on $CO_2$ emissions.

The response of each significant variable are assumed:

- GDP the variable is understood as value “1” increasing with positive impact in $CO_2$ emission of 0,000494 unit per capita.
- UPO the variable is understood as value “1” increasing with negative impact in $CO_2$ emission of -1.162.008 unit per capita.
- FA the variable is understood as value “1” increasing with negative impact in $CO_2$ emission of -47.327 unit per capita.
- AL the variable is understood as value “1” increasing with positive impact in $CO_2$ emission of 156.590 unit per capita.

| $CO_2$ | Coef | Std. Err | t | P>\|t\| | [95% Conf | Interval] |
|---|---|---|---|---|---|---|
| GDP | .0000327 | 9.88e-06 | 3.31 | 0.001 | .0000131 | .0000523 |
| UPO | -854.240 | 162165.3 | -5.27 | 0.000 | -1175972 | -532509.4 |
| FA | -34.863 | 14.026 | -2.49 | 0.015 | -62.692 | -7.035 |
| AL | 117.093 | 34.297 | 3.41 | 0.001 | 49.047 | 185.138 |
| dummy_gix | .0205142 | .0366403 | 0.56 | 0.577 | -.0521791 | .0932076 |
| dummy_cc | -.0481523 | .0611515 | -0.79 | 0.433 | -.1694752 | .0731705 |
| dummy_rq | -.0047125 | .0406229 | -0.12 | 0.908 | -.0853071 | .0758821 |
| **$CO_2$** | | | | | | |
| L1. | .3842189 | .0911675 | 4.21 | 0.000 | .2033452 | .5650926 |

**Table 4:** fixed effect model - time lag 1998

The data were being adapted for estimating the regression considering one year in time-lag of the dependent variable used as a regressor for evaluating 1 year of studied period the dummy variables are not significant (figure 7). The results did not change in relation to the previous regression, so it is confirmed that the sample (countries and time) affects to evaluate the statistical significance of these variables, and the impact of $CO_2$ emissions.

The regression shows the variables GDP, UPO, FA, AL as continuous quantitative and the GIX, RQ, and CC as nominal variables. In table 4 P> = 0.0000 which means that the model is globally significant. The variables GDP, UPO, FA, AL has p-value < 0.05 which means a significant influence on $CO_2$ emissions, Otherwise the variables GIX, RQ, and CC has p-value > 0.05 which means is not significant influence on $CO_2$ emissions.

The response of each significant variable is assumed:

- GDP the variable is understood as value “1” increasing with positive impact in $CO_2$ emission of 0,000327 unit per capita.
- UPO the variable is understood as value “1” increasing with negative impact in $CO_2$ emission of -854.240 unit per capita.
- FA the variable is understood as value “1” increasing with negative impact in $CO_2$ emission of -34.863 unit per capita.
- AL the variable is understood as value “1” increasing with positive impact in $CO_2$ emission of 117.093 unit per capita.

**GDP**

The GDP is an independent variable. The regression shows statistic significance with a p-value = 0.000. The variable has an impact in the $CO_2$ emissions, per every 1 unit of GDP grow up, $CO_2$ emissions increase in 0.000484. The South American countries are not known for economic growth and productivity, some economical activities are related to natural resources as mining, energy, tourism, forest products, being a region with invaluable biodiversity.

The regression showed that GDP did not affect dramatically $CO_2$ emissions in the last 20 years, this means that economic growth can improve the supply of goods and services, contributing to regional development, and still, $CO_2$ emissions should not increase at the same rhythm. In reports such as IADB (2013), the footprint in LAC decreased by about 11% in the last 20 years, the decline emissions are attributed to a reduced rate of deforestation and improvements in energy efficiency. The report shows it is far too short a trend from which to draw long-term conclusions, but the recent pattern in the region seems to imply that it is possible to decouple growth in the value of economic activity from GHG emissions and that there are immediate opportunities to do so. It will depend on economic management in the next years, and the actions taken by governments and industries in these countries.

**URBAN POPULATION**

The urbanization is a characteristic of South America cities how was described before, the overpopulation without urban planning is a problematic aspect because the urban areas are responsible for more than 70% of such emissions (Johansson, 2012; Seto, 2014) therefore this indicator is an approach into climate change, the reports researched, and studies as a bibliographic review give an overview that how is the behavior of this variable. The urban population is an independent variable. The regression shows statistic significance with a p-value = 0.000. The variable has an impact in the $CO_2$ emissions, per every 1 unit of urban population grow up, $CO_2$ emissions decrease in – 1.16, this result was unexpected.

As it was described before, every year South American countries become increasingly urbanized, through a rapid shift from rural to city and the agglomeration in megacities. The study included countries with big cities like São Paulo, Rio de Janeiro, Bogotá, Buenos Aires, Lima (more than 10 million habitants). These cities of course add negative impacts to the environment, and the pollution is undeniable. In this way, it was necessary to consider the urban pollution and to understand how much it is linked to the urban population per capita with GHG emissions specifically $CO_2$. According to UN environment (2019) in per-capita terms, it is the richest and most prosperous countries that contribute by far the most to emissions. This is true both for countries by income level (the developed world accounts for more than half of total emissions, with a far higher carbon footprint per capita) and for individuals by income level within countries (people in the world's richest quintiles, both from developed and developing countries, produce both higher carbon footprints per capita and greater aggregate emission). Countries with higher population growth rates are typically also poorer, have lower carbon footprints per capita, and experience slower growths in income per capita, for this reason increased population does not always lead to increased consumption or resource use.

In this sense, the urban population variable is significant for $CO_2$ emissions, but this independent variable influence the dependent variable in a negative way. While the urban population increase the $CO_2$ emissions decrease, even when the variable in per capita units can be measured in high populations and take in the countries where important economic growth, richest, high incomes are more relevant because these urban areas have more consumptions and therefore more pollutants. It would be expected that the South American countries that are part of the study, show a coefficient be no negative, show some influence in the $CO_2$ emissions in increase way.

Authors like Ribeiro and Rybski (2019) describe that researchers using urban scaling are assuming population size as the most relevant urban feature for describing $CO_2$ emissions, while those working with the per capita density scaling consider population density as the most significant covariate. Both approaches, however, have produced controversial results regarding the influence of population or population density on urban emissions, part of these contrasts can be attributed to different methodologies for estimating $CO_2$ emissions and defining the limits of urban areas. Also because both approaches ignore that population and area are correlated, and the influence of a possible interconnected role between these quantities on urban emissions, when described in terms of population and density, found that urban emissions display decreasing returns to scale, meaning that doubling population and density of a city always associates with less than doubling its emissions. The urban population variable in per capita units can be affected the result, also as the authors describe it is important to include other variables with influence the whole to determine how this social indicator influences $CO_2$ emissions.

**FOREST AREA**

The forest area is an independent variable. The regression shows statistic significance with a p-value = 0.004. The variable has an impact in the $CO_2$ emissions, per every 1 unit of forest area grow up, $CO_2$ emissions decrease is -40.81684. The effect of forest area variable determinate influence in depended variable, the seven South America countries has an important forest area and richness in natural resources, the diversity is the main characteristic, this region owns one of the largest expansions of primary forest in the world, primary forests, therefore, are a priority for conservation given they tend to support high concentrations of biological diversity, sequester and store substantial amounts of carbon, and play a vital role in hydrological cycles among myriad other ecosystem services (Mackey, 2014). The forest area in South America has an important role in $CO_2$ emissions, tropical forests have several hundred tree species per hectare, researchers have found that in the tropical forests of Amazonia only 1.4% of forest tree species account for 50% of the carbon capture value of these forests (Fauset, 2016).

The forest area effect contributes to reduce the $CO_2$ emissions the studied period support this, although is a biological process for control, and clean the atmosphere, but could be not enough for the next years, because  the countries studied are in development, in the last years have made efforts for has an economic growth that include, foreign investments, industry, infrastructure etc. How was describe before this region has extensive biodiversity, but only a small proportion of the land surface is under protection, also are involve the five biodiversity hotspots therefore the goals must be set a priority for the conservation, in the reports analysed from non-government organizations been studying, and proposing programs focused to adaptation and mitigation planned for the year 2030 and 2050. One of the most important programs is REDD+ (Reducing Emissions from Deforestation and Degradation in Developing Countries) is a voluntary climate change mitigation approach that has been developed by Parties to the UNFCCC (United Nations Framework Convention on Climate Change. It aims to incentivize developing countries to reduce emissions from deforestation and forest degradation, conserve forest carbon stocks, sustainably manage forests, and enhance forest carbon stocks.

## AGRICULTURAL LAND

The agricultural land is an independent variable. The regression shows statistic significance with a p-value = 0.000. The variable has an impact in the $CO_2$ emissions, per every 1 unit of agricultural land grow up, $CO_2$ emissions increase in 150.920. The agricultural is an economic activity that contributes to GDP, export revenues, employment, and rural livelihoods about 9% of the region's LAC population is employed in agriculture, this indicator confirms the influence of agriculture on the environment, although worldwide exist other countries with more agricultural production.

In South America agriculture increasingly becomes one of the main economic activities: Soy, livestock, wheat, etc. are cropped and used as raw material for the food industry. The land richness is the main aspect, because of their resources, extended areas of land like the Amazon and Andes regions have been attractive for the agricultural and food industry. Agriculture activity involves many factors that contribute to negative environmental impacts such as energy consumption (none renewable energy), water consumption, pollution, use of fertilizers, and overgrazing. According to the UNEP-WCMC (2016) the expansion and intensification of agriculture and pastureland are resulting in the decline in area and quality of habitats and associated pollution of watercourses and loss of biodiversity. Small scale agriculture expansion is also affecting natural habitats in other regions, including in the biodiversity hotspots of the Andes and Amazonia, with evidence of agriculture moving into protected areas in some places (CEPF 2015; CPEF 2005).

## GINI INDEX:

As it was described before, it is not statistically significant. Looking into the results from tables 1 to 4, even though this variable has an important role in the chosen countries because the inequality is the main characteristic in this region, the selected period of 20 years was not enough for the variable to be mathematically significant. Also, the countries selected are very similar to each other in terms of inequalities conditions, low incomes, no access to goods and services, bad employments rights. Because of that, the changes related to inequality are not observable, since 1997 - 2016 may be a period where the impact of this indicator in the studied countries did not generate large changes. In the same way, it is important to know that having similar conditions in inequality, that is, less heterogeneity of the data, will influence the results.

However, in the literature review, studies were found regarding the influence of inequality (GINI index) and $CO_2$ emissions. The authors Grunewald and Martinez (2017), based on a substantially larger data set (in both regional and temporal coverage) than the existing literature, investigated the theoretically ambiguous link between income inequality and emissions. They found that the relationship depends on the level of income, using an arguably superior group-fixed effects estimator, that shows that for low and middle-income economies, higher income inequality is associated with lower carbon emissions while in upper-middle-income and high-income economies, higher income inequality increases per capita emissions. The sample was analysed 42 countries over the period from 1975 to 1992, this confirms that the countries and period chosen was not enough for evaluating using the regression model used.

**CORRUPTION CONTROL**

The results suggested that surprisingly corruption control has no statistical significance for our sample and time range (tables 1 to 4). This variable has an important role in the countries chosen for the study because corruption is a feature of governments, but the selected period of 20 years was not enough for this variable to be significant. Also, the selected countries are not so different from each other in governance and corruption conditions, and because of that, the changes related to corruption are not observable. From 1997 to 2016 the impact of this indicator in the countries studied did not generate large changes. In the same way, it is important to know that having similar corruption issues, therefore less heterogeneity in the data, will influence the results.

However, in the literature review, studies were found regarding the influence of corruption control and $CO_2$ emissions. Authors such as Zhang (2016) have studied the effects of corruption on $CO_2$ emissions through the analyse of 19 APEC (Asia-Pacific Economic Cooperation) countries during 1992–2012. The author argues that there is heterogeneity regarding the effect of corruption on $CO_2$ emissions among APEC countries with different levels of $CO_2$ emissions specifically in the lower emission countries where the effect is statistically negative. However, in the higher emission countries, the effect becomes insignificant. This confirms that the countries and numbers chosen for this study were not enough for evaluating by means of the regression model used.

## REGULATORY QUALITY

As it was described before, it is not statistically significant. Looking at the results from tables 1 to 4, this variable has an important role in the chosen countries because the regulatory quality is the main feature to define institutional quality. The period selected (20 years) could be not enough for being significant, the countries selected are not different from each other in institutional and regulatory quality, because of that the changes related to regulatory are not observable. The years studied since 1997 - 2016 maybe did not generate large changes, the results show the impact of this indicator was not significant.

The reports reviewed affirm that regulatory quality request acceleration of recent trends that are only likely to be achieved through strong policy, regulatory, and enforcement action combined with forceful economic incentives. Quick action would also be required to combat new and emerging threats, including the potential damage from uncontrolled mining, agriculture in the Amazon and Andes Piedmont regions that could quickly undermine recent gains.

## CHAPTER 4. CONCLUSIONS AND FURTHER RESEARCH

The reports contributed to interpreting the results. The independent variables and the dependent variable are important socioeconomic factors in environmental studies, and in understanding the reality that these countries face to environmental issues.

For the study $CO_2$ emissions were taken as the dependent variable. Although $CO_2$ is not the most toxic GHG when compare to methane, it is found in the environment in the highest percentage. In the last years, $CO_2$ emissions in South American have been approximately 9 -10% of the total global emissions, but this percentage is increasing. As evidenced by the results, variables such as agricultural land cause a significant increase in emissions. Countries like Brazil, Colombia, and Argentina that use big extensions of land for agricultural activities and livestock, have increased their $CO_2$ emissions. The interest of foreign companies to invest in this region has increased in the last decade, therefore national, local, and regional governments, public, and private companies create projects that involve agricultural activity and promote economic growth.

The seven countries included in the study are developing countries. Brazil and Chile are outstanding for advance and growth more than the other countries, but there are weakness and issues that do not allow these countries to continue advancing continuously. In the current system economic growth is the first that governments must think about (technology, infrastructure, agriculture, etc.) to achieve development, especially in regions as South American where natural resources are seen by governments and companies as an important source of economic income. According to the results obtained, GDP influences $CO_2$ emissions. From the bibliographic review it is surmised that the influence depends on how much annual economic growth GDP the countries have, as well as the activities related to $CO_2$ emissions. Reports such as IADB (2013) acknowledge that in the last years in Latin America the carbon footprint has decreased, but how long this none modification system will be give the same results ? being aware that not all these economic activities are managed under environmental standards and focused on sustainable development, economic growth requires that the region seeks changes. As evidenced in the study results, agriculture is an economic activity that must be managed differently. Changes such as the energy transition, use non-polluting fertilizers, environmental policies towards the protection natural areas, implementation of sustainable agriculture, agreements with foreign companies that seek to invest in the region where environmental protection and non-pollution would be main objectives beyond production, are a possible solution.

On the other hand, the forest area is a variable that shows how important is protecting the biodiversity threatened by human activity. In the last years the study of carbon capture has been a trend as a proposal to remove or avoid $CO_2$ from the atmosphere, being a process that is carried out in a biological way and helps to control $CO_2$ emissions. South America is a region where the big cities are built in the middle of big forest areas, especially in countries like Brazil, Colombia, Ecuador, Bolivia, and Peru where the lack of opportunities forces the population to move from rural areas to urban areas.

For future studies is interesting to research how will be sustainably planned the South American cities? the biological processes that nature offers are an advantage that these countries should consider in the next years as pollution in urban areas alternative. The urban population variable as described above, shows statistical significance but the coefficient result is negative. To evaluate the impact of this variable on $CO_2$ emissions, it is necessary to include another factors or sub variables that involve the urban population according to the studies mentioned in this work. So, it is recommended for future studies to include the factors that are related to the urban population to evaluate variables such as $CO_2$ emissions.

Finally, the dummy variables GIX, CC, and RQ are not significant in the model results. Even applying time lag, the regression model was not enough for them to be significant because most of the chosen countries have similar conditions. The exception is Chile, which has the best economy in the region and has experienced significant growth in the last years. Inequality, corruption, and regulatory quality are more seriously in the rest of South America. Institutional quality and governance are the baselines the inequality, within corruption, the abuse of power, poor governance action, manipulation of state entities are some characteristics that have affected this region for years. The inequality of the population, health, education, job opportunities, incomes are a part of the problems that even today have not been overcome and advance to quiet steps. The evolution of the environment and socio-economic indicators studied depends on the actions that institutions and governments decide in the next years. None country is exempt of corruption and inequality, those are issues that every country around the world has, but how can environmental pollution be managed despite inequality and corruption? Are there alternatives? These are questions that could be considered for future studies set within the context that South America and Latin America.

The regression model was appropriate, as it allows for this type of econometric analyse. It defines which variables influence the $CO_2$ emission, and allowed for making an analyse of the reality of South American countries` biodiversity. The exception was variables such as urban population, where more in depth research was needed to get a more accurate result. In relation to the dummy variables the sample type did not respond as expected with this regression model. For future studies it would be important to include variety in the individuals, for instance, European or American countries could be compared to assess the differences with South American ones. The region has a long way to go to regulate inequality, corruption and regulatory quality, also the environment is affected by the lack of good management of natural resources. Topics such as energy transition and use of renewable energy, are important for the daily activities like agriculture, transport, and industry. In the next years these will be key aspects for institutions and governments of the region concerning pollution and emission of greenhouse gases. There are several programs and agreements where the changes have to be reflected for 2030 and 2050, the changes must be immediate, the protection of the environment for present, and future generations is an important motivator to generate a positive impact on the care and use of natural resources.

While we live in a world in which a tree is worth more, financially, dead than alive, in which the exotic animals are worth more dead than alive. For so long as the economy works in that way, corporations and governments go unregulated, it going to continue to destroy forests, threaten many animal species, to mine the earth, and to continue to pull oil out the ground, even though we know it is destroying the planet, this is the short time thinking based on the actual economical model, of profit at all cost, where each developed country and developing country acting in selfish interest. This is has been affecting the environment for many years, this model has been flawed since always. Now civilization must be radical changes in the next years.

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# 6.ANNEXES

**Table 5** : Sample per capita units

| CO2 | COUNTRY | YEAR | FA | UPO | GDP | AL | GIX | CC | RQ |
|---|---|---|---|---|---|---|---|---|---|
| 1,5 | Colombia | 1997 | 0,01659 | 1,92616E-06 | 2827,38 | 0,011951 | 56,9 | -0,51225 | -0,10549 |
| 1,5 | Colombia | 1998 | 0,016245 | 1,90536E-06 | 2566,024 | 0,011871 | 56,9 | -0,49731 | 0,002287 |
| 1,3 | Colombia | 1999 | 0,015913 | 1,88541E-06 | 2209,931 | 0,011710 | 58,7 | -0,49731 | 0,002287 |
| 1,3 | Colombia | 2000 | 0,015594 | 1,86619E-06 | 2520,481 | 0,011319 | 58,7 | -0,39675 | 0,10262 |
| 1,3 | Colombia | 2001 | 0,015272 | 1,84765E-06 | 2439,682 | 0,010370 | 57,2 | -0,39675 | 0,10262 |
| 1,3 | Colombia | 2002 | 0,014962 | 1,82988E-06 | 2396,627 | 0,010179 | 55,8 | -0,23817 | 0,028216 |
| 1,2 | Colombia | 2003 | 0,014666 | 1,81302E-06 | 2281,402 | 0,010137 | 53,4 | -0,17899 | -0,08793 |
| 1,2 | Colombia | 2004 | 0,014384 | 1,79723E-06 | 2782,623 | 0,010075 | 54,8 | -0,12893 | -0,04655 |
| 1,2 | Colombia | 2005 | 0,014116 | 1,7826E-06 | 3404,19 | 0,009979 | 53,7 | -0,13226 | 0,007987 |
| 1,2 | Colombia | 2006 | 0,013863 | 1,76901E-06 | 3731,168 | 0,009762 | 53,7 | -0,12255 | 0,101746 |
| 1,2 | Colombia | 2007 | 0,013621 | 1,7563E-06 | 4703,213 | 0,009702 | 53,7 | -0,21596 | 0,241372 |
| 1,2 | Colombia | 2008 | 0,013391 | 1,74453E-06 | 5461,781 | 0,009629 | 55,5 | -0,23762 | 0,261975 |
| 1,3 | Colombia | 2009 | 0,013173 | 1,73379E-06 | 5195,393 | 0,009506 | 54,4 | -0,30945 | 0,148284 |
| 1,3 | Colombia | 2010 | 0,012966 | 1,724E-06 | 6326,549 | 0,009399 | 54,7 | -0,38539 | 0,253475 |
| 1,4 | Colombia | 2011 | 0,012835 | 1,7155E-06 | 7324,383 | 0,009137 | 53,5 | -0,28879 | 0,359238 |
| 1,4 | Colombia | 2012 | 0,012714 | 1,70804E-06 | 8042,53 | 0,009249 | 52,7 | -0,38745 | 0,400677 |
| 1,6 | Colombia | 2013 | 0,012593 | 1,70034E-06 | 8212,668 | 0,009638 | 52,8 | -0,40521 | 0,402893 |
| 1,6 | Colombia | 2014 | 0,012461 | 1,69079E-06 | 8114,084 | 0,009578 | 52,7 | -0,36863 | 0,496235 |
| 1,6 | Colombia | 2015 | 0,012311 | 1,67851E-06 | 6175,876 | 0,009399 | 51,1 | -0,29817 | 0,465427 |
| 1,8 | Colombia | 2016 | 0,012139 | 1,66298E-06 | 5871,224 | 0,009272 | 50,8 | -0,32425 | 0,402009 |
| 1,7 | Ecuador | 1997 | 0,011714 | 4,91865E-06 | 2356,371 | 0,006704 | 50,8 | -0,68487 | -0,30827 |
| 1,7 | Ecuador | 1998 | 0,011403 | 4,86054E-06 | 2293,89 | 0,006580 | 49,7 | -0,84938 | -0,15596 |
| 1,3 | Ecuador | 1999 | 0,011107 | 4,80594E-06 | 1578,934 | 0,006490 | 58,6 | -0,84938 | -0,15596 |
| 1,4 | Ecuador | 2000 | 0,010826 | 4,75502E-06 | 1445,279 | 0,006361 | 56,4 | -0,89424 | -0,54399 |
| 1,5 | Ecuador | 2001 | 0,01057 | 4,70775E-06 | 1894,615 | 0,006028 | 56,4 | -0,89424 | -0,54399 |
| 1,5 | Ecuador | 2002 | 0,010326 | 4,65007E-06 | 2172,102 | 0,005699 | 56,4 | -0,88609 | -0,66972 |
| 1,5 | Ecuador | 2003 | 0,010092 | 4,5862E-06 | 2425,852 | 0,005423 | 53,4 | -0,75858 | -0,66255 |
| 1,6 | Ecuador | 2004 | 0,009866 | 4,52429E-06 | 2691,278 | 0,005536 | 53,9 | -0,7033 | -0,71637 |
| 1,7 | Ecuador | 2005 | 0,009645 | 4,46345E-06 | 3002,137 | 0,005425 | 53,1 | -0,71296 | -0,78752 |
| 1,8 | Ecuador | 2006 | 0,009429 | 4,40325E-06 | 3328,883 | 0,005295 | 52,2 | -0,75131 | -1,11178 |
| 1,9 | Ecuador | 2007 | 0,009217 | 4,34398E-06 | 3567,836 | 0,005184 | 53,3 | -0,77182 | -1,14148 |
| 1,8 | Ecuador | 2008 | 0,009012 | 4,28599E-06 | 4249,019 | 0,005122 | 49,7 | -0,6871 | -1,13879 |
| 2 | Ecuador | 2009 | 0,008813 | 4,22994E-06 | 4231,616 | 0,005100 | 48,4 | -0,80422 | -1,29621 |
| 2,2 | Ecuador | 2010 | 0,008621 | 4,17624E-06 | 4633,59 | 0,004995 | 48,7 | -0,7731 | -1,17082 |
| 2,2 | Ecuador | 2011 | 0,008438 | 4,12303E-06 | 5200,556 | 0,004819 | 45,9 | -0,70845 | -1,03147 |
| 2,2 | Ecuador | 2012 | 0,008262 | 4,07054E-06 | 5682,045 | 0,004851 | 46,1 | -0,57806 | -1,01731 |
| 2,3 | Ecuador | 2013 | 0,008089 | 4,01879E-06 | 6056,331 | 0,004783 | 46,9 | -0,57095 | -0,92819 |
| 2,4 | Ecuador | 2014 | 0,007915 | 3,96575E-06 | 6377,092 | 0,003512 | 45 | -0,75493 | -1,00722 |
| 2,3 | Ecuador | 2015 | 0,00774 | 3,91056E-06 | 6124,492 | 0,003570 | 46 | -0,67125 | -1,15737 |
| 2,2 | Ecuador | 2016 | 0,007561 | 3,85262E-06 | 6060,093 | 0,003345 | 45 | -0,68033 | -1,01845 |
| 1 | Peru | 1997 | 0,030415 | 2,84789E-06 | 2306,439 | 0,008859 | 53,7 | -0,39889 | 0,494784 |
| 1 | Peru | 1998 | 0,029816 | 2,81455E-06 | 2163,12 | 0,008809 | 56,1 | -0,36576 | 0,615365 |
| 1,1 | Peru | 1999 | 0,029267 | 2,78511E-06 | 1924,487 | 0,008753 | 56,3 | -0,36576 | 0,615365 |
| 1 | Peru | 2000 | 0,028778 | 2,76047E-06 | 1955,588 | 0,008739 | 49,1 | -0,393 | 0,439704 |
| 0,9 | Peru | 2001 | 0,028368 | 2,74067E-06 | 1941,476 | 0,008622 | 51,3 | -0,393 | 0,439704 |
| 1 | Peru | 2002 | 0,028006 | 2,72499E-06 | 2021,24 | 0,008396 | 53,6 | -0,27312 | 0,016094 |
| 0,9 | Peru | 2003 | 0,027683 | 2,71257E-06 | 2145,643 | 0,008362 | 53,1 | -0,07642 | 0,160397 |
| 1,1 | Peru | 2004 | 0,027386 | 2,70212E-06 | 2417,036 | 0,008292 | 49,9 | -0,32176 | 0,212778 |
| 1 | Peru | 2005 | 0,027104 | 2,69266E-06 | 2729,499 | 0,008338 | 50,4 | -0,32996 | 0,031204 |
| 1 | Peru | 2006 | 0,026825 | 2,68382E-06 | 3154,331 | 0,008331 | 50,3 | -0,20019 | 0,134765 |
| 1,1 | Peru | 2007 | 0,026556 | 2,67543E-06 | 3606,07 | 0,008318 | 50 | -0,24627 | 0,277983 |
| 1,2 | Peru | 2008 | 0,026293 | 2,66267E-06 | 4220,617 | 0,008303 | 47,5 | -0,18695 | 0,345373 |
| 1,3 | Peru | 2009 | 0,026032 | 2,64793E-06 | 4196,313 | 0,008317 | 47 | -0,30523 | 0,386653 |
| 1,4 | Peru | 2010 | 0,025772 | 2,633E-06 | 5082,355 | 0,008276 | 45,5 | -0,22881 | 0,450334 |
| 1,5 | Peru | 2011 | 0,025507 | 2,6181E-06 | 5869,323 | 0,008237 | 44,7 | -0,21996 | 0,463544 |
| 1,5 | Peru | 2012 | 0,02524 | 2,60293E-06 | 6528,972 | 0,008246 | 44,4 | -0,37045 | 0,491973 |
| 1,5 | Peru | 2013 | 0,024957 | 2,58578E-06 | 6756,753 | 0,008186 | 43,9 | -0,42349 | 0,458948 |
| 1,6 | Peru | 2014 | 0,024639 | 2,56471E-06 | 6672,88 | 0,007903 | 43,2 | -0,56032 | 0,52091 |
| 1,6 | Peru | 2015 | 0,024277 | 2,53873E-06 | 6229,102 | 0,007658 | 43,4 | -0,53384 | 0,491347 |
| 1,6 | Peru | 2016 | 0,023865 | 2,50724E-06 | 6204,997 | 0,007659 | 43,6 | -0,36738 | 0,508346 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3,3 | Chile | 1997 | 0,010593 | 5,76023E-06 | 5745,374 | 0,010295 | 43,6 | 1,454119 | 1,54276 |
| 3,3 | Chile | 1998 | 0,010495 | 5,70694E-06 | 5446,581 | 0,010161 | 55,5 | 1,380602 | 1,392356 |
| 3,5 | Chile | 1999 | 0,010405 | 5,65713E-06 | 4957,778 | 0,009932 | 55,5 | 1,380602 | 1,392356 |
| 3,2 | Chile | 2000 | 0,01032 | 5,61016E-06 | 5074,902 | 0,009849 | 52,8 | 1,586007 | 1,410081 |
| 3 | Chile | 2001 | 0,010232 | 5,56602E-06 | 4574,594 | 0,009764 | 52,8 | 1,586007 | 1,410081 |
| 3 | Chile | 2002 | 0,010148 | 5,52179E-06 | 4446,251 | 0,009924 | 52,8 | 1,592268 | 1,44762 |
| 3,1 | Chile | 2003 | 0,010069 | 5,46794E-06 | 4772,563 | 0,009732 | 51,5 | 1,311239 | 1,459134 |
| 3,3 | Chile | 2004 | 0,009991 | 5,41525E-06 | 6194,853 | 0,009950 | 51,5 | 1,373608 | 1,402693 |
| 3,3 | Chile | 2005 | 0,009913 | 5,3627E-06 | 7598,525 | 0,009816 | 51,5 | 1,470515 | 1,357459 |
| 3,4 | Chile | 2006 | 0,009832 | 5,30997E-06 | 9464,55 | 0,009661 | 48,2 | 1,457343 | 1,473752 |
| 3,8 | Chile | 2007 | 0,00975 | 5,25705E-06 | 10502,35 | 0,009517 | 48,2 | 1,396431 | 1,505748 |
| 4 | Chile | 2008 | 0,009669 | 5,20455E-06 | 10751,48 | 0,009447 | 48,2 | 1,376727 | 1,518668 |
| 3,8 | Chile | 2009 | 0,00959 | 5,15315E-06 | 10208,91 | 0,009346 | 49 | 1,380127 | 1,462517 |
| 4 | Chile | 2010 | 0,009513 | 5,10323E-06 | 12808,03 | 0,009227 | 49 | 1,497289 | 1,438484 |
| 4,4 | Chile | 2011 | 0,009593 | 5,05594E-06 | 14637,24 | 0,009162 | 47,6 | 1,528443 | 1,459092 |
| 4,4 | Chile | 2012 | 0,009674 | 5,01076E-06 | 15351,55 | 0,009054 | 47,6 | 1,582224 | 1,538509 |
| 4,6 | Chile | 2013 | 0,009751 | 4,9652E-06 | 15842,94 | 0,008981 | 47,3 | 1,541565 | 1,491449 |
| 4,2 | Chile | 2014 | 0,009817 | 4,916E-06 | 14671 | 0,008875 | 47,3 | 1,488503 | 1,494421 |
| 4,5 | Chile | 2015 | 0,00987 | 4,86161E-06 | 13574,17 | 0,008784 | 47,7 | 1,27997 | 1,345232 |
| 4,7 | Chile | 2016 | 0,009905 | 4,80101E-06 | 13748,09 | 0,008645 | 47,7 | 1,140054 | 1,373064 |
| 1,6 | Brazil | 1997 | 0,031631 | 4,7275E-07 | 5282,009 | 0,015523 | 59,8 | -0,01858 | 0,296933 |
| 1,6 | Brazil | 1998 | 0,031002 | 4,69894E-07 | 5087,152 | 0,015320 | 59,6 | 0,075473 | 0,364665 |
| 1,6 | Brazil | 1999 | 0,030398 | 4,67135E-07 | 3478,373 | 0,015132 | 59 | 0,075473 | 0,364665 |
| 1,7 | Brazil | 2000 | 0,029823 | 4,64511E-07 | 3749,753 | 0,014955 | 59 | 0,040204 | 0,361691 |
| 1,7 | Brazil | 2001 | 0,029254 | 4,60242E-07 | 3156,799 | 0,014869 | 58,4 | 0,040204 | 0,361691 |
| 1,7 | Brazil | 2002 | 0,02871 | 4,56061E-07 | 2829,283 | 0,014808 | 58,1 | 0,081059 | 0,296639 |
| 1,6 | Brazil | 2003 | 0,028192 | 4,52139E-07 | 3070,91 | 0,014767 | 57,6 | 0,091483 | 0,30962 |
| 1,7 | Brazil | 2004 | 0,027697 | 4,48468E-07 | 3637,462 | 0,014789 | 56,5 | 0,023013 | 0,03344 |
| 1,7 | Brazil | 2005 | 0,027225 | 4,4504E-07 | 4790,437 | 0,014637 | 56,3 | -0,13979 | 0,039209 |
| 1,7 | Brazil | 2006 | 0,026842 | 4,41857E-07 | 5886,464 | 0,014497 | 55,6 | -0,10904 | -0,03246 |
| 1,7 | Brazil | 2007 | 0,026478 | 4,38899E-07 | 7348,031 | 0,014287 | 54,9 | -0,07593 | -0,02543 |
| 1,8 | Brazil | 2008 | 0,02613 | 4,36124E-07 | 8831,023 | 0,014243 | 54 | 0,00789 | 0,053929 |
| 1,7 | Brazil | 2009 | 0,025794 | 4,3347E-07 | 8597,915 | 0,014108 | 53,7 | -0,06931 | 0,099461 |
| 1,9 | Brazil | 2010 | 0,025469 | 4,3091E-07 | 11286,24 | 0,013973 | 53,7 | 0,04628 | 0,152444 |
| 2 | Brazil | 2011 | 0,025187 | 4,2848E-07 | 13245,61 | 0,013942 | 52,9 | 0,165902 | 0,165336 |
| 2,1 | Brazil | 2012 | 0,024913 | 4,26134E-07 | 12370,02 | 0,013830 | 52,7 | -0,03728 | 0,093902 |
| 2,2 | Brazil | 2013 | 0,024648 | 4,2385E-07 | 12300,32 | 0,013906 | 52,8 | -0,08471 | 0,073424 |
| 2,3 | Brazil | 2014 | 0,024389 | 4,21634E-07 | 12112,59 | 0,013986 | 51,5 | -0,33845 | -0,0782 |
| 2,2 | Brazil | 2015 | 0,024137 | 4,19471E-07 | 8814,001 | 0,013894 | 51,3 | -0,39649 | -0,19266 |
| 2 | Brazil | 2016 | 0,023891 | 4,17349E-07 | 8712,887 | 0,013753 | 53,7 | -0,38144 | -0,20732 |
| 3,7 | Argentina | 1997 | 0,009182 | 2,48375E-06 | 8213,127 | 0,035963 | 49,1 | -0,10132 | 0,518067 |
| 3,7 | Argentina | 1998 | 0,008997 | 2,46119E-06 | 8289,506 | 0,035584 | 50,7 | -0,11342 | 0,570878 |
| 3,8 | Argentina | 1999 | 0,008817 | 2,43923E-06 | 7774,736 | 0,035213 | 49,8 | -0,11342 | 0,570878 |
| 3,8 | Argentina | 2000 | 0,008641 | 2,41769E-06 | 7708,101 | 0,034854 | 51,1 | -0,19212 | 0,257245 |
| 3,4 | Argentina | 2001 | 0,008457 | 2,39644E-06 | 7208,372 | 0,034501 | 53,3 | -0,19212 | 0,257245 |
| 3,2 | Argentina | 2002 | 0,008277 | 2,37542E-06 | 2593,404 | 0,034157 | 53,8 | -0,46821 | -0,91903 |
| 3,4 | Argentina | 2003 | 0,008101 | 2,35471E-06 | 3349,806 | 0,034364 | 51,2 | -0,47834 | -0,70893 |
| 3,8 | Argentina | 2004 | 0,007929 | 2,33451E-06 | 4277,721 | 0,034902 | 48,6 | -0,42499 | -0,71376 |
| 3,8 | Argentina | 2005 | 0,007761 | 2,31484E-06 | 5109,851 | 0,035430 | 48 | -0,38819 | -0,54837 |
| 4 | Argentina | 2006 | 0,007602 | 2,29576E-06 | 5919,012 | 0,035914 | 46,7 | -0,34125 | -0,64063 |
| 4,1 | Argentina | 2007 | 0,007446 | 2,27712E-06 | 7245,448 | 0,036295 | 46,6 | -0,34029 | -0,66822 |
| 4,4 | Argentina | 2008 | 0,007293 | 2,25872E-06 | 9020,873 | 0,035993 | 45,3 | -0,43558 | -0,73752 |
| 4,1 | Argentina | 2009 | 0,007142 | 2,24024E-06 | 8225,137 | 0,035519 | 44,1 | -0,445 | -0,84504 |
| 4,2 | Argentina | 2010 | 0,007011 | 2,22732E-06 | 10385,96 | 0,036158 | 44,5 | -0,36147 | -0,76237 |
| 4,4 | Argentina | 2011 | 0,006859 | 2,2052E-06 | 12848,86 | 0,035937 | 42,7 | -0,36616 | -0,72221 |
| 4,4 | Argentina | 2012 | 0,00671 | 2,18341E-06 | 13082,66 | 0,035764 | 41,4 | -0,44314 | -0,92922 |
| 4,3 | Argentina | 2013 | 0,006565 | 2,16215E-06 | 13080,25 | 0,035353 | 41 | -0,43228 | -0,95726 |
| 4,3 | Argentina | 2014 | 0,006424 | 2,14151E-06 | 12334,8 | 0,034849 | 41,7 | -0,54162 | -1,07426 |
| 4,4 | Argentina | 2015 | 0,006286 | 2,12147E-06 | 13789,06 | 0,034476 | 41,7 | -0,54706 | -0,91144 |
| 4,3 | Argentina | 2016 | 0,006152 | 2,102E-06 | 12790,24 | 0,034113 | 42 | -0,28404 | -0,46963 |
| 0,8 | Bolivia | 1997 | 0,076728 | 7,5858E-06 | 998,5153 | 0,046456 | 58,2 | -0,82483 | 0,004969 |
| 0,9 | Bolivia | 1998 | 0,074884 | 7,50164E-06 | 1049,499 | 0,045675 | 58,2 | -0,35791 | 0,185638 |
| 0,8 | Bolivia | 1999 | 0,073103 | 7,41958E-06 | 1003,392 | 0,044894 | 58,1 | -0,35791 | 0,185638 |
| 0,9 | Bolivia | 2000 | 0,071382 | 7,33964E-06 | 997,5825 | 0,044122 | 61,6 | -0,46021 | 0,035398 |
| 0,8 | Bolivia | 2001 | 0,069718 | 7,26157E-06 | 948,8712 | 0,043304 | 57,4 | -0,46021 | 0,035398 |
| 0,8 | Bolivia | 2002 | 0,068111 | 7,1811E-06 | 904,2266 | 0,042676 | 59,3 | -0,89962 | -0,05929 |
| 0,9 | Bolivia | 2003 | 0,06656 | 7,10187E-06 | 907,5371 | 0,041149 | 59,3 | -0,81514 | -0,08449 |
| 1 | Bolivia | 2004 | 0,065062 | 7,02511E-06 | 967,407 | 0,040376 | 55 | -0,77584 | -0,20282 |
| 1 | Bolivia | 2005 | 0,063618 | 6,95059E-06 | 1034,311 | 0,040036 | 58,5 | -0,73624 | -0,69257 |
| 1,1 | Bolivia | 2006 | 0,061976 | 6,87865E-06 | 1218,874 | 0,039500 | 56,7 | -0,43457 | -0,88807 |
| 1,1 | Bolivia | 2007 | 0,060391 | 6,80885E-06 | 1372,628 | 0,039117 | 54,5 | -0,40371 | -0,98191 |
| 1,2 | Bolivia | 2008 | 0,058858 | 6,74128E-06 | 1715,209 | 0,038559 | 50,8 | -0,52322 | -0,87097 |
| 1,3 | Bolivia | 2009 | 0,057375 | 6,67531E-06 | 1754,211 | 0,038112 | 49,2 | -0,63032 | -0,87931 |
| 1,4 | Bolivia | 2010 | 0,055937 | 6,61088E-06 | 1955,462 | 0,037335 | 49,2 | -0,46576 | -0,80276 |
| 1,5 | Bolivia | 2011 | 0,054754 | 6,54796E-06 | 2346,337 | 0,036774 | 46,1 | -0,56942 | -0,75572 |
| 1,6 | Bolivia | 2012 | 0,053606 | 6,48652E-06 | 2609,881 | 0,036281 | 46,6 | -0,7292 | -0,82358 |
| 1,6 | Bolivia | 2013 | 0,052495 | 6,42161E-06 | 2908,2 | 0,035796 | 47,6 | -0,58992 | -0,77685 |
| 1,7 | Bolivia | 2014 | 0,05142 | 6,35566E-06 | 3081,879 | 0,035214 | 47,8 | -0,63013 | -0,87025 |
| 1,7 | Bolivia | 2015 | 0,050382 | 6,29206E-06 | 3035,972 | 0,034648 | 46,7 | -0,69637 | -0,88582 |
| 1,8 | Bolivia | 2016 | 0,04938 | 6,23089E-06 | 3076,659 | 0,034160 | 44,6 | -0,72439 | -0,92409 |

**Figure 1:** Regression fixed effects

```
. xtset country1 year, yearly
       panel variable:  country1 (strongly balanced)
        time variable:  year, 1997 to 2016
                delta:  1 year

. xtreg co2 gdp upo fa al gix cc rq i.year, fe

Fixed-effects (within) regression               Number of obs     =        140
Group variable: country1                        Number of groups  =          7

R-sq:                                           Obs per group:
     within  = 0.9007                                         min =         20
     between = 0.0741                                         avg =       20.0
     overall = 0.0845                                         max =         20

                                                F(26,107)         =      37.32
corr(u_i, Xb)  = -0.9141                        Prob > F          =     0.0000

------------------------------------------------------------------------------
         co2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         gdp |   .0000484   9.69e-06     4.99   0.000     .0000292    .0000676
         upo |   -1169930     122663    -9.54   0.000     -1413095   -926764.6
          fa |  -40.81684   14.05113    -2.90   0.004    -68.67156   -12.96211
          al |   150.9209   32.50464     4.64   0.000     86.48427    215.3576
         gix |  -.0120044    .006935    -1.73   0.086    -.0257523    .0017434
          cc |  -.2507119   .1000758    -2.51   0.014    -.4491006   -.0523233
          rq |  -.0051709   .0508805    -0.10   0.919    -.1060355    .0956938
             |
        year |
       1998  |   .0266732   .0682289     0.39   0.697    -.1085828    .1619291
       1999  |    .001784   .0722953     0.02   0.980    -.1415331    .1451011
       2000  |  -.0495424    .069962    -0.71   0.480     -.188234    .0891491
       2001  |  -.1441763   .0696233    -2.07   0.041    -.2821962   -.0061563
       2002  |  -.1600184   .0719762    -2.22   0.028    -.3027028   -.0173341
       2003  |  -.1868579   .0696381    -2.68   0.008    -.3249074   -.0488085
       2004  |  -.1334928    .069437    -1.92   0.057    -.2711434    .0041579
       2005  |  -.2153412   .0723175    -2.98   0.004    -.3587021   -.0719802
       2006  |  -.2169704   .0756363    -2.87   0.005    -.3669105   -.0670302
       2007  |  -.2081196   .0793504    -2.62   0.010    -.3654225   -.0508167
       2008  |  -.1968111   .0837237    -2.35   0.021    -.3627836   -.0308386
       2009  |  -.2502935   .0845172    -2.96   0.004    -.4178389    -.082748
       2010  |  -.2096517     .09282    -2.26   0.026    -.3936565   -.0256469
       2011  |  -.1599667   .1024246    -1.56   0.121    -.3630116    .0430782
       2012  |  -.1986549   .1063038    -1.87   0.064    -.4093898    .0120801
       2013  |   -.169586    .109018    -1.56   0.123    -.3857014    .0465295
       2014  |  -.1793219   .1093733    -1.64   0.104    -.3961417    .0374979
       2015  |  -.1390124   .1067529    -1.30   0.196    -.3506377    .0726128
       2016  |  -.1296056    .106479    -1.22   0.226    -.3406878    .0814766
             |
       _cons |   4.859572   .4537185    10.71   0.000     3.960128    5.759016
-------------+----------------------------------------------------------------
     sigma_u |    2.91624
     sigma_e |  .12273634
         rho |   .9982318   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(6, 107) = 58.49                     Prob > F = 0.0000
```

**Figure 2:** Regression random effects

```
. estimate store fe

. xtreg co2 gdp upo fa al gix cc rq i.year, re

Random-effects GLS regression                   Number of obs     =        140
Group variable: country1                        Number of groups  =          7

R-sq:                                           Obs per group:
     within  = 0.6849                                         min =         20
     between = 0.9937                                         avg =       20.0
     overall = 0.9627                                         max =         20

                                                Wald chi2(26)     =    2918.22
corr(u_i, X)   = 0 (assumed)                    Prob > chi2       =     0.0000
```

| co2 | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| gdp | .0001353 | .0000145 | 9.36 | 0.000 | .000107 | .0001636 |
| upo | 77041.18 | 14548.28 | 5.30 | 0.000 | 48527.08 | 105555.3 |
| fa | -34.41883 | 2.553984 | -13.48 | 0.000 | -39.42454 | -29.41311 |
| al | 40.99365 | 2.941645 | 13.94 | 0.000 | 35.22813 | 46.75917 |
| gix | -.0407957 | .0076752 | -5.32 | 0.000 | -.0558388 | -.0257526 |
| cc | .767004 | .079936 | 9.60 | 0.000 | .6103323 | .9236758 |
| rq | -.3661535 | .066671 | -5.49 | 0.000 | -.4968263 | -.2354808 |
| year | | | | | | |
| 1998 | .097507 | .1332722 | 0.73 | 0.464 | -.1637017 | .3587156 |
| 1999 | .1805853 | .1358764 | 1.33 | 0.184 | -.0857274 | .4468981 |
| 2000 | .0600177 | .1342735 | 0.45 | 0.655 | -.2031535 | .3231889 |
| 2001 | -.0247318 | .1343357 | -0.18 | 0.854 | -.2880249 | .2385613 |
| 2002 | .0083332 | .1371448 | 0.06 | 0.952 | -.2604658 | .2771321 |
| 2003 | -.0775628 | .1354653 | -0.57 | 0.567 | -.3430699 | .1879443 |
| 2004 | -.080378 | .1347439 | -0.60 | 0.551 | -.3444711 | .1837151 |
| 2005 | -.2022074 | .1353536 | -1.49 | 0.135 | -.4674956 | .0630808 |
| 2006 | -.3540574 | .1379726 | -2.57 | 0.010 | -.6244788 | -.0836361 |
| 2007 | -.3586097 | .1386293 | -2.59 | 0.010 | -.6303181 | -.0869013 |
| 2008 | -.4221267 | .1421333 | -2.97 | 0.003 | -.700703 | -.1435505 |
| 2009 | -.3987051 | .1427452 | -2.79 | 0.005 | -.6784806 | -.1189295 |
| 2010 | -.505454 | .1479736 | -3.42 | 0.001 | -.7954769 | -.2154311 |
| 2011 | -.6094379 | .1582546 | -3.85 | 0.000 | -.9196112 | -.2992646 |
| 2012 | -.5921614 | .1614491 | -3.67 | 0.000 | -.9085958 | -.2757269 |
| 2013 | -.548122 | .1624086 | -3.37 | 0.001 | -.8664369 | -.2298071 |
| 2014 | -.4567442 | .1630951 | -2.80 | 0.005 | -.7764047 | -.1370837 |
| 2015 | -.3257633 | .1589193 | -2.05 | 0.040 | -.6372393 | -.0142872 |
| 2016 | -.2884636 | .1567007 | -1.84 | 0.066 | -.5955914 | .0186641 |
| _cons | 3.65994 | .4243897 | 8.62 | 0.000 | 2.828151 | 4.491729 |
| sigma_u | 0 | | | | | |
| sigma_e | .12273634 | | | | | |
| rho | 0 | (fraction of variance due to u_i) | | | | |

**Figure 3:** Test hausman result

```
. estimate store re

. hausman fe re

Note: the rank of the differenced variance matrix (2) does not equal the number of coefficients being
        tested (26); be sure this is what you expect, or there may be problems computing the test.
        Examine the output of your estimators for anything unexpected and possibly consider scaling your
        variables so that the coefficients are on a similar scale.
```

| | ---- Coefficients ---- | | | |
|---|---|---|---|---|
| | (b) fe | (B) re | (b-B) Difference | sqrt(diag(V_b-V_B)) S.E. |
| gdp | .0000484 | .0001353 | -.0000869 | . |
| upo | -1169930 | 77041.18 | -1246971 | 121797.2 |
| fa | -40.81684 | -34.41883 | -6.398009 | 13.81707 |
| al | 150.9209 | 40.99365 | 109.9273 | 32.37126 |
| gix | -.0120044 | -.0407957 | .0287912 | . |
| cc | -.2507119 | .767004 | -1.017716 | .0602113 |
| rq | -.0051709 | -.3661535 | .3609827 | . |
| year | | | | |
| 1998 | .0266732 | .097507 | -.0708338 | . |
| 1999 | .001784 | .1805853 | -.1788014 | . |
| 2000 | -.0495424 | .0600177 | -.1095601 | . |
| 2001 | -.1441763 | -.0247318 | -.1194444 | . |
| 2002 | -.1600184 | .0083332 | -.1683516 | . |
| 2003 | -.1868579 | -.0775628 | -.1092951 | . |
| 2004 | -.1334928 | -.080378 | -.0531148 | . |
| 2005 | -.2153412 | -.2022074 | -.0131338 | . |
| 2006 | -.2169704 | -.3540574 | .1370871 | . |
| 2007 | -.2081196 | -.3586097 | .15049 | . |
| 2008 | -.1968111 | -.4221267 | .2253157 | . |
| 2009 | -.2502935 | -.3987051 | .1484116 | . |
| 2010 | -.2096517 | -.505454 | .2958023 | . |
| 2011 | -.1599667 | -.6094379 | .4494712 | . |
| 2012 | -.1986549 | -.5921614 | .3935065 | . |
| 2013 | -.169586 | -.548122 | .378536 | . |
| 2014 | -.1793219 | -.4567442 | .2774223 | . |
| 2015 | -.1390124 | -.3257633 | .1867508 | . |
| 2016 | -.1296056 | -.2884636 | .158858 | . |

```
                          b = consistent under Ho and Ha; obtained from xtreg
           B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(2) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =      125.10
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```

**Figure 4:** General regression fixed effects

```
. xtset country1 year, yearly
       panel variable:  country1 (strongly balanced)
        time variable:  year, 1997 to 2016
                delta:  1 year

.
end of do-file

. do "/var/folders/83/wrp09kmn09jclr93f07jnx0c0000gn/T//SD00396.000000"

. xtreg co2 gdp upo fa al gix cc rq i.year, fe

Fixed-effects (within) regression               Number of obs     =        140
Group variable: country1                        Number of groups  =          7

R-sq:                                           Obs per group:
     within  = 0.9007                                         min =         20
     between = 0.0741                                         avg =       20.0
     overall = 0.0845                                         max =         20

                                                F(26,107)         =      37.32
corr(u_i, Xb)  = -0.9141                        Prob > F          =     0.0000

------------------------------------------------------------------------------
         co2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         gdp |   .0000484   9.69e-06     4.99   0.000     .0000292    .0000676
         upo |   -1169930     122663    -9.54   0.000     -1413095   -926764.6
          fa |  -40.81684   14.05113    -2.90   0.004    -68.67156   -12.96211
          al |   150.9209   32.50464     4.64   0.000     86.48427    215.3576
         gix |  -.0120044    .006935    -1.73   0.086    -.0257523    .0017434
          cc |  -.2507119   .1000758    -2.51   0.014    -.4491006   -.0523233
          rq |  -.0051709   .0508805    -0.10   0.919    -.1060355    .0956938
             |
        year |
        1998 |   .0266732   .0682289     0.39   0.697    -.1085828    .1619291
        1999 |    .001784   .0722953     0.02   0.980    -.1415331    .1451011
        2000 |  -.0495424    .069962    -0.71   0.480     -.188234    .0891491
        2001 |  -.1441763   .0696233    -2.07   0.041    -.2821962   -.0061563
        2002 |  -.1600184   .0719762    -2.22   0.028    -.3027028   -.0173341
        2003 |  -.1868579   .0696381    -2.68   0.008    -.3249074   -.0488085
        2004 |  -.1334928    .069437    -1.92   0.057    -.2711434    .0041579
        2005 |  -.2153412   .0723175    -2.98   0.004    -.3587021   -.0719802
        2006 |  -.2169704   .0756363    -2.87   0.005    -.3669105   -.0670302
        2007 |  -.2081196   .0793504    -2.62   0.010    -.3654225   -.0508167
        2008 |  -.1968111   .0837237    -2.35   0.021    -.3627836   -.0308386
        2009 |  -.2502935   .0845172    -2.96   0.004    -.4178389    -.082748
        2010 |  -.2096517     .09282    -2.26   0.026    -.3936565   -.0256469
        2011 |  -.1599667   .1024246    -1.56   0.121    -.3630116    .0430782
        2012 |  -.1986549   .1063038    -1.87   0.064    -.4093898    .0120801
        2013 |   -.169586    .109018    -1.56   0.123    -.3857014    .0465295
        2014 |  -.1793219   .1093733    -1.64   0.104    -.3961417    .0374979
        2015 |  -.1390124   .1067529    -1.30   0.196    -.3506377    .0726128
        2016 |  -.1296056    .106479    -1.22   0.226    -.3406878    .0814766
             |
       _cons |   4.859572   .4537185    10.71   0.000     3.960128    5.759016
-------------+----------------------------------------------------------------
     sigma_u |    2.91624
     sigma_e |  .12273634
         rho |   .9982318   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(6, 107) = 58.49                     Prob > F = 0.0000
```

**Dummy variables**

**Table 6:** dummy variables interpretation.

| | |
|---|---|
| GINI index | where "1" means high inequality and "0" means low inequality |
| Corruption control | where "1" means low corruption level and "0" means high corruption level |
| Regulatory quality | where "1" means low regulatory quality and "0" means high regulatory quality |

| country | country1 | dummy_gix | dummy_cc | dummy_rq |
|---|---|---|---|---|
| Argentina | 1 | 0 | 1 | 1 |
| Argentina | 1 | 0 | 1 | 1 |
| Argentina | 1 | 0 | 1 | 1 |
| Argentina | 1 | 0 | 0 | 1 |
| Argentina | 1 | 0 | 0 | 1 |
| Argentina | 1 | 0 | 0 | 0 |
| Argentina | 1 | 0 | 0 | 0 |
| Argentina | 1 | 0 | 0 | 0 |
| Argentina | 1 | 0 | 0 | 0 |
| Argentina | 1 | 0 | 0 | 0 |
| Argentina | 1 | 0 | 0 | 0 |
| Argentina | 1 | 0 | 0 | 0 |
| Argentina | 1 | 0 | 0 | 0 |
| Argentina | 1 | 0 | 0 | 0 |
| Argentina | 1 | 0 | 0 | 0 |
| Argentina | 1 | 0 | 0 | 0 |
| Argentina | 1 | 0 | 0 | 0 |
| Argentina | 1 | 0 | 0 | 0 |
| Argentina | 1 | 0 | 0 | 0 |
| Argentina | 1 | 0 | 0 | 0 |
| Bolivia | 2 | 1 | 0 | 0 |
| Bolivia | 2 | 1 | 0 | 1 |
| Bolivia | 2 | 1 | 0 | 1 |
| Bolivia | 2 | 1 | 0 | 0 |
| Bolivia | 2 | 1 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Bolivia | 2 | 1 | 0 | 0 |
| Bolivia | 2 | 1 | 0 | 0 |
| Bolivia | 2 | 1 | 0 | 0 |
| Bolivia | 2 | 1 | 0 | 0 |
| Bolivia | 2 | 1 | 0 | 0 |
| Bolivia | 2 | 1 | 0 | 0 |
| Bolivia | 2 | 1 | 0 | 0 |
| Bolivia | 2 | 1 | 0 | 0 |
| Bolivia | 2 | 1 | 0 | 0 |
| Bolivia | 2 | 0 | 0 | 0 |
| Bolivia | 2 | 0 | 0 | 0 |
| Bolivia | 2 | 0 | 0 | 0 |
| Bolivia | 2 | 0 | 0 | 0 |
| Bolivia | 2 | 0 | 0 | 0 |
| Bolivia | 2 | 0 | 0 | 0 |
| Brazil | 3 | 1 | 1 | 1 |
| Brazil | 3 | 1 | 1 | 1 |
| Brazil | 3 | 1 | 1 | 1 |
| Brazil | 3 | 1 | 1 | 1 |
| Brazil | 3 | 1 | 1 | 1 |
| Brazil | 3 | 1 | 1 | 1 |
| Brazil | 3 | 1 | 1 | 1 |
| Brazil | 3 | 1 | 1 | 0 |
| Brazil | 3 | 1 | 0 | 0 |
| Brazil | 3 | 1 | 1 | 0 |
| Brazil | 3 | 1 | 1 | 1 |
| Brazil | 3 | 1 | 1 | 1 |
| Brazil | 3 | 1 | 1 | 1 |
| Brazil | 3 | 1 | 1 | 1 |
| Brazil | 3 | 1 | 1 | 1 |
| Brazil | 3 | 1 | 1 | 1 |
| Brazil | 3 | 1 | 1 | 1 |
| Brazil | 3 | 1 | 0 | 0 |
| Brazil | 3 | 1 | 0 | 0 |
| Brazil | 3 | 1 | 0 | 0 |
| Chile | 4 | 0 | 1 | 1 |
| Chile | 4 | 1 | 1 | 1 |
| Chile | 4 | 1 | 1 | 1 |
| Chile | 4 | 0 | 1 | 1 |
| Chile | 4 | 0 | 1 | 1 |
| Chile | 4 | 0 | 1 | 1 |

| | | | | |
|---|---|---|---|---|
| Chile | 4 | 0 | 1 | 1 |
| Chile | 4 | 0 | 1 | 1 |
| Chile | 4 | 0 | 1 | 1 |
| Chile | 4 | 0 | 1 | 1 |
| Chile | 4 | 0 | 1 | 1 |
| Chile | 4 | 0 | 1 | 1 |
| Chile | 4 | 1 | 1 | 1 |
| Chile | 4 | 1 | 1 | 1 |
| Chile | 4 | 0 | 1 | 1 |
| Chile | 4 | 0 | 1 | 1 |
| Chile | 4 | 0 | 1 | 1 |
| Chile | 4 | 0 | 1 | 1 |
| Chile | 4 | 0 | 1 | 1 |
| Chile | 4 | 0 | 1 | 1 |
| Peru | 5 | 0 | 0 | 1 |
| Peru | 5 | 1 | 0 | 1 |
| Peru | 5 | 1 | 0 | 1 |
| Peru | 5 | 0 | 0 | 1 |
| Peru | 5 | 0 | 0 | 1 |
| Peru | 5 | 0 | 0 | 0 |
| Peru | 5 | 0 | 1 | 0 |
| Peru | 5 | 0 | 0 | 1 |
| Peru | 5 | 0 | 0 | 0 |
| Peru | 5 | 0 | 0 | 0 |
| Peru | 5 | 1 | 0 | 1 |
| Peru | 5 | 0 | 0 | 1 |
| Peru | 5 | 0 | 0 | 1 |
| Peru | 5 | 0 | 0 | 1 |
| Peru | 5 | 0 | 0 | 1 |
| Peru | 5 | 0 | 0 | 1 |
| Peru | 5 | 0 | 0 | 1 |
| Peru | 5 | 0 | 0 | 1 |
| Peru | 5 | 0 | 0 | 1 |
| Peru | 5 | 0 | 0 | 1 |
| Colombia | 6 | 1 | 0 | 0 |
| Colombia | 6 | 1 | 0 | 0 |
| Colombia | 6 | 1 | 0 | 0 |
| Colombia | 6 | 1 | 0 | 0 |
| Colombia | 6 | 1 | 0 | 0 |
| Colombia | 6 | 1 | 0 | 0 |
| Colombia | 6 | 0 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Colombia | 6 | 1 | 0 | 0 |
| Colombia | 6 | 0 | 0 | 0 |
| Colombia | 6 | 0 | 0 | 0 |
| Colombia | 6 | 1 | 0 | 1 |
| Colombia | 6 | 1 | 0 | 1 |
| Colombia | 6 | 1 | 0 | 1 |
| Colombia | 6 | 1 | 0 | 1 |
| Colombia | 6 | 1 | 0 | 1 |
| Colombia | 6 | 1 | 0 | 1 |
| Colombia | 6 | 1 | 0 | 1 |
| Colombia | 6 | 1 | 0 | 1 |
| Colombia | 6 | 1 | 0 | 1 |
| Colombia | 6 | 1 | 0 | 1 |
| Ecuador | 7 | 0 | 0 | 0 |
| Ecuador | 7 | 0 | 0 | 0 |
| Ecuador | 7 | 1 | 0 | 0 |
| Ecuador | 7 | 1 | 0 | 0 |
| Ecuador | 7 | 1 | 0 | 0 |
| Ecuador | 7 | 1 | 0 | 0 |
| Ecuador | 7 | 0 | 0 | 0 |
| Ecuador | 7 | 0 | 0 | 0 |
| Ecuador | 7 | 0 | 0 | 0 |
| Ecuador | 7 | 0 | 0 | 0 |
| Ecuador | 7 | 1 | 0 | 0 |
| Ecuador | 7 | 1 | 0 | 0 |
| Ecuador | 7 | 0 | 0 | 0 |
| Ecuador | 7 | 1 | 0 | 0 |
| Ecuador | 7 | 0 | 0 | 0 |
| Ecuador | 7 | 0 | 0 | 0 |
| Ecuador | 7 | 0 | 0 | 0 |
| Ecuador | 7 | 0 | 0 | 0 |
| Ecuador | 7 | 0 | 0 | 0 |
| Ecuador | 7 | 0 | 0 | 0 |

**Figure 5.** Dummy variable results.

**Figure 6:** Regression fixed effects with dummy variables

```
. . xtreg co2 gdp upo fa al dummy_gix dummy_cc dummy_rq i.year, fe

Fixed-effects (within) regression               Number of obs     =        140
Group variable: country1                        Number of groups  =          7

R-sq:                                           Obs per group:
     within  = 0.8998                                         min =         20
     between = 0.1034                                         avg =       20.0
     overall = 0.1139                                         max =         20

                                                F(26,107)         =      36.95
corr(u_i, Xb)  = -0.9136                        Prob > F          =     0.0000
```

| co2 | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| gdp | .0000494 | 9.75e-06 | 5.07 | 0.000 | .0000301 | .0000688 |
| upo | -1162008 | 128154.6 | -9.07 | 0.000 | -1416059 | -907956.3 |
| fa | -47.32774 | 13.88556 | -3.41 | 0.001 | -74.85425 | -19.80124 |
| al | 156.5907 | 33.28048 | 4.71 | 0.000 | 90.61599 | 222.5653 |
| dummy_gix | -.0018264 | .0388595 | -0.05 | 0.963 | -.0788609 | .075208 |
| dummy_cc | -.0915712 | .063763 | -1.44 | 0.154 | -.2179738 | .0348314 |
| dummy_rq | -.0588954 | .0418562 | -1.41 | 0.162 | -.1418704 | .0240796 |
| year | | | | | | |
| 1998 | -.0045551 | .0677285 | -0.07 | 0.947 | -.138819 | .1297088 |
| 1999 | -.0462876 | .069812 | -0.66 | 0.509 | -.1846818 | .0921065 |
| 2000 | -.1087006 | .0683291 | -1.59 | 0.115 | -.244155 | .0267538 |
| 2001 | -.2006499 | .0688443 | -2.91 | 0.004 | -.3371257 | -.0641742 |
| 2002 | -.2241661 | .0696068 | -3.22 | 0.002 | -.3621534 | -.0861787 |
| 2003 | -.229031 | .0688241 | -3.33 | 0.001 | -.3654667 | -.0925953 |
| 2004 | -.1734665 | .0707035 | -2.45 | 0.016 | -.313628 | -.0333051 |
| 2005 | -.2814554 | .0750679 | -3.75 | 0.000 | -.4302687 | -.1326421 |
| 2006 | -.2753034 | .0764643 | -3.60 | 0.000 | -.426885 | -.1237218 |
| 2007 | -.2340535 | .0886016 | -2.64 | 0.009 | -.4096959 | -.0584111 |
| 2008 | -.2069994 | .0932971 | -2.22 | 0.029 | -.3919501 | -.0220487 |
| 2009 | -.2344508 | .0943693 | -2.48 | 0.015 | -.4215269 | -.0473746 |
| 2010 | -.2145897 | .1060207 | -2.02 | 0.045 | -.4247634 | -.0044159 |
| 2011 | -.155148 | .111976 | -1.39 | 0.169 | -.3771274 | .0668314 |
| 2012 | -.1737699 | .11652 | -1.49 | 0.139 | -.4047572 | .0572174 |
| 2013 | -.1473744 | .1207241 | -1.22 | 0.225 | -.3866959 | .091947 |
| 2014 | -.1457176 | .1201579 | -1.21 | 0.228 | -.3839167 | .0924815 |
| 2015 | -.0969018 | .1168577 | -0.83 | 0.409 | -.3285587 | .134755 |
| 2016 | -.0959519 | .1176787 | -0.82 | 0.417 | -.3292361 | .1373324 |
| _cons | 4.362531 | .322823 | 13.51 | 0.000 | 3.722572 | 5.00249 |
| sigma_u | 2.8608448 | | | | | |
| sigma_e | .12328486 | | | | | |
| rho | .99814636 | (fraction of variance due to u_i) | | | | |

```
F test that all u_i=0: F(6, 107) = 88.32                      Prob > F = 0.0000
```

**Figure 7:** Regression fixed effect time lack 1998

```
. . xtreg co2 gdp upo fa al dummy_gix dummy_cc dummy_rq i.year l1.co2, fe

Fixed-effects (within) regression               Number of obs     =        133
Group variable: country1                        Number of groups  =          7

R-sq:                                           Obs per group:
     within  = 0.9187                                         min =         19
     between = 0.2328                                         avg =       19.0
     overall = 0.2474                                         max =         19

                                                F(26,100)         =      43.47
corr(u_i, Xb)  = -0.8592                        Prob > F          =     0.0000
```

| co2 | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| gdp | .0000327 | 9.88e-06 | 3.31 | 0.001 | .0000131 | .0000523 |
| upo | -854240.8 | 162165.3 | -5.27 | 0.000 | -1175972 | -532509.4 |
| fa | -34.86367 | 14.0266 | -2.49 | 0.015 | -62.69204 | -7.035297 |
| al | 117.0932 | 34.29763 | 3.41 | 0.001 | 49.04768 | 185.1387 |
| dummy_gix | .0205142 | .0366403 | 0.56 | 0.577 | -.0521791 | .0932076 |
| dummy_cc | -.0481523 | .0611515 | -0.79 | 0.433 | -.1694752 | .0731705 |
| dummy_rq | -.0047125 | .0406229 | -0.12 | 0.908 | -.0853071 | .0758821 |
| year | | | | | | |
| 1999 | -.0522124 | .0608351 | -0.86 | 0.393 | -.1729074 | .0684827 |
| 2000 | -.0701383 | .0617532 | -1.14 | 0.259 | -.1926549 | .0523783 |
| 2001 | -.1586614 | .0624123 | -2.54 | 0.013 | -.2824856 | -.0348372 |
| 2002 | -.1323585 | .0666268 | -1.99 | 0.050 | -.2645442 | -.0001727 |
| 2003 | -.1218227 | .0686816 | -1.77 | 0.079 | -.2580851 | .0144397 |
| 2004 | -.0431689 | .0705219 | -0.61 | 0.542 | -.1830822 | .0967445 |
| 2005 | -.1690746 | .0728626 | -2.32 | 0.022 | -.3136321 | -.0245172 |
| 2006 | -.1455883 | .0755922 | -1.93 | 0.057 | -.2955609 | .0043844 |
| 2007 | -.1390709 | .0818374 | -1.70 | 0.092 | -.3014341 | .0232922 |
| 2008 | -.1246385 | .0859853 | -1.45 | 0.150 | -.2952308 | .0459539 |
| 2009 | -.1876452 | .0853474 | -2.20 | 0.030 | -.3569721 | -.0183184 |
| 2010 | -.1312367 | .0982101 | -1.34 | 0.184 | -.3260827 | .0636093 |
| 2011 | -.0846995 | .104286 | -0.81 | 0.419 | -.2916 | .1222009 |
| 2012 | -.1443838 | .1075165 | -1.34 | 0.182 | -.3576935 | .0689259 |
| 2013 | -.1161067 | .1117079 | -1.04 | 0.301 | -.3377321 | .1055187 |
| 2014 | -.134265 | .110861 | -1.21 | 0.229 | -.35421 | .08568 |
| 2015 | -.0933332 | .1076441 | -0.87 | 0.388 | -.3068959 | .1202296 |
| 2016 | -.1000965 | .1084807 | -0.92 | 0.358 | -.3153191 | .1151261 |
| co2 | | | | | | |
| L1. | .3842189 | .0911675 | 4.21 | 0.000 | .2033452 | .5650926 |
| _cons | 2.902217 | .5063424 | 5.73 | 0.000 | 1.897649 | 3.906786 |
| sigma_u | 2.1036771 | | | | | |
| sigma_e | .11273321 | | | | | |
| rho | .99713648 | (fraction of variance due to u_i) | | | | |

```
F test that all u_i=0: F(6, 100) = 6.91                     Prob > F = 0.0000
```