DISTRIBUTIONAL IMPACT OF AN ETHANOL-BASED CLEAN DEVELOPMENT MECHANISM PROJECT IN BRAZIL

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Roberta Haikal de Souza
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This thesis entitled
DISTRIBUTIONAL IMPACT OF AN ETHANOL-BASED CLEAN DEVELOPMENT
MECHANISM PROJECT IN BRAZIL

by

ROBERTA HAIKAL DE SOUZA

has been approved for
the Department of Latin American Studies and
the Center for International Studies by

Ariaster Baumgratz Chimeli
Assistant Professor of Economics

Josep Rota
Director, Center for International Studies
The global warming threat spurred various corrective measures to reduce Greenhouse Gases emissions such as the Clean Development Mechanism (CDM), which is currently the most prominent instrument. This fact allied with Brazil’s past experience with its ethanol program, made me decide to evaluate if an Ethanol-Based CDM project would be more equitably distributed when compared to current CDM projects in Brazil, since it would affect all municipalities in the country. Tests with current CDM projects confirm that they are concentrated in more developed municipalities. However, tests with an Ethanol-Based CDM project provide counter-intuitive results and show that, although reaching all municipalities in the country, the effects of this type of CDM program would be as concentrated as the effects of current CDM projects in Brazil.

Approved:

Ariaster Baumgratz Chimeli

Assistant Professor of Economics
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**ABBREVIATIONS AND ACRONYMS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>CDM</td>
<td>Clean Development Mechanism</td>
</tr>
<tr>
<td>CER</td>
<td>Credit Emission Reduction</td>
</tr>
<tr>
<td>CH$_4$</td>
<td>Methane</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>COP</td>
<td>Conference of the Parties</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
</tr>
<tr>
<td>HFCs</td>
<td>Hydrofluorocarbons</td>
</tr>
<tr>
<td>N$_2$O</td>
<td>Nitrous Oxide</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for Economic Co-operation and Development</td>
</tr>
<tr>
<td>PFCs</td>
<td>Perfluorocarbons</td>
</tr>
<tr>
<td>SF$_6$</td>
<td>Sulphur hexafluoride</td>
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<tr>
<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
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</tbody>
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INTRODUCTION

Over the last 250 years, the concentration of carbon dioxide (CO$_2$) in the atmosphere has increased more than 30 percent. This increase in CO$_2$ concentration in the atmosphere, mainly attributed to human activities generating greenhouse gases (GHG), is leading to a warming in the global temperature. This warming process began with the industrial revolution two centuries ago and accelerated in the last fifty years. Unless there is a change in the CO$_2$ emissions trend, the world might face damaging climate alteration and great economic losses.

In order to reduce emissions and to solve the climate problem, some strategies are available and being discussed. This paper examines two options that are being highlighted as potential options to curb CO$_2$ emissions: (1) the use of ethanol as a substitute for fossil fuels and (2) the Clean Development Mechanism projects (CDM) of the Kyoto Protocol. Ethanol is a biomass fuel that can be used to displace petroleum transportation fuels and their associated CO$_2$ emissions. The CDM project is a mechanism that enables developed countries to have lower costs in reducing their targeted GHG emissions (as stated in the Kyoto Protocol) by investing in developing countries. The CDM is also an instrument that enables transfer of technology to the host countries and promotes their development as well.

Both options were analyzed in the Brazilian context because Brazil launched the largest ethanol program during the 1970s and, therefore, has the technology and experience necessary to resume the program. Another reason is that Brazil is one of the most prominent countries hosting CDM projects and has 28 projects passing over the
legal procedures of certification until January 05, 2005. The main objective of this thesis is to investigate the distributional impact of a potential Ethanol-Based CDM Project in Brazilian municipalities. To answer my research question, Is an Ethanol-Based CDM project more equitably distributed compared to current CDM projects in Brazil?, I analyze the scope of both projects as well as the characteristics of the affected regions.

This work is divided into five chapters. The first chapter will address the anthropogenic interference in the atmosphere. It is a review of the advancement of carbon emissions and the climatic consequences of high concentration of carbon dioxide in the atmosphere. The second chapter will present the ethanol project and the CDM project in the Brazilian context as alternatives to curb carbon emissions. The following chapter is a literature review of both projects and an analysis of the negative and positive characteristics of each alternative. The fourth chapter presents the tests necessary to evaluate if an Ethanol-Based CDM Project is more equitably distributed across Brazilian municipalities than current CDM Projects in Brazil. The methodological approach used in this study is based on the Probit Modeling and other statistical indicators. Finally, the concluding section offers an analysis of the tests’ results as well as a discussion of the alternative that better contributes to reducing GHG emissions.
CHAPTER I – ANTHROPOGENIC INTERFERENCE IN THE ATMOSPHERE

This chapter will address a concerning anthropogenic interference in the atmosphere that contributes to air pollution and, consequently, harm the environment. It is a study of the advancement of carbon emissions and the climatic consequences of high concentration of carbon dioxide in the atmosphere.

CLIMATE CHANGE

Science has extensively focused on the effects of climate change in the world, giving particular attention to the high concentrations of CO$_2$ and other GHGs. Some of the concerning effects of climate change are the probable higher average temperatures and ensuing ripple effects on earth: rising sea levels, alteration in precipitation, the strength of storms, and other geophysical modifications (E&MJ 1998).

Globally, the average temperature of the earth’s surface has increased approximately 0.6º C since the beginning of the industrial revolution and the Intergovernmental Panel on climate change$^1$ has projected an average raise of 5.8ºC in the temperature of the earth by 2100 (IPCC 1996 2001, Barker and Terry 2002).

IPCC also identifies “warming” as the risk posed in natural systems. Coral reefs, for example, are extremely important due to their elevated degree of biodiversity and

$^1$ “Intergovernmental Panel on Climate Change” means the Intergovernmental Panel on Climate Change established in 1988 jointly by the World Meteorological Organization and the Unites Nations Environment Programme.
economic value. They are known as good indicator systems because they are easily found in oceans all over the world and, most importantly, they respond to increases in water temperature by producing a phenomenon called “bleaching.” Bleaching is a natural process that occurs when water temperature is close to the limit of coral’s thermal condition. In this process, corals expel vital symbiotic algae. Without these algae, corals could weaken or even die. Some studies predict that continuous global warming of 1°C would cause this natural process to occur annually, resulting in a high risk of permanent eradication of corals in the oceans. Additionally, temperature changes are reducing the number of various migratory species of bird and causing adversities related to food production (IPCC 2001).

Freshwater availability and health problems are potential consequences of climate changes as well. Current studies consider that approximately three million people from Africa, the Middle East, and the Indian subcontinent would suffer a terrible water shortage with a 3°C raise in the temperature. Malaria would be a threat for 280 million people from China and Central Asia, and 80 million people from Bangladesh, Egypt and China would be exposed to annual flooding (UNEP 2004, Repetto 2001).

Global warming could also cause tragic events such as the disintegration of the West Antarctic Ice Sheet (WAIS) and the declining or shutdown of the density-driven circulation of the oceans. Although these phenomena have a small chance to occur, their incidence would lead to immeasurable costs to humanity (O’Neill 2002).

Another critical issue is the adverse climate change effects that will occur in developing countries. This is a concerning problem because the population in these countries is less expected to adapt to changes in the temperature. There could be serious
climate impacts in agriculture, leading to a reduction in productivity. Tropical areas, such as Latin America and Africa, where various crops are cultivated in a limit tolerance temperature and where there is lack of irrigation, are more vulnerable and would be the most affected areas. Moreover, a decline in grain crops in Africa would intensify malnutrition in the country (IPCC 2001, Beg et al. 2002).

In summary, these are only a few facts that illustrate the real and urgent need to engage in the climate change debates in order to avoid increased costs to the less developed nations. Developing countries are far from being considered great GHG emitters and are the ones that will pay for the progress of the developed nations (Beg et al. 2002).

In fact, these emissions are not uniformly distributed among countries. Developed countries’ releases are responsible for a larger part of past and current emissions. OECD\(^2\) countries contribute to more than half of CO\(_2\) emissions, an average per capita emission three times higher than the global per capita average (UNEP 2004). Regarding individual nations’ emissions, The United States is the world leader in CO\(_2\) discharges, accounting for almost one fourth of total emissions. In the second position comes China, with 14\%, followed by Russia, with 6\%. India and Japan are important polluters, emitting together 5 percent of total CO\(_2\) in the world (Earth Policy Institute

\(^2\) The Organization for Economic Co-operation and Development is forum where the governments of 30 market democracies work together to address the economic, social, and environmental and governance challenges of the globalizing world economy, as well as to exploit its opportunities.
2003). Figure 1 and Figure 2 show, respectively, the rank of CO₂ emitters in 1958 and 2000 and the percentage of these emissions per region in 1998.

Figure 1: Top 20 CO₂ Emitters in 2000

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Rank</th>
<th>Emissions</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>USA</td>
<td>1</td>
<td>2000</td>
</tr>
<tr>
<td>2</td>
<td>China</td>
<td>9</td>
<td>1950</td>
</tr>
<tr>
<td>3</td>
<td>Russia (FSU=2)</td>
<td>12</td>
<td>1950</td>
</tr>
<tr>
<td>4</td>
<td>Japan</td>
<td>8</td>
<td>1950</td>
</tr>
<tr>
<td>5</td>
<td>India</td>
<td>16</td>
<td>1950</td>
</tr>
<tr>
<td>6</td>
<td>Germany</td>
<td>14</td>
<td>1950</td>
</tr>
<tr>
<td>7</td>
<td>UK</td>
<td>14</td>
<td>1950</td>
</tr>
<tr>
<td>8</td>
<td>Canada</td>
<td>14</td>
<td>1950</td>
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<tr>
<td>9</td>
<td>Italy</td>
<td>14</td>
<td>1950</td>
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<tr>
<td>10</td>
<td>South Korea</td>
<td>14</td>
<td>1950</td>
</tr>
<tr>
<td>11</td>
<td>Mexico</td>
<td>14</td>
<td>1950</td>
</tr>
<tr>
<td>12</td>
<td>Saudi Arabia</td>
<td>14</td>
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<td>13</td>
<td>France</td>
<td>14</td>
<td>1950</td>
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<tr>
<td>14</td>
<td>Australia</td>
<td>14</td>
<td>1950</td>
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<tr>
<td>15</td>
<td>Ukraine (FSU=2)</td>
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<td>16</td>
<td>South Africa</td>
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<tr>
<td>17</td>
<td>Iran</td>
<td>14</td>
<td>1950</td>
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<tr>
<td>18</td>
<td>Brazil</td>
<td>14</td>
<td>1950</td>
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<tr>
<td>19</td>
<td>Poland</td>
<td>14</td>
<td>1950</td>
</tr>
<tr>
<td>20</td>
<td>Spain</td>
<td>14</td>
<td>1950</td>
</tr>
</tbody>
</table>

Source: CDIAC 2003

Figure 2: 1998 Carbon Dioxide Emissions

Source: UNFCCC, 2000
All potential consequences to the environment and problems involved in the increase of emissions throughout the world have spurred domestic actions and international efforts to tackle the issue of stabilizing GHGs release.

Defining climate changes’ policies that consider a holistic approach and are long-standing remains an essential global challenge. It is necessary to engage in serious and long-term initiatives and agreements that lead to the stabilization of greenhouse gases concentrations at levels that reduce dangerous anthropogenic interference with the climate system. Dangerous interference can be viewed from a variety of perspectives, and the choice will ultimately involve a mixture of scientific, economic, political, ethical, and cultural considerations. All perspectives to tackle the issue of climate change will contribute to the goal of reaching better air quality and to reduce harmful emissions (O’Neill 2002).

**DETERIORATING AIR QUALITY**

Since the beginning of the Industrial Revolution, air pollution has been one of the most serious environmental problems. Air pollution is often regarded as the product of development and therefore it tends to increase as long as energy in the forms of oil, coal and natural gas is utilized to produce goods. Air pollution is defined as the existence of contaminants and particulates in the atmosphere and these substances are generated by both natural sources and human activities. Human activities, however, represent the major source of emissions. Pollution in the atmosphere is increasing due to urbanization and industrialization causing the worsening of air quality. In recent times, air pollution
has come to the forefront of public concern. Being a public bad, air pollution does not have well-defined property rights. Most of the times, polluters do not consider this issue as relevant as it should be, since taking precautions to reduce emissions and to improve air quality means to have higher costs and, consequently, lower profits (Onursal and Gautan 1997).

Deteriorating air quality is a growing threat to ecosystems and human well beings. Air pollution is currently a concerning issue because it is one of the most serious environmental harms leading to considerable economic losses to countries and great damage to humans, plants, and animals. Air pollution causes human health problems, smog, acid rain, and structure and building damage. Globally, it degrades the stratospheric ozone layer and causes changes to the global climatic system due to the high levels of greenhouse gases (GHG) concentration. The GHGs are ozone, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur hexafluoride (SF₆). Figure 3 shows the percentage of the main GHGs in the atmosphere (Kyoto Protocol 1997).
These gases that trap energy from the sun are responsible for keeping the average temperature of the earth about 33°C higher, making the surface of the earth warm enough to sustain life (World Resource Institute, 2004). In the continuing process of receiving solar energy and returning to the atmosphere, an energy balance is expected to occur. Nonetheless, the GHGs in high concentrations in the atmosphere hinder the maintenance of this balanced process, leading to high temperatures and the intensification of global warming (Kim 2004).

In response to this concern of pollutants in the atmosphere, particularly the high concentration of greenhouse gases and the necessity of controlling and reducing emission, several abatement measures have been discussed to stabilize discharges. The reductions of CO₂ related to the burning of fossil fuel have been the center of attention. Carbon dioxide’s (CO₂) reduction has been the focus of the proposals on reducing greenhouse gases because it is ranked the most important GHG in concentration in the atmosphere (Kheshgi et al. 2000).
Moreover, it is also observed that 98 percent of CO$_2$ emissions originate from the combustion of fossil fuels in the United States. The figures below show the increasing concentration of some GHGs over time, and clearly illustrate the astonishing level of pollution during the industrial age (Kheshgi et al. 2000, Leaf 2003).

**Figure 4: Carbon Dioxide Concentration**

![Carbon Dioxide Concentration](source: IPCC 2001)

**Figure 5: Nitrous Oxide Concentration**

![Nitrous Oxide Concentration](source: IPCC 2001)
CARBON EMISSIONS CLIMBING

A negative aspect of economic growth is the increase in the rate of CO$_2$ emissions by approximately 32 percent since the beginning of the industrial age. The amount of CO$_2$ in the atmosphere climbed from 280 parts per million (ppm) to today’s 370 ppm (Earth Policy Institute 2003). Three fourths of CO$_2$’s anthropogenic releases in the atmosphere are due to the burning of fossil fuels with the remaining part attributed to
land use transformation (Marland 2003). Considering the burning of fossil fuels, power generation is responsible for 42 percent of emissions, transportation for 22 percent, and direct uses of fuel in industry and buildings for 36 percent (Robert et al 2004).

Approximately 283 billion tons of carbon dioxide have been discharged in the atmosphere since 1751 through the burning of fossil fuels and cement production. Most of the released CO\textsubscript{2} took place since the mid 1970s. A Global Assessment of CO\textsubscript{2} generated by fossil fuel estimates that 6611 million metric tons of carbon dioxide were in the atmosphere in 2000, an increase of 1.8 percent from 1999 discharges. It is relevant to notice that liquid and solid fuels were the primarily responsible for the total CO\textsubscript{2} burning in 2000, accounting for 76.8 percent of the emissions from fossil fuels (Marland 2003). Figure 8 shows the proportion of CO\textsubscript{2} discharges of the burning of different fossil fuels from 1975 to 2000 while Figure 9 shows the CO\textsubscript{2} emissions per capita in 2000 in the world.

**Figure 8: Global CO\textsubscript{2} emissions from different sources (1751-2000)**

SOURCE: MARLAND ET AL. 2003
**CO₂ EMISSIONS IN BRAZIL**

The energy sector in Brazil does not generate large amounts of CO₂ compared with developed countries. Some of the reasons are that hydropower energy is responsible for more than 95 percent of the electricity produced in the country and Brazil has been investing in renewable energy, mainly in biomass\(^3\) to reduce oil dependency (COPPE 2002).

Although the national production of CO₂ is not significant compared to developed countries, it has grown rapidly since the beginning of the last century, achieving 83.9 million metric tons of carbon in 2000. There was, however, a period when these rates were not increasing so fast. It happened after 1975, when the Brazilian government

---

\(^3\) Materials that are biological in origin, such as grasses, trees, municipal wastes, etc.
subsidized the use of ethanol in large scale. During this period, a total of 384.99 million tons of CO₂ were avoided (See Figure 10) (Ribeiro et al. 2000).

Brazilian emissions have increased significantly during almost the whole century; however the national per capita emission of 0.50 metric tons of carbon was much lower than the global per capita average of 1.09 metric tons of carbon. Fossil-fuel emissions from liquid-fuel accounted for 69.5 percent of CO₂ discharges, while coal burning accounted for 16.7%. In the last two decades of the twentieth century, the use of natural gas has also increased, representing 6 percent of the CO₂ emissions from fossil fuels (Marland et al. 2003, Ribeiro et al. 2000).

**TRANSPORT AND GLOBAL WARMING**

Petroleum consumption is responsible for approximately 25 percent of greenhouse gas emission (Barnett and Dessai 2002). Therefore, it is essential to consider the influence of the transportation sector when considering measures to avoid global
warming. In brief, since the transport sector’s emissions have been progressively increasing due to fossil fuel burning, it is critical to curb the increasing rate of anthropocentric emissions in this sector.

On one hand, automobiles bring many advantages to society such as mobility, comfort, and agility. On the other hand, transport has become one of the major sources of air pollution, particularly carbon compounds and NOx. An old vehicle fleet, vehicles lacking engine maintenance, the slow speed caused by congestions increase drastically the burning of petroleum fuels, contributing to the degradation of the urban air quality and deterioration of the environment as a whole. Figure 11 shows the increasing rate of CO$_2$ generated by the transport sector during the period between 1990 and 1994 in Brazil (Mierlo et al. 2003).

Figure 11: Average Emissions Fleet Factors

SOURCE: MINISTRY OF SCIENCE AND TECHNOLOGY 2002
This reality has been the reason for several studies to find different ways of controlling and reducing the pollution rate caused by vehicles. There are various technologies to mitigate vehicular air pollution and to limit negative externalities caused by transportation emissions. Considering the technologies that have the potential to fuel vehicles with reduced emissions, ethanol is an attractive alternative. In Brazil, this cleaner burning fuel has been largely used to power passenger vehicles and is proven to be a significant alternative to reduce CO$_2$ releases (Lave et al. 2001, Jacobi 1997, Kheshgi et al. 2000).
CHAPTER II – TACKLING THE ISSUE

In this chapter, I present ethanol as a possible substitute for fossil fuels to reduce CO₂ emissions. I also discuss the history of CDM in order to set up the stage for the analysis of an Ethanol-Based project as an alternative CDM in Brazil.

An Ethanol-Based CDM would be a project to enhance ethanol supply and demand in the country. This type of project could be considered as a national project since it would reach all Brazilian municipalities with vehicles, corresponding to 99 percent of all municipalities in the country. An Ethanol-Based CDM is a potential project for Brazil for two main reasons. First, Brazil had experience with a national ethanol program during the 1970s and 1980s and, therefore, has the basis and technology to produce ethanol in large-scale again. Additionally, the fact that Brazil is one of the most prominent countries to host CDM projects makes it pertinent to evaluate if an Ethanol-Based CDM project would be interesting to the country considering the project’s distributional patterns.

THE ENERGY CHALLENGE AND THE USE OF ETHANOL

The economic growth and environmental tradeoff is one of the most critical challenges of the world nowadays. As population increases and the standard of living improves, more energy is required to supply human necessities and increasing consumption. To avoid energy shortage and to reduce CO₂ emissions from fossil fuels, alternative, renewable, and cleaner burning fuels are being developed to tackle energy concerns.
In Brazil, ethanol is produced from sugar cane, and it has been used as a renewable fuel since the mid 1970. During that time, the Brazilian government established and subsidized the National Alcohol Program (Proalcool) with the primary intention of reducing petroleum imports for gasoline fueled vehicles. The reduction of CO\(_2\) was not the main reason for the adoption of the program. Nonetheless, the production of approximately 12 billion liters of ethanol per year, which fueled 4.2 million hydrous ethanol\(^4\) vehicles and 5 million cars fueled by gasohol\(^5\) (Kheshgi 2000), led to an average reduction of 20,360 \(10^3\) t CO\(_2\) per year from the atmosphere (Ribeiro et al. 1999).

The reason why ethanol reduces CO\(_2\) emissions significantly is the almost complete reabsorption of CO\(_2\) emitted during the burning of the fuel. Although energy from fossil fuels also stores chemical energy, when biomass is burnt and CO\(_2\) is emitted, new biomass which is grown can absorb CO\(_2\) through photosynthesis (see Figure 12). If biomass cultivation and its conversion into ethanol production did not demand energy, the net production of CO\(_2\) during a full biomass cycle would be zero. In practice, as the process requires fossil fuel, there are net CO\(_2\) emissions. Nonetheless, avoided emissions are estimated to be 29 percent of harvested cane (Kheshgi et al 2000). Given this fact, ethanol is a potential cleaner burning alternative to reduce carbon emissions and a potential basis for CDM projects. Additionally, as mentioned in the first chapter of this thesis, the transport sector is one of the main responsible emitters of CO\(_2\), the most important GHG. In Brazil, emissions by liquid fossil fuels accounts for approximately 77

\(\footnote{Pure ethanol that runs on alcohol engine vehicles} \)
\(\footnote{Ethanol used in a mixture of gasoline and ethanol in a percentage of 24\%} \)
percent of total CO$_2$ in the country (Ministry of Science and Technology 2002). Thus, it is relevant to invest in cleaner fuels, such as ethanol in order to reduce GHG emissions and tackle the issue of climate change.

Figure 12: CO$_2$ Cycle

SOURCE: RIBEIRO ET AL 1999
INTERNATIONAL TREATIES TO REDUCE CO₂ EMISSIONS

In addition to the regional measures to reduce the discharge of pollutants into the atmosphere such as the use of ethanol as a renewable fuel in Brazil, international treaties and climate conferences have been proposed in order to slow down the increase of GHGs emissions and consequently reduce the threat of global warming.

The first World Climate Conference was held in Geneva in 1979. This conference presented climate consequences of human interference in the environment. One of the most prominent meetings regarding climate changes was held in Toronto in 1988 and is known as The Changing Atmosphere: Implications for Global Security. This conference resulted in the ‘Toronto target’, a voluntary agreement among the developed nations to reduce annual CO₂ emissions to 20 percent below 1988 levels by the year 2005 (Kim 2004, Dobes 1999).

At that time, human interferences in climate change had already become an issue of concern throughout the world. Consequently, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in May, 1992, as a result of efforts from all nations to deal with climate change. That document is a specific call to developed countries and other nations identified in Annex I to stabilize GHG

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6 Annex I countries are the 36 industrialized countries and economies in transition listed in Annex I of the United Nations Framework Convention on Climate Change (UNFCCC or the Convention). Their responsibilities under the Convention are various, and include a non-binding commitment to reducing their greenhouse gas emissions to 1990 levels by the year 2000.
concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. During the United Nations Conference on Environment and Development, known as the Earth Summit, the UNFCCC was opened for signatures and enforced in March, 1994 (Dobes 1999).

After that, the Conference of the Parties (COP) to the convention was adopted as an annual instrument to monitor and implement measures to avoid climate change. The first COP, held in Berlin, resulted, with great enthusiasm by the participants, in the creation of a stringent agreement committing the countries to reduce emissions. Given this, the Kyoto Protocol was adopted in 1997 in Kyoto, Japan, as an amendment to the UNFCCC. It is the initial step and the most detailed international commitment to reduce emissions of greenhouse gases (Kim 2004).

KYOTO PROTOCOL

The Kyoto Protocol is a global agreement created to combat global warming. It aims at reductions in net emissions and the stabilization of GHGs in the earth’s atmosphere at a level that would prevent risky human interference in the climate system. In short, it is the most prominent attempt to address the concerning issue of climate change. The protocol, adopted in 1997 was opened for signatures on March 16, 1998, closed on March 15, 1999, and will come into force on February 16, 2005.

The Kyoto Protocol was ratified by 141 countries, all committed to help solve the potential problems caused by increasing global temperature. Among these countries,
Annex B\(^7\) countries must limit their emissions of CO\(_2\) and five other GHGs linked to global warming (methane, nitrous oxide, sulfur hexafluoride, HFCs and PFCs) by an average of 5.2 percent compared to 1990’s emissions levels up to 2012’s (Nature 2003). National targets range from 8 percent for 15 countries in the European Union, 7 percent for the United States, 6 percent for Japan and Canada, and 0 percent for Russia. It also allows Australia and Iceland to increase their emissions by 8 percent and 10 percent respectively (see Figure 13 for a map of the countries included in the Kyoto Protocol).

---

\(^7\) Annex B countries are the 39 emissions-capped industrialized countries and economies in transition listed in Annex B of the Kyoto Protocol.
There is a term in the Kyoto Protocol (1997) stating that it will enter into force “on the ninetieth day after the date on which not less than 55 parties to the Convention, incorporating Parties included in Annex I, have deposited their instruments of ratification, acceptance, approval, or accession”. Given this, the ratification of Russia on November 18, 2004 was a decisive fact for the Protocol to come into force on February 16, 2005

The goals of the Protocol will make CO₂ reductions achievable through three flexible mechanisms; Joint Implementation, JI (article 6) Emissions Trading, ET (article 17), and the Clean Development Mechanism, CDM, (article12). JI is a mechanism that allows Annex I countries to invest in other countries which also have emission targets. ET enables Annex I countries to buy and sell portions of emissions allowance on an international carbon trading market. The CDM, the most well-known of the three mechanisms, is an instrument that enables Annex 1 countries to obtain credits of CO₂ reduction by investing in developing countries (Rowlands 2001, Millock 2002).

CDM PROJECTS

The atmosphere is equally damaged by high concentrations of GHG emissions, independently of the place of emission and uniformly helped by emissions reductions wherever they occur. Consequently, the CDM is a potential instrument for developed countries to reduce their emissions. As mentioned before, the Clean Development Mechanism defined in Article XII of the Kyoto Protocol to the UNFCCC is an instrument to lower the costs of reducing GHG target emissions of developed countries committed to the Protocol. Moreover, this is the only instrument of the Kyoto Protocol in which there
is the participation of developing countries (that ratified the Kyoto Protocol). The CDM is also a measure to promote sustainable development in developing countries and to encourage transferring of technology to host countries (UN 1997). Through this instrument, which moved from an early implementation phase to full operations on February 16, 2005, developed countries or private companies can participate and receive credits for financing emission reducing projects in developing countries.

Theoretically, anyone can develop or invest in a CDM as a business project. If a company or institution has a project to abate GHG, the project can be implemented. Nonetheless, the project will only receive carbon credits as a CDM project if it fulfills the local governments and the United Nations’ legal requirements. In practice, however, negotiations occur mostly between private institutions. It is relevant to point out that only the developed countries committed to the Kyoto Protocol are allowed to use the final certified emission reduction (CER) (DNV 2004, PNUD 2005).

In this system, carbon is a tradable commodity with an associated value. When a project is qualified for a CDM project, the tonnes of reduced CO$_2$, or CER, are certified by a designated operational entity. The certification occurs (1) after a project is approved by all involved parties, (2) after proving to be long-standing projects to reduce emissions and (3) after promising that reductions would be additional$^8$ to any other project that

$^8$ Article 12.5 of the Kyoto Protocol requires that projects demonstrate ‘*reductions in emissions that are additional to those that would have occurred in the absence of the certified Project activity’*. This means that all CDM projects have to show ‘additionality’ i.e. that they would not have been carried out if the CDM did not exist.
would otherwise occur. The CDM Executive Board (operated under the authority of the COP) is responsible for the supervision of the CDM activities (PNUD 2005). Typically, CDM projects fall into the following categories:

- Renewable energy
- Fuel switching (in industry, transport, residential sector, etc.)
- Solid waste management
- Advanced coal-based power generation technologies
- Renovation and modernization
- Demand-side management
- Industrial energy efficiency improvement

Regarding the CDM projects in Brazil, up to the date of January 5, 2005, 28 projects located in 73 municipalities in Brazil were in the process of legal procedures to receive certification. Among these projects, two have already been approved by the Comissão Interministerial de Mudanças Climáticas (Brazilian commission of Climate Change), and they have been sent to the executive board of the CDM. Furthermore, one of these conducted projects has already been registered by the executive board (CDM Watch 3003).
By the approximation of the day that the Protocol entered into force (February 16, 2005), it is predicted that more projects are going to be developed as potential CDM projects. An interesting fact is that Brazil is considered to have the most potential to export carbon credits in Latin America, followed by Colombia, Panama, Costa Rica and Peru (Lasso 2005). The following tables present the current CDM projects in Brazil. It is described (1) the category of each project, (2) the description of the projects, (3) the amount of GHG reductions claimed, (4) the participants in the projects, (5) the duration, and (6) the Brazilian municipality hosting each project.
<table>
<thead>
<tr>
<th>PROJECT</th>
<th>CATEGORY</th>
<th>DESCRIPTION OF THE PROJECT</th>
<th>GHG REDUCTIONS CLAIMED (in T CO₂e)</th>
<th>PARTICIPANTS</th>
<th>DURATION (years)</th>
<th>HOST MUNICIPALITY/STATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plantar avoided fuel switching and sequestration project</td>
<td>Fuel Switching, Sinks and sequestration, Gas Capture or destruction</td>
<td>The project involves the replanting of 23,100 ha of Eucalyptus plantations to produce wood for charcoal which will then be used in pig iron production instead of coal</td>
<td>12,800,000</td>
<td>Plantar, S.A.</td>
<td>28</td>
<td>Curvelo, Felixlandia and Sete Lagoas/ MG</td>
</tr>
<tr>
<td>Catanduva biomass project</td>
<td>Renewables</td>
<td>Retrofit of cogeneration plant in sugermill to generate bagasse-powered electricity for export to grid. A 15MW turbo-generator and a 66kgf/cm² boiler will be installed</td>
<td>259,506</td>
<td>Ecoinvest CERUPT</td>
<td>10</td>
<td>Catanduva/ SP</td>
</tr>
<tr>
<td>Onyx landfill gas project</td>
<td>Gas Capture or destruction</td>
<td>Landfill gas recovery project</td>
<td>700,000</td>
<td>Onyx, SASA and CERUPT</td>
<td>10</td>
<td>Tremembé/ SP</td>
</tr>
<tr>
<td>V&amp;M do avoided fuel switch project</td>
<td>Fuel Switching, Gas Capture or destruction</td>
<td>Continued use of plantation-derived charcoal in the production of steel instead of switching to coke made from imported coal. The project is an &quot;avoided fuel switch&quot; project</td>
<td>20,505,857</td>
<td>Ecossecurities Toyota Tsusho IFC-Netherlands Carbon Facility (INCaF)</td>
<td>21</td>
<td>Belo Horizonte/ MG</td>
</tr>
<tr>
<td>Salvador de Bahia landfill gas project</td>
<td>Gas Capture or destruction</td>
<td>The project will expand the coverage of the existing landfill gas collection system and use part of the captured gas to generate electricity. The electricity generation plant is expected to be BMW initially, increasing to 40MW by 2019</td>
<td>16,102,938</td>
<td>VEGA</td>
<td>17</td>
<td>Salvador/ BA</td>
</tr>
<tr>
<td>NovaGerar landfill gas project</td>
<td>Gas Capture or destruction</td>
<td>Collection of methane for use in electricity generation for export to the grid at the Maruama and Adrianopolis landfills. No credits will be claimed for displacement of grid electricity</td>
<td>11,800,000</td>
<td>Ecossecurities S.A. Paulista Netherlands CDM Facility</td>
<td>21</td>
<td>Nova Iguaçu/RJ</td>
</tr>
<tr>
<td>Aquarius hydroelectric project</td>
<td>Renewables</td>
<td>4.2MW hydroelectric project on the Correntes River in Mato Grosso</td>
<td>313,782</td>
<td>Electric Power Development Company, Japan</td>
<td>21</td>
<td>Itiquira/ MT and Sonora/MS</td>
</tr>
</tbody>
</table>

SOURCES: CDM WATCH, DNV, UNFCCC, ECOSECURITIES
<table>
<thead>
<tr>
<th>PROJECT</th>
<th>CATEGORY</th>
<th>DESCRIPTION OF THE PROJECT</th>
<th>GHG REDUCTIONS CLAIMED (in T CO₂e)</th>
<th>PARTICIPANTS</th>
<th>DURATION (YEARS)</th>
<th>HOST MUNICIPALITY/STATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTE Barreiro fuel switch project</td>
<td>Renewables</td>
<td>Construction of a 12.9MW thermoelectric plant to provide electricity for the Barreiro Integrated Steel Plant using blast furnace gas which would otherwise be flared, wood tar that is a by-product of plantation-derived charcoal and, &quot;exceptionally&quot;, natural gas</td>
<td>709,358</td>
<td>V&amp;M do Brasil, Ecosecurities and CEMIG</td>
<td>21</td>
<td>Belo Horizonte/ MG</td>
</tr>
<tr>
<td>Granja Becker animal waste reduction project</td>
<td>Gas Capture or destruction</td>
<td>Improve animal waste management systems so as to reduce methane and nitrous oxide emissions</td>
<td>420,021</td>
<td>Granja Becker, LB Pork and AgCert Canada</td>
<td>21</td>
<td>Patos de Minas/ MG</td>
</tr>
<tr>
<td>Vale do Rosário bagasse project</td>
<td>Renewables</td>
<td>Increasing efficiency in the bagasse cogeneration plant at Vale do Rosário's sugar mill allowing electricity to be sold to the grid which displaces fossil-fuelled supply</td>
<td>669,640</td>
<td>Usina Vale Do Rosário, Ecoinvest and Swedish Energy Agency (STEM)</td>
<td>7 with option of renewal</td>
<td>Morro Agudo/ SP</td>
</tr>
<tr>
<td>Barralcool bagasse project</td>
<td>Renewables</td>
<td>This project activity consists of the expansion of the bagasse cogeneration facility at Usina Barralcool S.A. (Barralcool) a Brazilian sugar mill, using residue from sugarcane processing. With the implementation of this project, the mill has been able to sell electricity to the national grid, avoiding that fossil-fuelled thermal plants dispatch the same amount of energy to that grid.</td>
<td>123,338</td>
<td>Usina Barralcool and Ecoinvest</td>
<td>7 with option of renewal</td>
<td>Barra do Bugres/ MT</td>
</tr>
<tr>
<td>Gerdau carbonisation improvement project</td>
<td>Gas Capture or destruction</td>
<td>Introduction of a methane incineration device to reduce methane emissions associated with the production of charcoal for the steel factories of Brazilian steel producer Gerdau</td>
<td>8,542,416</td>
<td>Gerdau and Ecosecurities</td>
<td>21</td>
<td>Tres Marias/MG, Olhos D’Agua/MG, Rio Pardo de Minas/MG</td>
</tr>
<tr>
<td>Passo do Meio hydroelectric project</td>
<td>Large Hydro</td>
<td>Construction of a 30MW hydroelectric plant</td>
<td>865,115</td>
<td>Brascan Energética S.A. and Ecoinvest</td>
<td>10</td>
<td>São Francisco de Paula/ RS</td>
</tr>
<tr>
<td>Lara landfill gas project</td>
<td>Gas Capture or destruction</td>
<td>Capture of landfill gas from the Lara landfill in São Paulo for use in electricity generation. The project will involve installation of a pilot gas engine/generator set of 1MW in 2004/2005, then additional sets of up to 10MW in 2005/2006. Only reductions from capture of methane will be claimed</td>
<td>10,953,988</td>
<td>Lara Energia and Ferrostaal AG</td>
<td>21</td>
<td>Mauá/ SP</td>
</tr>
</tbody>
</table>

SOURCES: CDM WATCH, DNV, UNFCCC, ECOSECURITIES
<table>
<thead>
<tr>
<th>PROJECT</th>
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<th>DESCRIPTION OF THE PROJECT</th>
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<th>PARTICIPANTS</th>
<th>DURATION (years)</th>
<th>HOST MUNICIPALITY/ STATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marca landfill gas project</td>
<td>Gas Capture or destruction</td>
<td>Collection of landfill gas from Marca landfill for generation of electricity for export to the grid. Excess gas, and gas collected during periods when electricity is not produced, will be flared. Only reductions from the capture of methane will be claimed at this stage</td>
<td>4,859.503</td>
<td>Marca Ltda and Ecossecurities</td>
<td>21</td>
<td>Cariacica/ES</td>
</tr>
<tr>
<td>CST steel making efficiency project</td>
<td>Energy Efficiency</td>
<td>The project has two parts: Introduction of a gas recovery system and use of the gas for electricity generation and modification of existing motors to enhance their efficiency</td>
<td>331.156</td>
<td>Companhia Siderúrgica de Tubarão (CST) and PricewaterhouseCoopers</td>
<td>7</td>
<td>Serra/ES</td>
</tr>
<tr>
<td>Caieiras landfill gas project</td>
<td>Gas Capture or destruction</td>
<td>Installation of methane collection and flaring equipment</td>
<td>14,694.224</td>
<td>Essencis Soluções Ambientais</td>
<td>21</td>
<td>Caieiras/SP</td>
</tr>
<tr>
<td>Irani biomass project</td>
<td>Renewables, Gas Capture or destruction</td>
<td>Construction and operation of a 9.43MW biomass plant to generate electricity for use by Celulose Irani in paper manufacturing. Credits are claimed both for displacement of grid electricity and methane avoided by not sending biomass to landfill</td>
<td>3,702.046</td>
<td>Celulose Irani and Ecossecurities</td>
<td>21</td>
<td>Vargem Bonita/SC</td>
</tr>
<tr>
<td>Cargill fuel switching project</td>
<td>Fuel Switching</td>
<td>Replacement of 3 fuel-oil powered boilers with a biomass powered boiler for production of steam for use in Cargill's Uberlândia industrial plant in Minas Gerais</td>
<td>1,372.010</td>
<td>Cargill Agricola and Polén Technologies – Altran Group</td>
<td>10</td>
<td>Uberlandia/MG</td>
</tr>
<tr>
<td>Corn products oil to gas fuel switch project</td>
<td>Fuel Switching</td>
<td>Construction of a combined cycle gas plant to replace oil-fired steam boilers and grid electricity</td>
<td>903.175</td>
<td>Corn Products Brazil and ICF Consulting</td>
<td>10</td>
<td>Mogi Guacu/SP</td>
</tr>
<tr>
<td>AES-Tietê resevoir reforestation project</td>
<td>Sinks and Sequestration</td>
<td>Reforestation of native vegetation cover of approximately 4,188 hectares around the reservoirs of AES-Tietê hydropower plants in Brazil. The reservoirs are Bariri, Barra Bonita, Itatinga and Promissão</td>
<td>5,287.550</td>
<td>AES-Tietê (claiming L-CERs)</td>
<td>30</td>
<td>Adolfo Sales, Anhembi, Araçatuba, Bariri, Barra Bonita, Boraceia, Barroera, Botucatu, Cafelândia, Conchas, Dois Corregos, Guiacuru, Iacanga, Itatinga, Iguaçu do Tietê, Itapua, Itaju, Itapevi, Jau, Jose Bonifacio, Laranjal Paulista, Linha Macatuba, Mendo, Minas do Tietê, Nova Aliança, Novo Horizonte, Pedemeteras, Piracicaba, Pirajuí, Pongai, Potiendaba, Pompéia, Regiopolis, Sabino, Santa Maria da Serra, Sao Manuel, Sao Pedro, Uberaba, Uru, Urupes</td>
</tr>
</tbody>
</table>

SOURCES: CDM WATCH, DNV, UNFCCC, ECOSECURITIES
<table>
<thead>
<tr>
<th>PROJECT</th>
<th>CATEGORY</th>
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<th>DURATION (years)</th>
<th>HOST MUNICIPALITY/ STATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosipar blast furnace gas project</td>
<td>Renewables</td>
<td>Expansion from 4MW to 10MW of a plant fired by blast furnace gas which generates part of the electricity used by the Cosipar Pig Iron Plant. The gas would otherwise be flared and grid electricity used</td>
<td>429,577</td>
<td>Cosipar and Ecosecurities</td>
<td>21</td>
<td>Marabá/ PA</td>
</tr>
<tr>
<td>Faxinal dos Guedes swine manure</td>
<td>Gas Capture or destruction</td>
<td>Installation of not-heated anaerobic digesters to capture and flare greenhouse gases (mainly methane) from the anaerobic lagoons treatment systems at the Faxinal dos Guedes, Toledo Luz Marina and Toledo Su Sebáuás farm</td>
<td>not clear</td>
<td>Sadia</td>
<td>10</td>
<td>Faxinal dos Guedes/ SC Toledo/ PR</td>
</tr>
<tr>
<td>Imbituva biomass project</td>
<td>Gas Capture or destruction,</td>
<td>Construction of a 13.8MW biomass plant which will use 200,000 tonnes of biomass waste per year from 25 sawmill companies in the state of Paraná. The project will claim credit from displacement of grid electricity and from the avoidance of methane emissions as a result of not sending biomass waste to landfill</td>
<td>6,560,050</td>
<td>Usina Termoelétrica Winimport and Ecosecurities</td>
<td>21</td>
<td>Imbituva/ PR</td>
</tr>
<tr>
<td>Inácio Martins biomass project</td>
<td>Renewables</td>
<td>Construction of a 15MW biomass plant which will use 200,000 tonnes of biomass waste per year from 25 sawmill companies in the state of Paraná. The project will claim credit from displacement of grid electricity and from the avoidance of methane emissions as a result of not sending biomass waste to landfill</td>
<td>6,684,852</td>
<td>Abilio Bornia and Ecosecurities</td>
<td>21</td>
<td>Inácio Martins/PR</td>
</tr>
<tr>
<td>Estre Paulínia landfill gas project</td>
<td>Gas Capture or destruction</td>
<td>EPLGP is a landfill gas collection and flare project in Brazil. The purpose is to avoid methane emissions from the landfill managed by ESTRE in Paulínia municipality through installing an active gas recovery with a flaring system in the landfill.</td>
<td>1,484,016</td>
<td>Estre</td>
<td>20</td>
<td>Paulínia/ SP</td>
</tr>
<tr>
<td>Moema bagasse cogeneration project</td>
<td>Renewables</td>
<td>Increased efficiency of bagasse cogeneration facility at Usina Moema sugar mill allowing electricity to be sold to the grid and thus displacing fossil-fuelled supply</td>
<td>428,340</td>
<td>Usina Moema</td>
<td>7 with option of renewal (reduction figure given above is for first 7 year period)</td>
<td>Orindiúva/ SP</td>
</tr>
<tr>
<td>Santa Elisa Bagasse project</td>
<td>Renewables</td>
<td>Increasing efficiency of the bagasse cogeneration plant at the Santa Elisa sugar mill allowing electricity to be exported to the grid which displaces fossil-fuelled supply</td>
<td>422,931</td>
<td>Companhia Energética Santa Elisa, Ecoenergy and Swedish Energy Agency (STEM)</td>
<td>7 with option of renewal (reduction figure given above is for first 7 year period)</td>
<td>Sertãozinho/ SP</td>
</tr>
</tbody>
</table>

**Sources:** CDM Watch, DNV, UNFCCC, Ecosecurities
CHAPTER III – LITERATURE REVIEW: ETHANOL & CDM PROJECTS

This literature review discusses the development of the Brazilian alcohol program, presenting its advantages and disadvantages. Similarly, it presents what has been discussed, negatively or positively, about the structure and impacts of CDM projects in general. This chapter is relevant to my thesis for two reasons. First, this work is one of the few studies considering an ethanol program as a CDM project. In fact, the only other study, in my knowledge, regarding an ethanol-based CDM was a discussion between Germany and Brazil for ethanol-fueled automobile’s manufacturing. However, the Brazil-Germany proposal, would differ from the one proposed in my thesis since it would not have national scope and does not take into consideration the enhancement of ethanol supply. The second reason why this chapter is important is that it shows the nationwide impacts of the Brazilian ethanol program and helps with the analysis of whether or not an Ethanol-Based CDM would be better distributed than the current CDM projects.

This review is divided in four parts. The first part addresses the different uses of ethanol and the different types of ethanol used to fuel vehicles. The second part of this study introduces the Proalcool Program, explains its objectives, and discusses its social, environmental, and economic costs and benefits. The third part examines the current issues and trends related to ethanol in Brazil, analyzing the increasing use of flex-fuel cars in the country’s fleet. Moreover, it examines the possibility for Brazil to increase its ethanol production and demand to become a world leader in flex-fuel technology. The
last part of this review analyzes the positive and negative issues currently highlighted about the CDM projects in general and also in the Brazilian context.

**ETHANOL PROJECT: PROALCOOL PROGRAM IN BRAZIL**

Proalcool was the largest effort ever made to substitute fossil fuels with biomass, implemented in the 1970s and 1980s. Although Proalcool’s implementation happened mainly for economic and social reasons, its consequences positively impacted the environment since ethanol is a cleaner fuel.

Before explaining the ethanol program in Brazil (Proalcool Program), I will first describe the characteristics of ethanol and how it affects the environment. Moreover, I will discuss the important facts of the Program, including costs and its consequences in the current Brazilian vehicle market.

**Ethanol**

Ethanol is ethyl alcohol (CH\textsubscript{3}CH\textsubscript{2}OH), a liquid resulted from the fermentation of biomass’ materials containing starches, sugars or cellulose. In Brazil, ethanol is produced by fermenting sugarcane; while in the United States, by fermenting corn. Sorghum, potatoes, other farm plants, and even biomass waste can also generate ethanol. Typically, anything that contains carbon can be used in ethanol production (Copersucar Uniao 2003).

Ethanol is used not only as a product that increases octane and improves the emissions quality of gasoline, but also as an alternative fuel by itself. There are two types of ethanol: hydrous and anhydrous (Hu et al. 2004). Anhydrous ethanol can be mixed with gasoline to produce gasohol (a mixture of up to 24 percent ethanol), while hydrous
ethanol is used as a straight fuel (see Table 5). Besides its utilization as fuel for vehicles that have engines properly constructed for alcohol use, hydrous ethanol can also be used for domestic consumption.

Table 5: Comparative Table

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>ETHANOL</th>
<th>GASOHOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPOSITION</td>
<td>Hydrous Ethanol + water</td>
<td>Gasoline + Anhydrous Ethanol</td>
</tr>
<tr>
<td>EVAPORATION</td>
<td>Less volatile</td>
<td>More volatile</td>
</tr>
<tr>
<td>ENERGY</td>
<td>5089 Kcal / L</td>
<td>8050 Kcal / L</td>
</tr>
<tr>
<td>DISPONOBILITY</td>
<td>Renewable Resource</td>
<td>Non-renewable Resource</td>
</tr>
<tr>
<td>EFFICIENCY</td>
<td>10,7 Km/ L</td>
<td>13,6 Km/ L</td>
</tr>
</tbody>
</table>

SOURCE: ALTERNATIVE ENERGY SYSTEMS CONSULTING 2003

One of the differences between hydrous and anhydrous ethanol is that hydrous ethanol is 94 percent water-free, while anhydrous ethanol is 99.8 percent pure. In addition, they are produced differently and, consequently, production costs diverge. To produce hydrous ethanol, it is necessary the addition of benzene in the process. On the other hand, to produce anhydrous ethanol it is necessary to remove almost all water in its production, which requires an extra distillation column – one more compared to hydrous ethanol (Brilhante 1997).

Figure 14 presents the consumption of alcohol per segment in Brazil in 1992. It shows that 73 percent of ethanol production was utilized to make hydrous ethanol while 18 percent was linked to anhydrous’ ethanol production.
Ethanol is almost the same alcohol used in beverage alcohol but it meets fuel grade standards. The ethanol fuel has to be denatured and this is done by adding a small quantity of gasoline to it.

The history of ethanol as a fuel used for transportation goes back many years to Henry Ford, who was one of the transportation pioneers. In the 1880s, Ford constructed the quadricycle fueled with ethanol, which was one of his first automobiles. After that, Ford constructed the popular Ford Model T, which could run on either ethanol or gasoline. Ford’s intention was to construct an affordable vehicle for working families. Moreover, he wanted to create a vehicle using a fuel that would improve rural farms (Copersucar Uniao 2003).

The use of ethanol to fuel automobiles in Brazil initiated in the 1920s. In 1931, the use of 5 percent of alcohol in gasohol mixture became mandatory as a measure to combat the low prices of sugar in the international market. This was also a measure to curtail the imports of petroleum, since Brazil did not produce any at that time. In 1933, the creation of the Sugar and Alcohol Institute (IAA) was an important measure to
expand the capacity of alcohol production. Additionally, the creation of the IAA was an important step to reduce the problem of sugar excess production and low prices in the country (Brilhante 1997). During the 1970s, more specifically in 1974, sugar exports fell approximately 50%, and it was a strong reason for the adoption of Proalcool in Brazil (Gianini 1999). Another critical cause for the implementation of the Program was the high prices of oil in the international market and the desire of reducing its dependency. In 1973, during the first oil crisis, petroleum accounted for 43 percent of the total primary requirement of energy in Brazil. At that time, the country produced only 23 percent of the consumed oil in the country, being excessively dependent on oil imports to produce fuel for increasing Brazilian’s transport sector (Finep 1985).

The study of ethanol use in Brazil as an alternative fuel is relevant due to its large and fast-growing automobile fleet. With a fleet of more than twenty-one million cars, it is important for the Brazilian government to adopt alternative fuels to address economic, social, and environmental problems related to vehicular pollution. Table 6 presents the numbers of the Brazilian automobile’s fleet in 1998 (Ribeiro et al. 2000).

<table>
<thead>
<tr>
<th></th>
<th>Alcohol Fleet</th>
<th>Gasohol Fleet</th>
<th>Total Fleet</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>80,827</td>
<td>352,819</td>
<td>433,646</td>
</tr>
<tr>
<td>Northeast</td>
<td>496,269</td>
<td>1,650,624</td>
<td>2,146,893</td>
</tr>
<tr>
<td>Southeast</td>
<td>2,903,367</td>
<td>10,072,724</td>
<td>12,976,091</td>
</tr>
<tr>
<td>South</td>
<td>731,938</td>
<td>3,508,007</td>
<td>4,239,945</td>
</tr>
<tr>
<td>Middle-west</td>
<td>351,316</td>
<td>1,165,460</td>
<td>1,516,776</td>
</tr>
<tr>
<td>Total</td>
<td>4,563,717</td>
<td>16,749,634</td>
<td>21,313,351</td>
</tr>
</tbody>
</table>

SOURCE: GEIOPOT, 1999
Alcohol and the Environment

Environmental protection was not an initial objective of PNA (the National Alcohol Program). In fact, there were no apparent plans concerning environmental impacts in the beginning of Proalcool. Nonetheless, Proalcool was an important program to reduce the toxic pollutants released by vehicles.

Considering the benefits of using ethanol fuel instead of fossil fuels, it is unquestionable that ethanol has the advantage of being a renewable fuel (Borrero 2003). According to Bohm (1998), “ethanol may not be the most ecological fuel, but it is less toxic than gasoline”. Compared to petroleum fuels, ethanol-blended fuels reduce tailpipe exhaust discharges of carbon dioxide, hydrocarbons, carbon monoxide, butadiene, toluene, particulate, nitrogen oxides, benzene, and xylenes. According to Kheshgi et al, avoided CO$_2$ emissions regarding fossil fuel emissions used to produce ethanol amount to 29%. Rask (1995) asserts that, compared to gasoline emissions, alcohol fueled automobiles release 57 percent less carbon monoxide, 64 percent less hydrocarbons, 13 percent less nitrogen oxides, and there is no lead discharges.

Another advantage of ethanol over oil fuels is that it is a good substitute for MTBE (methyl tertiary butyl ether), a toxic oxygenate added to fuel to make it burn emitting less pollutants. Ethanol is used in the production of ETBE (ethyl tertiary butyl ether), a substitute of MTBE. Both ETBE and MTBE are fuel additives developed primarily to reduce tailpipe emission (Keating 2004).

According to Jacobi (1997), the combustion of hydrous ethanol and gasohol has affected the ambient concentration in Greater Sao Paulo Area (GSPA). The GSPA is the most important economic area in Brazil, where air pollution is one of the most serious
environmental problems. A study of the Interagency Assessment of Oxygenated Fuels that analyzes the possibility of ethanol accumulating in the environment for a long period concluded that ethanol’s degradation in groundwater and in the atmosphere is rapid (Armstrong 1999).

Another positive aspect related to the use of ethanol is that it might be an interesting substitute for fossil fuels. The reduction of the number of petroleum-fueled automobiles cuts carbon dioxide (CO$_2$) emissions and consequently diminishes the threat of global warming. According to Ribeiro et al. (2000), one of the reasons why CO$_2$ is considered the most important greenhouse gas is its high levels in the atmosphere. One of the causes of its high concentration in the air is the large and increasing vehicle fleet of urban and industrialized centers in the world.

Nonetheless, there are also negative aspects related to the use of ethanol as an alternative fuel. Aldehydes’ emissions emitted from ethanol-fueled automobiles are greater than from other fuels. In addition, it is still uncertain if ozone emissions are reduced or not when fossil fuels are replaced by ethanol. Another disadvantage of ethanol production is that turning sugar cane into ethanol utilizes more energy than producing petroleum from crude oil and final prices are still not as competitive, although they have decreased greatly due to increases in productivity and new technologies.

**Proalcool Program**

The Brazilian National Alcohol Program, or Proalcool, was a national program implemented in Brazil between 1975 and 1985. The program is comprised of two stages: the first one took place from 1975 to 1978 and the second stage from 1979 to 1985. Both
phases occurred during the military dictatorship government, which considered the
development of ethanol as an alternative to diminish the fossil-fuel dependency and to
solve the sugar-cane production’s surplus.

Proalcool is considered a unique example of a long-term commitment to a
renewable oil substitute (Rask, 1995). According to Goldemberg (2003), Proalcool has
been the most successful experience of a biomass energy program in the world. He
validates this argument stating that the Proalcool had positive environmental, social, and
economic results and that Brazil accomplished its initial objectives for the program.

Rask (1995) considers that one of Proalcool’s most important objectives was the
massive use of a green fuel that would be less toxic than petroleum fuel. The literature,
however, considers that environmental issues were not the primary concern for the
program but a consequence of the ethanol use. The literature states that the program’s
initial objective was the reduction of the dependency of oil imports. The Brazilian
government initiated the program due to the high price of petroleum barrels and the
instability of oil supply in the international market. To reduce the dependence of oil
imports and to develop the program, the government launched Proalcool in the 1970’s.

Since the beginning of Proalcool, ethanol had been produced in two main regions
of Brazil, the center-south (C-S) and the north-northeast (N-N) (See Figure 15). The
former region encompasses three states – Rio de Janeiro, Sao Paulo, and Minas Gerais –
and was responsible for more than 80 percent of ethanol production in the country. The
latter region is one of the poorest areas in the country and was characterized by high costs
of ethanol production compared to the C-S areas (Borrero 2003). Despite its cost
disadvantage, N-N production was extremely important for the region’s development, which is considered an important achievement of the program (Oliveira 2002).

**Figure 15: Major Ethanol Producer States in Brazil**

To achieve its objectives, the National Alcohol Program initiated the production of anhydrous alcohol in 1975 with the intention of substituting 20 percent of the gasoline production forecasted for 1980 (Rask, 1995). Moreover, during the first phase of the program, the Brazilian government facilitated the growth and expansion of distilleries to make Proalcool work (Oliveira 2002). The beginning of the program was considered slow, and it was only in 1977, when the international sugar prices were extremely low, that the government decided to strengthen the program.
In order to improve the program in the late 1970s (beginning of the second phase), the Brazilian government focused on the production of hydrous ethanol and on the encouragement of alcohol-fueled car production. To achieve these goals, the federal government took measures that include the commitment with the vehicle industry to expand the production of alcohol fueled cars; the agriculturist zoning to avoid competition between sugarcane and other crops; fiscal advantage to buyers of alcohol fueled cars; the reduction of the price of alcohol to 65 percent of gasohol’s price; and the promise of buying the whole alcohol production.

The adoption of these measures led to the increase of alcohol production from 0.9 billion liters in 1976 to 9.2 billion liters in 1984. The alcohol annual production growth of 40 percent was essential to the advancement of the program, which made it viable, wide-ranging, and sustainable (Lima, 1995).

Proalcool hit its highest point in 1985 when approximately 91 percent of the automobiles produced in Brazil were ethanol fueled. Figure 16 shows the evolution of alcohol production in Brazil from 1975 to 1993. Through this graph, it is possible to observe that alcohol production initiated in 878 million liters to 11,764.87 million liters in 1993. The ethanol production growth persisted until 1985/1986 and then encountered many problems (Copersucar Uniao 1999).
A crisis occurred first due to the declining in international oil prices and also because of public deficits. This condition made the Brazilian government to cut incentives and subsidies, causing an impressive reduction on the production of ethanol-fueled automobiles. Economically, it was not interesting to continue producing ethanol when the petroleum prices fell and the price of sugar rose. It was more profitable to export sugar and to import oil, than to produce ethanol. The production of ethanol, which hit a peak level of 90 percent of the total of automobiles produced in Brazil in the late 1980s, dropped to less than 2 percent in the beginning of the 1990s. Despite this extreme reduction of the production of ethanol-fueled cars, currently this type of vehicle accounts for approximately 20 percent of the national fleet.

Despite this crisis, the Proalcool program makes Brazil one of the few countries in the world that has tried do adopt a plan to break up the total dependency on petroleum fuels (Oliveira 2002).
Cost Effectiveness

Only a few studies address the economic cost of Proalcool in the literature. Although the literature is rich in articles discussing the program, there is little emphasis in the cost effectiveness of PNA.

According to Goldemberg (2004), the Brazilian Government invested heavily to launch and to develop the PNA from 1975 to 1989. He stated that a total of US$ 4.92 billion was spent in Proalcool (Goldemberg 2004, 304). However, this investment can be considered successful regarding that Brazil saved US$52.1 billion with unavoidable imports evaluated at international prices from 1975 to 2002.

Rask’s evaluation of the program considered the development of Proalcool in two different areas in Brazil: the center-south and the north-northeast regions. The author concludes that ethanol production in Brazil was economically viable during the early 1980s in the center-south region. It was viable because the price of one barrel of oil at that time ranged from US$ 21 to US$ 25. This view differs from previous studies that consider that ethanol production would be economically viable only if the cost of an oil barrel were greater than US$ 30. Rask states that, although not efficient in terms of costs, the production in the north-northeast region was valuable because of the social development that took place in the area.

Considering the costs of the program as a whole, the short-term success of the program is questionable. However, a long-term analysis could show that Proalcool is very successful once oil prices increase, making ethanol’s price more attractive than petroleum and making Brazil a leader in ethanol-fuel technology (Oliveira 2002).
Taking into consideration current automobile market issues, less than 20 percent of the Brazilian car fleet runs on ethanol. However, there is an increasing use of hybrid cars in the Brazilian fleet. Currently, there are already 200,000 flex-fuel automobiles in the country since their launch in 2003. Flex-fuel vehicles can run on either ethanol or gasohol and their use is a probable tendency in the market and a possibility of enlarging the Brazilian’s ethanol demand. Because of the instability of the petroleum market and current wars related to petroleum issues, there is a real possibility of worldwide demand of flex-fuel cars running on ethanol in the near future.

Brazilians are already switching the high-cost, petroleum-fueled vehicles to flex-fuel engine cars (See Figure 17), which have been expanding in the market. In Brazil, the sales of flex-fuel cars initiated in 2003 and it already represents 24 percent of new car sales (See Figure 18). Some researches foresee that flex-fuel cars will achieve approximately 40 percent of total car sales by next year.

The high prices of oil in the international market and the desire for cleaner burning fuels are some of the reasons for the potential for widespread use of flex-fuel vehicles worldwide. The increase in use of this technology is expected to occur in other
countries. Therefore, as few countries in the world have competitive ethanol industries, the increase of flex-fuel technology in the market will probably favor Brazil, and the country has the possibility to be a world’s leader in flex-fuel cars and technology exports (Benson 2004).
Figure 18: Monthly Ethanol Vehicle Sales

Brazil – Ethanol Vehicle Sales

CDM PROJECTS

The CDM projects of the Kyoto Protocol are not only the most prominent tool of the Protocol but also the most controversial element. Much has been discussed about this instrument that reduces developed countries’ costs of achieving their emission targets to the Protocol. These discussions have been dominated by two divergent views. On the one hand, the supporters of the Kyoto Protocol argue that CDM will approximate the north and the south in the battle of emissions reduction and it will enable the transfer of technology for developing countries. Additionally, most of the proponents of CDM emphasize the fact that this instrument is positive to developing countries because it will promote sustainable development in the host countries. The enthusiasts also believe that the CDM is a great instrument of reducing GHG emissions because it is based on “economic principles designed to maximize efficiency” (Rowlands 2001, 796). According to Duic et al. (2001), CDM will enable developed countries to have their costs
of mitigating global warming reduced by half by investing in developing countries instead of their own boundaries. For Woerdman (1999), besides the reduced costs, the possibility of pre-budget banking makes CDM a more attractive instrument.

On the other hand, many flaws of the CDM have been observed by scholars, environmentalists, NGOs, and governments. Most critiques relate to the fact that although CDM aims to promote sustainable development in developing countries, the developed countries are the ones that are really benefiting from the CDM by having lower costs in achieving emissions reduction. According to Mendis et al. (2004), the most critical factor for the success of CDM carbon market is an efficient international market. Painuly (2001) argues that some issues related to the CDM such as, baseline, financial additionality, project eligibility criteria, and risk of leakage are still unclear and all these uncertainties make the project difficult to be operated. For him, it would be more interesting if CDM considered an equitable basis (emissions per capita) as a better way to allocate emissions instead of setting targets as a percentage of 1990 emissions.

Among all potential problems referred to CDM, an interesting critique of Repetto is that “the CDM is an international payment for a service, the reduction of greenhouse gas emissions. A fundamental flaw is that neither the sellers nor the buyers of the credits have a private interest in the actual delivery of the service” (Repetto 2001, 309). According to him, as long as the buyer receives the certified emission reductions and the host country is paid for this service; both parties are not really worried if the emissions reductions really occurred (Repetto 2001, 309).

Another relevant issue is pointed out by Lasso (2005). She argues that most of the developed countries have been investing in CDM projects that generate large amount
of cheap CERs. The cheapest projects are the ones that aim to reduce the emissions of
gases such as methane and HFC-23. Moreover, according to her, the main problem with
CDM is that only a small part of the CDM projects in Latin America is categorized as
renewable energy. Basically, it has been occurring regardless of all the theory behind
CDM, which postulates that it would promote sustainable development in developing
countries. Lasso states that this mechanism is neither a development fund nor a way of
implementing renewable projects. In reality, it is a mechanism that enables developed
countries to have lower costs in reducing their targeted emissions (Lasso 2005).

Therefore, the parties committed to the Kyoto Protocol are not interested in
looking for projects that might reduce larger amounts of GHG or in promoting
sustainable development in developing nations. What they are really interested in is to
achieve the emissions reductions they need, during the specified timeframe. Thus, CDM
is working well in the perspective of a market-mechanism but it is not achieving the
aimed goals in the perspective of a development instrument (Pearson 2004).
CHAPTER IV – EMPIRICAL STRATEGY

As mentioned before, I am comparing two different alternatives. The first one, the current CDM projects targets specifics municipalities in Brazil. The other alternative, an Ethanol-Based CDM has a national scope, since it considers all the municipalities that have automobiles.

To evaluate if an Ethanol-Based CDM Project would be more equitably distributed across Brazilian municipalities than current CDM Projects in Brazil, I ran three different tests. Test 1 will verify if the current CDM projects tend to concentrate in more developed municipalities in the country. Test 2 is a simple comparison of the average HDI for both alternatives. Lastly, test 3 will verify if an Ethanol-Based CDM project would be more equitably distributed over the Brazilian municipalities than the current CDM projects.

TEST 1 – DEVELOPMENT LEVEL

The objective of this first test is to verify if the current CDM Projects are concentrated in more developed municipalities in Brazil. To do that, I analyzed data of socio-economic indicators for 5507 municipalities in the country extracted from the United Nations Development Programme database from the year 2000. Rabelo (2004) used a different test with the same objective. However, my test differs from hers in that it allows for the simultaneous contribution of several variables to the probability of existence of a CDM project in a given Brazilian municipality.
The choice of the socio-economic indicators for this preliminary step of my methodology was based on a large list of indicators. I selected indicators from distinct areas such as education, infra-structure, income distribution, and health. Then, I calculated the correlation among these variables and selected those with lower correlation indices. The indicators that I initially chose include: (1) Percentage of people between 18 and 24 years of age attending university; (2) Monthly income; (3) Poverty intensity; (4) Percentage of households with piped water; (5) Percentage of households with electric energy; (6) Mortality rate for children under 1 year of age; (7) Number of physicians per thousand of people; (8) literacy rate; (9) Life expectancy at birth; (10) average of years of education for people who are 25 years old or over, and (11) the Gini Index for income.  

Analyzing the correlation matrix, I verified that some of previous indicators selected were correlated. This is relevant to be considered because one implication of these correlations is that there will be some redundancy in the information provided by the correlated variables. For this reason, I reduced the number of indicators in such a way that there was no significant loss of information. Therefore, the less correlated indicators selected to be used in my tests include: (1) mortality rate for children under one year of age; (2) Gini index for income; (3) income per capita; (4) percentage of households with piped water; and (5) number of physicians per thousand people. Additionally, I created regional dummy indicators to test the spatial distribution of the

---

9 The Gini Index measures inequality over the entire distribution of income or consumption. A value of 0 represents perfect equality, and a value of 1 perfect inequality.
current CDM Projects. These variables are *CDM projects in the south*, *CDM projects in the north*, *CDM projects in the northeast*, *CDM projects in the center-west region of the country*. The southeast area was omitted to avoid perfect collinearity in the estimated regression.

After selecting these explanatory variables, I first analyzed the simple descriptive statistics based on a dummy variable (CDM). This dummy variable was created in the following way: the value of “0” representing the municipalities that do not have a CDM Project and the value of “1” representing the municipalities that have a CDM Project in Brazil (See Table 7).

<table>
<thead>
<tr>
<th>Table 7: Descriptive Statistic for Explanatory Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
</tr>
<tr>
<td><strong>Dep=0</strong></td>
</tr>
<tr>
<td>MORTALITY RATE UNDER 1 YEAR OLD</td>
</tr>
<tr>
<td>HOUSEHOLDS WITH PIPED WATER</td>
</tr>
<tr>
<td>GINI INDEX</td>
</tr>
<tr>
<td>INCOME</td>
</tr>
<tr>
<td># PHYSICIANS PER THOUSAND PEOPLE</td>
</tr>
<tr>
<td>CDM PROJECTS IN THE SOUTH</td>
</tr>
<tr>
<td>CDM PROJECTS IN THE NORTH</td>
</tr>
<tr>
<td>CDM PROJECTS IN THE NORTHEAST</td>
</tr>
<tr>
<td>CDM PROJECTS IN THE MIDDLE WEST</td>
</tr>
</tbody>
</table>

As demonstrated in the table above, municipalities hosting CDM projects (Dep=1) have on average a lower *mortality rate for children under 1 year of age* and a lower *Gini index*. In addition, these municipalities also have higher percentage of *households with piped water*, higher *income* as well as more *physicians per thousand people* than the municipalities not hosting CDM projects (Dep=0). It is observed that even though the projects are going to richer municipalities (higher income), they tend to concentrate in municipalities with slightly better income distribution (lower *Gini Index*).
Although these results show an indication that the hypothesis is correct, more rigorous tests are needed in order to achieve econometrically significant results. The chosen model was the Probit Model because it helps estimate the impact of different variables on the probability of the existence of a CDM project in a given municipality. In this model, the CDM variable is the dependent variable and the indicators cited above are the independent variables (see Table 8).

<table>
<thead>
<tr>
<th>Table 8: Probit Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
</tr>
<tr>
<td><strong>MORTALITY RATE UNDER 1 YEAR OLD</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>HOUSEHOLDS WITH PIPED WATER</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>GINI INDEX</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>INCOME</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong># PHYSICIANS PER THOUSAND PEOPLE</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>CDM PROJECTS IN THE SOUTH</strong></td>
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<td></td>
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<tr>
<td><strong>CDM PROJECTS IN THE NORTH</strong></td>
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<tr>
<td></td>
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<tr>
<td><strong>CDM PROJECTS IN THE NORTHEAST</strong></td>
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<tr>
<td></td>
</tr>
<tr>
<td><strong>CDM PROJECTS IN THE MIDWEST</strong></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

*Notes:* ML-Binary Probit; dependent variable is CDM; Standard errors in parenthesis. *[*][**][***]denotes significance at the 1 [3 ](7) percent level.
The results of the Probit Model enable us to better analyze the interactions between the chosen variables and the probability of existence of a CDM project in a municipality. The variable *mortality rate for children under 1 year of age* has the expected negative sign and is significant at the 1 percent level implying that municipalities hosting a CDM project tend to have lower mortality rates. The coefficient of the variable *households with piped water* is not significant, indicating that this variable is not related to the existence of a CDM project in a municipality. *Gini index* does not have the expected negative sign, which means that municipalities hosting CDM projects tend to be slightly less unequal, and is significant at the 7 percent level. Moreover, consistent with my hypothesis, *income* has a positive sign and is statistically significant; meaning that people in municipalities hosting CDM projects tend to have higher income. Also, the coefficient for the variable *number of physicians per thousand people* is not statistically significant. Moreover, the coefficients for the variables *CDM projects in the south*, *CDM projects in the north*, *CDM projects in the northeast*, and *CDM projects in the center-west region* have negative signs, indicating that these regions in Brazil are less likely to receive a CDM project than the southeast region (omitted dummy variable), the most developed region of the country. However, only the coefficient for the center-west region is statistically significant.

These econometric results are as expected. They emphasize that current CDM projects are in fact located in more developed municipalities, considering the socio-economic indicators previously cited. The results also give the necessary credibility to continue with the current hypothesis that Ethanol-Based CDM Project might be more
equitably distributed across Brazilian municipalities, since the pollution impacts of such a project are expected to be verified in most if not all municipalities in the country.

**TEST 2 – EQUITABLE DISTRIBUTION**

Test 2 is a first step to verify if the Ethanol-Based CDM project would be more equitably distributed over the Brazilian municipalities than the current CDM projects. I compared the average HDI (Human Development Index) for the municipalities currently hosting a CDM Project to the average HDI of all Brazilian municipalities, considering that an Ethanol-Based CDM Project would reach all municipalities in Brazil that have automobiles.

I decided to use the HDI because it is a more comprehensive measure of socio-economic development of countries and municipalities. The HDI basically combines three components of human development: Longevity, education, and standard of living. This index is provided by the United Nations Development Programme since 1990 and the sample I used in this second test is for the year 2000.

The results of Test 2 (see Table 9) show that the average HDI of the municipalities that have a CDM project is higher than the average HDI of the municipalities that would be reached by the Ethanol-Based CDM project, all Brazilian municipalities. This, however, is not a precise test since it does not take into consideration the extent to which these municipalities would be affected. Therefore it is important to run an additional test to tackle this problem.
Table 9: Descriptive Statistics (Test 2)

<table>
<thead>
<tr>
<th></th>
<th>HDI</th>
<th>Current CDM Projects</th>
<th>Ethanol-Based CDM Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.784767123</td>
<td>0.701439015</td>
<td></td>
</tr>
<tr>
<td>Standard Error</td>
<td>0.004576033</td>
<td>0.001122878</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>0.788</td>
<td>0.715</td>
<td></td>
</tr>
<tr>
<td>Mode</td>
<td>0.813</td>
<td>0.738</td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.039097641</td>
<td>0.082537246</td>
<td></td>
</tr>
<tr>
<td>Sample Variance</td>
<td>0.001528626</td>
<td>0.006812397</td>
<td></td>
</tr>
<tr>
<td>Kurtosis</td>
<td>2.993894738</td>
<td>-0.887107727</td>
<td></td>
</tr>
<tr>
<td>Skewness</td>
<td>-1.331301222</td>
<td>-0.321120926</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0.214</td>
<td>0.452</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>0.633</td>
<td>0.467</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>0.847</td>
<td>0.919</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>57.288</td>
<td>3789.875</td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td>73</td>
<td>5403</td>
<td></td>
</tr>
</tbody>
</table>

Notes: (1) 104 cities were not considered in the calculations because of discrepancies in the data (no register of vehicle fleet or no HDI associated). However, these omitted municipalities would not interfere in the calculations because the sum of the municipalities represent only 0.91% in terms of total population and 1.89% in terms of total number of municipalities.
(2) There are two CDM projects in Belo Horizonte. Therefore, I counted the city twice in my calculations, i.e. as if there were two cities with the same characteristics.

**TEST 3 – EQUITABLE DISTRIBUTION (WEIGHTED AVERAGE)**

I ran Test 3 to verify if the results obtained in Test 2 were correct and to include the pollution abatement impact factor in the comparison between current and ethanol-based CDM projects. To do that, I compared the weighted average HDI of the municipalities currently hosting a CDM Project to the weighted average HDI of the municipalities that the Ethanol-Based CDM Project would reach.

In the case of the current CDM projects, the weight of the HDI for each municipality is equal to the proportion of the population in each municipality relative to the national population. Regarding the Ethanol-Based CDM, the weight of the HDI for
each municipality is equal to the proportion of the automobile fleet in each municipality in the country relative to the national fleet. The choice of these weights for the impact of pollution abatement was due to the fact that although the automobile fleet reflects the source of emissions, whereas population refers to the direct consumers of pollution, both indicators are highly correlated (correlation coefficient is 0.9599).

The data for the national vehicle fleet for each municipality were obtained from Denatran (the Brazilian transit department) and is from the year 2004. The data of population for all municipalities were extracted from IBGEs (Brazilian Institute of Geography and Statistics) 2000 population census.

Table 10 presents the weighted average HDIs. The automobile fleet weighted average HDI for the affected Brazilian municipalities was very similar to the weighted average HDI for the municipalities currently hosting a CDM project. Furthermore, these averages were substantially above the national average HDI.

<table>
<thead>
<tr>
<th>Weighted HDI</th>
<th>Current CDM Projects</th>
<th>Ethanol-Based CDM Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.810988845</td>
<td>0.809267185</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.032524103</td>
<td>0.001864486</td>
</tr>
</tbody>
</table>
ANALYSIS OF RESULTS & DISCUSSION

There are two main problems related to CDM projects. The first problem, as many scholars have mentioned, regards the dilemma involved with the CDM policy initiative. Whereas CDM was conceived as an instrument to reduce GHG emissions and promote sustainable development in developing countries, the parties involved in this system (mainly private organizations) are interested mostly in the economic outcomes of the projects. The second problem with the CDM projects, which is verified in Brazil, is that the current CDM projects in the country are concentrated in more developed municipalities.

My thesis investigated the second problem. Thus, I decided to examine the distributional impacts of a potential Ethanol-Based CDM project to enhance supply and demand of a cleaner fuel in Brazil. My choice of analyzing this type of CDM project is due to Brazil's successful experience with a countrywide ethanol program.

Therefore, the main objective of this thesis was to evaluate whether or not an Ethanol-Based CDM project would be more equitably distributed when compared to current CDM projects in Brazil, since the former would in principle affect most municipalities in the country. Thus, I analyzed the distributional patterns of both alternatives in the country using Probit Modeling and other statistical indicators. The following table presents a summary of the results.
Table 11: Summary of the Results

| TEST 1 | Current CDM projects are typically concentrated in municipalities with higher levels of development confirming my expectations. An interesting fact, however, relates to the variable Gini (for Income), which came out to be opposite to what was expected. This result shows that the current CDM projects are also concentrated in municipalities with lower income inequality. |
| TEST 2 | Average HDI of Current CDMs (0.785) is higher than average HDI for Ethanol-Based CDM (0.701). This test is not precise because it does not take into consideration the extent to which the CDM project impacts the municipalities. |
| TEST 3 | However, when weighting the HDI for the Ethanol-Based CDM by the number of vehicles impacted, the results become inversed, i.e. weighting average HDI for Ethanol CDM (0.809) is lower than the average HDI for current CDMs (0.811). Contrary to what was expected, these results indicate that on average, an Ethanol-Based CDM would still be as concentrated as current CDM projects in regions with higher human development. |

Considering the current CDM projects, results of tests 1 and 2 confirm what I expected. These projects are in fact concentrated in more developed municipalities regarding socio-economic and human indicators. Also, when including the effects of these current CDM projects, test 3 shows a similar pattern of concentration in municipalities with high human development levels.

Regarding the potential Ethanol-Based CDM project, the results are much more interesting. On one hand, test 2 confirms what one might expect, that Ethanol-Based CDM project is more equitably distributed over the Brazilian territory. However, this result is not precise. It fails to address the effects caused by the project. Test 3 shows that, although reaching most municipalities in the country, the effects of an Ethanol-Based CDM project would be still fairly concentrated, on average, in municipalities with higher level of human development, although not as much as current CDM projects in Brazil.
The results of the tests performed in my research show that even a project such as an ethanol-based CDM would continue facing distributional problems. An ethanol project, in the same way as current CDM projects would affect Brazilian municipalities with higher levels of human development.

Although the results by themselves do not show a better option in terms of distributional effects, it is important to highlight that an Ethanol-Based CDM project would have advantages when compared to the current CDM projects in Brazil. One of the advantages of an Ethanol-Based CDM project is that, as a national project, the magnitude of its impacts would be greater than that of the current CDM projects. Therefore, a larger amount of CO₂ would be reduced, contributing to the reduction of global warming threat. Additionally, as the past experience of Proalcool confirms, an Ethanol-Based CDM project would promote the development of less privileged regions in the country in the same way that happened during the 1970s, when hundreds of thousands of steady jobs were created inside the Brazilian territory. A study of the Brazilian Ministry of Agriculture, Livestock, and Food Supplies (2005) shows that the Brazilian “Cerrado” region in the country would be an area for expanding sugar cane production. It also states that currently there are 90 million hectares of available area to cultivate sugar cane.

Moreover, another advantage of enhancing ethanol production in Brazil, according to the Seminar on Opportunities & Prospects for Use of Ethanol, an India-Brazil Partnership (2002), is that the employment per unit of capital invested in ethanol production is 20 times higher than that of oil production. Also, the enhancement of ethanol use would contribute to the national security while promoting sustainable
development in Brazil by reducing oil dependence and substituting non-renewable petroleum fuels by a cleaner and renewable biomass fuel.

More broadly speaking, considering Latin America and other developing countries, an Ethanol-Based CDM would also be viewed as an example of project to promote sustainable development while reducing CO₂ emissions and contributing to reducing global climate changes. A report of the Japanese Ministry of Economy, Trade, and Industry shows the world fueled by ethanol in 1993 (See Appendix A), and in 2003 (See Appendix B), as well as a projection of the world fuel ethanol in 2013 (See Appendix C). Through this report, we can notice how the use of ethanol is spreading throughout the world. In Latin America, it is predicted that Mexico, Costa Rica, Nicaragua, Guatemala, Honduras, Colombia, Peru, Argentina, and Paraguay are regions that will use/produce ethanol in few years.

In India, for example, there were already 295 distilleries installed in the country by 2002 which had the capacity of producing 3198 million liters of ethanol a year. The production of ethanol in India has being viewed as a great opportunity of improving the economy of the rural sector and a way to humanize life condition of poorer people from rural Indian areas.

Hence, the use cleaner fuels, such as ethanol is becoming increasingly important as observed in various countries in the world. Therefore, it is pertinent to continue evaluating ethanol programs as CDM projects for many reasons. As mentioned before, this type of project would have the potential to reduce larger amounts of CO₂, promote sustainable development, and create more jobs. Another relevant reason for considering an ethanol program as a CDM project is that it increases the chances of developing
countries adopting such projects since these projects would be financed by richer
countries, eliminating the financial constraints. Finally, it is relevant that developing
countries’ governments (since they have the power to approve the projects) attract and
endorse projects that not only protects the environment and benefits economically the
parties involved, but also promotes the development and the well-being of its population,
focusing on the less privileged communities within the country.
APPENDIX A: WORLD FUEL ETHANOL 1993

![Map of World Fuel Ethanol Production 1993](image)

- **Grains**: United States, Mexico
- **Sugar**: Brazil, Thailand, Australia, other countries in Africa and Asia
REFERENCES


Beg, Noreen; Morlot, Jan Corfee; Davidson, Ogunlade; Afrane-Oksesse, Yaw; Tyani, Lwazikazi; Denton, Fatma; Sokona, Youba; Thomas, Jean Philippe; La Rovere, Emilio Lèbre; Parikh, Jyoti K.; Parikh, Kiril; Atiq Rahman, A.. 2002. Linkages between climate change and sustainable development. Climate Policy. 2(2/3): 219-235.


Lasso, Maria Amparo. 2005. A campeã no mercado de carbono? *Terramérica*


