

GRAY SKIES OVER SANTIAGO:

AN ANALYSIS OF AIR POLLUTION MITIGATION POLICIES IN SANTIAGO, CHILE

By

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Approved by:

A handwritten signature in blue ink, appearing to read "Wayne Decker", is written over a horizontal line.

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Gray Skies Over Santiago

An analysis of air
pollution mitigation
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Chile

Andrew Seaton

ABSTRACT

Santiago, Chile, one of South America's premier cities, suffers from terrible bouts of air pollution, especially during the winter months when temperature inversion traps pollution in the Santiago Basin. Main contributors to the pollution are the city's industrial firms as well as emissions from automobiles. In order to mitigate this air pollution, the Chilean government implemented three large scale programs: Transantiago, an overhaul of their public transit system; a tradable emissions program; and the introduction of automotive catalytic converters. These policies were varied in their success, but offer suggestions for implementing new policies to mitigate air pollution in Santiago, Chile.

Keywords: Santiago, Chile; air pollution; policy; Transantiago; tradable emissions

INTRODUCTION

Chile's capital city, Santiago, is a burgeoning metropolis, home to approximately seven million citizens, or nearly 36% of the entire population of Chile (U.S. State Department 2011). The city is the center of industry and finance for Chile, generating about 45% of Chile's GDP. The financial district, known colloquially as *Sanhattan*, is populated with towering office buildings, large shopping malls, and Chile's stock exchange. The cultural center of Chile, Santiago is home to several art museums and many galleries, the National Library, several theaters, a myriad of jazz clubs, as well as the National Stadium (*Estadio Nacional*) where sporting events, including the final of the 1962 World Cup, are held. Santiago is also the educational center of Chile, home of two of Chile's largest and most prominent universities, *Universidad de Chile* and *Universidad Católica*. With the towering Andes as a backdrop, and replete with tree-lined avenues, city parks, an advanced mass transit system and unique and vibrant neighborhoods, Santiago is a wonderful place to live.

However the city currently faces a problem that threatens its inherent livability. Tremendous amounts of air pollution are putting people's health at risk, as well as miring the stunning city in an ugly gray smog. In order to combat this problem, actions must be taken. This thesis aims to depict how the air pollution became so horrendous, what actions have been taken to address the problem, and how these actions can be improved upon and combined with new actions to finally take a stronghold against the gray skies that recurrently blanket Santiago.

SANTIAGO AND CHILE: THEN AND NOW

Chile is one of Latin America's premier nations, being both economically prosperous as well as politically stable, especially when compared to its South American neighbors. It boasts one of Latin America's premier economies, leading all Latin American nations in human development, income per capita, and economic freedom. In May 2010 Chile entered the Organization for Economic Cooperation and Development (OECD), the first and currently only South American country to do so (OECD 2010). Despite its economic success, a large gap exists between the wealthy and the impoverished, and social mobility is extremely limited, both evidenced by Chile's poor performance on its GINI index. The country of Chile has recently been the focus of global newscasts, both because of the February 2010 earthquake that devastated Concepción and affected other areas as well as the rescue efforts to unearth the trapped miners in Copiapo. However, over the last several decades, Chile has quietly built one of the foremost economies in Latin America, and become a beacon for other South American nations.

Chile's capital city, Santiago, is nestled in Chile's vast Central Valley that covers a large portion of Central Chile, between the Andes Mountain Range and Chile's Coastal Mountain Range. The city is completely surrounded by mountains, creating a bowl shaped valley, while the *Mapocho* River divides Santiago. It was founded by Spanish Conquistadors in 1541, and proceeded to become the seat of government for Chile. However, whereas many Latin American capitals still feel the impact of their colonial legacies, Santiago is quite different. Because of the relative isolation from the rest of South America, courtesy of the formidable Andes, frequent earthquakes, and because of a weak colonial economy, Santiago was not

subject to heavy inclusion in the colonial empire. It would be disingenuous to say that colonialism has not affected the city and country whatsoever; although the legislature meets in the nearby city of Valparaíso, the presidential palace, *La Moneda*, is still located in Santiago as are the various State Ministries. Yet, due to the frequent earthquakes which regularly rock the country, many structures not built to withstand the tremors were destroyed, even ensuring that very few architectural remnants of colonialism remain intact.

Historically, Chile has maintained a relatively stable democracy, avoiding the coups and corrupt governments that have become characteristic of many South America nations and other former Iberian colonies. The glaring exception was the 1973 coup that disposed of Chile's first socialist president, Salvador Allende, and replaced him with a military junta that eventually gave rise to the rule of General Augusto Pinochet. Pinochet's rule finally ended in 1990 as Chile began the process of redemocratization, but despite his removal from "presidency", Pinochet still took a somewhat active role in the government and his legacy can still be seen today. Because this era had such far reaching effects on the nation, it is only prudent to give a brief history of this period and said effects.

RECENT POLITICAL HISTORY OF SANTIAGO AND CHILE

A brief history of Santiago and Chile is, I believe, important because it illustrates the incredibly complex and sometimes seemingly contradictory nature of the country. They are politically diverse, electing both left-wing and right-wing candidates regularly. They condemn the human rights violations conducted under the Pinochet regime, but maintain the neoliberal economic policies he put into place. The country is decidedly unique amongst its Iberian colonial counterparts, as its relative geographic isolation and weak colonial economic potential

resulted in a very weak colonial legacy. It is hard to fit Chile into a neat category, and correspondingly any and all policies intended to curb the effects of air pollution should be created and implemented with this in mind. What is particularly important, I believe, is that this opens the doors for many different policies to be implemented. It is important to note, however, that the sometimes ambiguous nature that pervades Chilean governance can create obstacles to effective government policies.

Chile's recent political history begins with Salvador Allende. Allende was a political journeyman, holding posts as a senator, deputy, and cabinet minister. He was a perennial presidential candidate, running in 1952, 1958, and 1964 as a member of the Socialist Party. These campaigns were all unsuccessful, until, in the 1970 election, he won a plurality of the vote in a three way race with 36.2% of the entire vote. It should be noted that this does not necessarily imply that Allende's presidency, and Chile's subsequent transition towards Marxism, was illegitimate; Radomiro Tomic, who ran on a platform similar Allende's, won 27.8% of the vote as well, giving left-wing candidates 64% of the vote, a majority. Despite pressure and clandestine interference on the part of the United States, Chile had become the first country in the Western Hemisphere to elect a socialist president. (Rector 2003)

Allende represented a moderate path towards socialism, seeking to enact policies that were lawful and democratic to preserve legitimacy, while some in the leftist parties favored a quicker and more intense transition towards Marxism. Initially, the Chilean economy strengthened under his policies, but this was not to last. The Chilean currency suffered rapid inflation, Real GDP contracted, and the government's fiscal deficit expanded. Despite Allende's policy of raising wages, increases in prices for food and an increasing imbalance in trade left the

Chilean consumer worse off. This was no doubt worsened by continued U.S. actions to, in the words of then President Richard Nixon, "...make the [Chilean] economy scream." (Kornbluh n.d.)

This began to frenzy the middle and upper classes of the country, leading them to strike and protest, seeking the removal of Allende from office. These protests were met by counter protests organized by the lower classes. One famous protest organized by the wealthy classes was "The March of the Empty Pots and Pans" where women protested by marching through the streets, banging empty pots and pans to symbolize the disappearance of consumer goods; this march intentionally coincided with a visit from Cuban president Fidel Castro who wished to observe and form a coalition with the newly Socialist nation. While this protest was successful, reports surfaced that many of the protesters were actually maids and nannies whom the upper-class women made to march in their stead while they simply drove their cars behind them.

The frustrations of the upper-class hardly went unnoticed, and some within society began to discuss the possibility of removing Allende. The Chilean Army, now headed by newly elected General Augusto Pinochet, had managed to convince other branches of the military that action needed to be taken. The Chilean Air Force led the attack on the Presidential Palace on September 11, 1973, and in several hours Allende had been deposed and control of the government was turned over to a military junta, of which Pinochet was eventually named the head.

What followed was a violent attack on the political left, followed by a violent repression of any political opposition. After the military junta had adequately taken control of the country, Pinochet was able to consolidate power and was appointed leader of the Junta and then,

finally, President of Chile. As President, Pinochet enacted many neoliberal economic reforms, proposed by a group of Chilean economists, named “Los Chicago Boys”, who studied under renowned economist Milton Friedman at the University of Chicago. These neoliberal economic policies became the cornerstone of Pinochet’s regime, and completely transformed Chile. Whereas before Chile was relatively isolated in the global marketplace, the neoliberal policies invited foreign investment and global market integration, and eschewed excessive government intervention. The new policies had a great impact on the Chilean economy, resulting in perennial growth in GDP dubbed the “Chilean Miracle” by Friedman.

Pinochet was eventually forced out of office, following the plebiscite of 1988, where 55% of the country voted to end his Presidency and return the government to civilian control. The first election after Pinochet left office was won by Patricio Aylwin, a member of the center-left coalition *Concertación*. The next 3 Chilean presidents were also members of the center-left coalition, including the last *Concertación* president, Michelle Bachelet, a socialist. However, in 2010, 20 years after Pinochet resigned, a right-wing candidate, Sebastian Piñera, won the presidency.

Because of ratifications to the Chilean Constitution in 1980, Pinochet would remain a senator-for-life, ensuring he would still have a relatively active role in the government while at the same time granting him immunity from prosecution. However, even after he resigned from his senatorial seat in 2002 and was subsequently charged with human rights abuses both in Chile and abroad, the neoliberal economic policies he established are still practiced and popular with many Chileans. Although this is an anecdotal and in no way a scientific exclamation, I can attest that everyone with whom I spoke while traveling in Chile looked favorably upon these

economic policies, though all denounced the human rights abuses perpetrated by Pinochet.

Often they implored me to separate Pinochet's economic policies from the man himself and the crimes he committed.

WHY ACTION MUST BE TAKEN

During my travels in Santiago, Chile I experienced the pollution and its effects firsthand.



This photograph was taken by the author from atop the Cerro San Cristobal in Santiago. This photo shows the smog trapped by a temperature inversion as it hovers over the valley.

It was visible in the air, even at street level, and it was nearly impossible not to feel its effects if you spent any amount of time outside. I found myself coughing more than usual, and when one blows their nose, what comes out is literally black. If one climbed high enough, one could see

more clearly how the smog blankets the city. I was able to take several photographs from atop the Cerro San Cristobal, and have included them herewith.

Although the aforementioned evidence is merely anecdotal, there have been a number of scientific studies and papers written concerning this subject. These studies describe not only how the air becomes so polluted, but how this pollution creates many adverse health effects for the citizenry of Santiago, also known as Santiaguinos. Numerous medical studies have found



This photograph, taken from the same location as the photograph above, shows the intensity of the air pollution that plagues Santiago, especially during the winter months.

that constant exposure to urban air pollution carries a relationship with increased respiratory and cardiac problems, resulting at times in hospitalization and death. A study conducted specifically in Santiago found that increasing levels of air pollution increased the rate and intensity of headaches by studying patients requiring hospitalization for headaches. (Dales,

Cakmak and Vidal, Air Pollution and Hospitalization for Headache in Chile 2009) Another study centered in Santiago found that increased air pollution also shares a relationship with venous thrombosis, where blood coagulates and clots in veins, which can separate and travel to the lungs, creating a pulmonary embolism which can block blood supply to the lungs. (Dales, Cakmak and Vidal, Air pollution and hospitalization for venous thromboembolic disease in Chile 2010) Finally, as might be expected, studies have found that chronic exposure to air pollution has exponentially dire effects on two subgroups of the population: the very young and very old. A medical study conducted in Santiago found that elderly residents were much more likely to die from exposure to air pollution than younger residents. (Dales, Cakmak and Vidal, Air pollution and hospitalization for venous thromboembolic disease in Chile 2010)

Santiago's unique attributes and geographic location are integral to the problem. As mentioned above, Santiago is home to around seven million people, the largest concentration of people in Chile, and is also Chile's industrial center. While this undoubtedly has allowed Chile's economy to boom, industry and the daily necessities of life in Santiago contribute heavily to the air pollution; just how much these contribute to the pollution will be further addressed. Furthermore, because the concentration of residents within the city is so high, the pollution affects not only a large number of people in absolute terms, but a large portion of Chileans in relative terms.

The basin in which Santiago sits creates a bowl shape. During the fall and winter months, frequent temperature inversions trap the pollution nearer to the ground; the shape of the basin prohibits the air and its contaminants to disperse outward. Santiago is also located relatively inland, unlike other major cities such as Viña del Mar and Valparaiso, which are

coastal cities located side by side about an hour north of Santiago. While these two cities support large populations and a large vehicle owning populace like Santiago, unlike Santiago these cities are not located in a basin, which allows for pollutants to disperse outward.

Santiago's air pollution is a serious problem that deserves attention. It poses many health risks, especially for residents who are either very young or very old. These health problems translate into greater costs that burden the healthcare system, which because it is public and provides universal care, ultimately becomes a burden for taxpayers. The extensive health risks aside, the air pollution makes an otherwise beautiful and vibrant city far less inhabitable. There are many economic, aesthetic, and moral grounds for addressing increased levels of air pollution, and it is therefore imperative that actions must be taken to mitigate this problem. Any strategy offered to resolve this problem should address as many of these grounds as possible in order to sway many sectors of Chilean society to support a movement to reduce pollution.

There are two main contributors to the pollution: industry and transit. Industrial complexes in and around Santiago are constantly emitting pollutants into the air. Daily vehicle traffic, whether it be the passenger vehicles owned by residents or the diesel-operated busses that are incorporated in Santiago's mass transit system, also make a large contribution to the pollution as well. Therefore any strategies to lessen emissions will inevitably focus on these two contributing factors.

BRIEF OVERVIEW OF POLLUTION MITIGATING POLICIES

Three large-scale attempts at mitigating air pollution were implemented in Santiago to address these two factors. A tradable emissions permit program was created and implemented in 1992, requiring mandatory compliance by 1994. In this free-market approach the total amount of pollution allowed is capped, and subsequently companies are awarded permits which allow them to pollute a certain amount annually. This incentivizes to lower their emissions in order to sell their permits to companies who cannot, thereby sparking private research and development to address the problem.

Another policy entices residents with vehicles to equip their vehicles with emission reducing catalytic converters; in an attempt to punish individuals who decline to do so are restricted in their driving privileges, not permitted to operate their vehicles every day of the week, enforced based on the last digit of one's license plate. This policy, which is a command and control policy, stands dialectically juxtaposed to the free-market policy mentioned previously in many ways, but as was mentioned before, the Chilean people are extremely complex and there is no reason either of these policies, if implemented correctly, cannot reduce air pollution in Santiago.

A third program which, although it was not designed solely to reduce air pollution but was very large and hoped to achieve this goal to some degree, was Transantiago. Transantiago is the current public transit system that operates in Santiago, and consists of bus and subway services. It is widely used by many Santiaguinos each day and represents a large public project undertaken by the Chilean government. This project had a tremendous impact on the city and had the potential of enticing a wider usage of public transit.

In order to explore mitigation techniques, these three programs will be investigated further. The efficacy of the three programs will be evaluated and where these programs fail, suggestions will be made to improve them. Further analysis will be lent as to the specifics of these programs, such as why they were unsuccessful or whether or not command-and-control policies are more effective than free market approaches.

POLLUTION FROM TRANSIT AND THE IMPLICATIONS OF TRANSANTIAGO AND

CATALYTIC CONVERTERS

Santiago is a large city in terms of population, but it is also relatively sprawled out. When viewing a map of the city, one can assume that, based on its relative shape, Santiago developed outward in a radial fashion. The city is more or less bounded by an expressway (which, confusingly is actually comprised of several expressways but can be driven in a continuous manner) that loops around the city. It is more or less a circle, and the diameter of the loop this expressway creates is around ten miles wide; for reference, the island of Manhattan with a population of around 1.5 million people is around 2 miles wide and 10 miles long, and is shaped more or less like a rectangle. However, the expressway does not completely surround the city, with sizeable residential areas surrounding even the expressway. It resembles water that had overflowed from an above ground pool.

Something else that is important to note is that residents often have a very strong connection to their own neighborhoods. Many of the people with which I spoke told me about the strong communities in these neighborhoods, including that their families lived nearby. This is inherently linked with the typical life cycle of an average Chilean. Chilean youths do not typically leave home when they attend a university or after they turn 18, and would most likely

not leave their house until they were married which may not happen until they are in their late 20s or early 30s, at which point they would most likely seek a space near their families, presumably in the same or a nearby *comuna*, which is essentially what we might call a neighborhood in the U.S. There are 52 *comunas* in Santiago, most of which have a governing board and mayor. Whether because individuals really do have strong ties to their *comuna* or whether, because social mobility is limited in Chile and therefore citizens tend not to move to other areas in Santiago because of an inability to afford it, I am unsure. However, what is clear is that residents are not likely to relocate frequently, something that is much more common in other places of the world, like the United States.



This photograph shows taxis, a bus, pedestrian foot traffic, personal passenger vehicles, as well as the air pollution that can be seen at ground level.

This being said, individuals may find employment in different areas of the city, and may change occupations relatively frequently. This is significant because it means that many in the city, at any given time in their life cycle, a resident might be traveling rather far from their home to their workplace, and that this individual will be unlikely to relocate to a *comuna* nearby their workplace. This creates a somewhat chaotic commute for many in the city,

reflected in the frenzied peak hours of transportation in the morning and evening. There are a myriad of transportation options offered, and are described below.

Pedestrian:

At all levels of transportation, there will inevitably be a pedestrian aspect involved. When utilizing mass transit systems, one must generally walk to a certain location to board a subway or bus. Even using personal vehicles usually entails some amount of walking as parking is limited in many areas, forcing one to park at a distance from their final location. However solely pedestrian modes of transportation, including bicycling, are somewhat common. For example, it is not uncommon for school-aged children to live nearby their schools, and therefore to walk to and from school each morning; younger children are often accompanied by their mothers. However, it is also not uncommon for school-aged children to utilize other modes of transportation. Bicycling is also an option, as long as your home-work commute is relatively short. However, bicycling is not necessarily promoted, and after general observation, one sees that there is not an extensive network of bike paths laid out in the city, making it somewhat dangerous for cyclists. Nevertheless, there are some who bicycle as a means of transportation.

Taxis and Colectivos:

Taxis are common in Santiago, and relatively inexpensive, especially for short distances. These taxis generally have a base price of around 40¢ USD, charging 20¢ for every 200 meters, or around 2\$ per mile. They are ubiquitous and one can obtain a ride in most parts of the city relatively easily. While there are unofficial taxis in Santiago, relatively unsafe and unwise to use,

official taxis, colored black and yellow and labeled with an official sticker, are easily spotted and are safe.

Colectivos are a sort of hybrid between a taxi and a bus. Colectivos are usually sedan-like vehicles, like taxis, and can carry several people at a time. However, unlike taxis which are ubiquitous and are able to travel wherever in the city one wishes to visit, colectivos travel fixed routes. Many times they are located near subway stations, and these colectivos will not depart until they are full, and the fares are based on how far one travels. They are more expensive than busses, but cheaper than taxis since each individual shares in the fare. For a fee, they will deviate from their fixed route, although only if it is not far. They are most prevalent at night, when busses run less frequently. Essentially, traveling by colectivo is a form of carpooling, except that one does not assist in the driving and the passengers may or may not know each other.

Transantiago:

Transantiago is the public transit system that currently services Santiago. The system was established in early 2007 under Michelle Bachelet's administration. It was an attempt at reforming the transit system that was in place prior. It incorporates bus and subway services, allowing both to act in concert with each other. Passengers pay fares using a contactless smart card using an electronic system. Both bus and metro fares are highest during peak usage hours, with a regular fare and low fare for corresponding usage times. Discounts are offered when transferring from busses to metros or vice versa, something that is only possible because of the smart card, called *Tarjeta Bip!*, named for the sound produced when the card is used at bus or metro stations.

Transantiago specifically targeted bus service, taking great lengths to standardize the system. Before the transformation, busses were independently owned and operated. This created many redundancies and posed a danger as competing bus drivers raced towards bus stops to collect fares. Because these busses are no longer privately owned, operators are no longer given incentives to race towards bus stops to collect passengers. Also, redundant routes were eliminated and therefore fewer busses were required. In some ways Transantiago can be seen as an attempt to reduce air pollution levels. Newer busses on the roads meant that they would be both more fuel efficient and less polluting, and fewer busses on the roads would undoubtedly reduce air pollution related to public transit within the city. Many hoped that implementing Transantiago would encourage an overall increase in the use of public transport by increasing the quality of service, including newer busses, shorter travel times, and safer streets.

Despite the anticipated arrival of the new system, many people were initially disappointed in Transantiago. Many claimed that the new bus routes were complex and confusing. Also, because Transantiago was designed with eliminating redundancies, concentrating on overlapping bus routes and thereby taking many busses off the road, many users complained that there were not enough busses to accommodate riders. These frustrations were further exacerbated because Transantiago was implemented overnight; on February 9, 2007, residents of Santiago travelled home on a public transit system they had known for years and awoke the next morning forced to use a widely different system. A lack of education on the new system left many perplexed and frustrated, and the consequences were felt by the Bachelet administrations whose popularity dove drastically from 55.2% to 42.7%, a

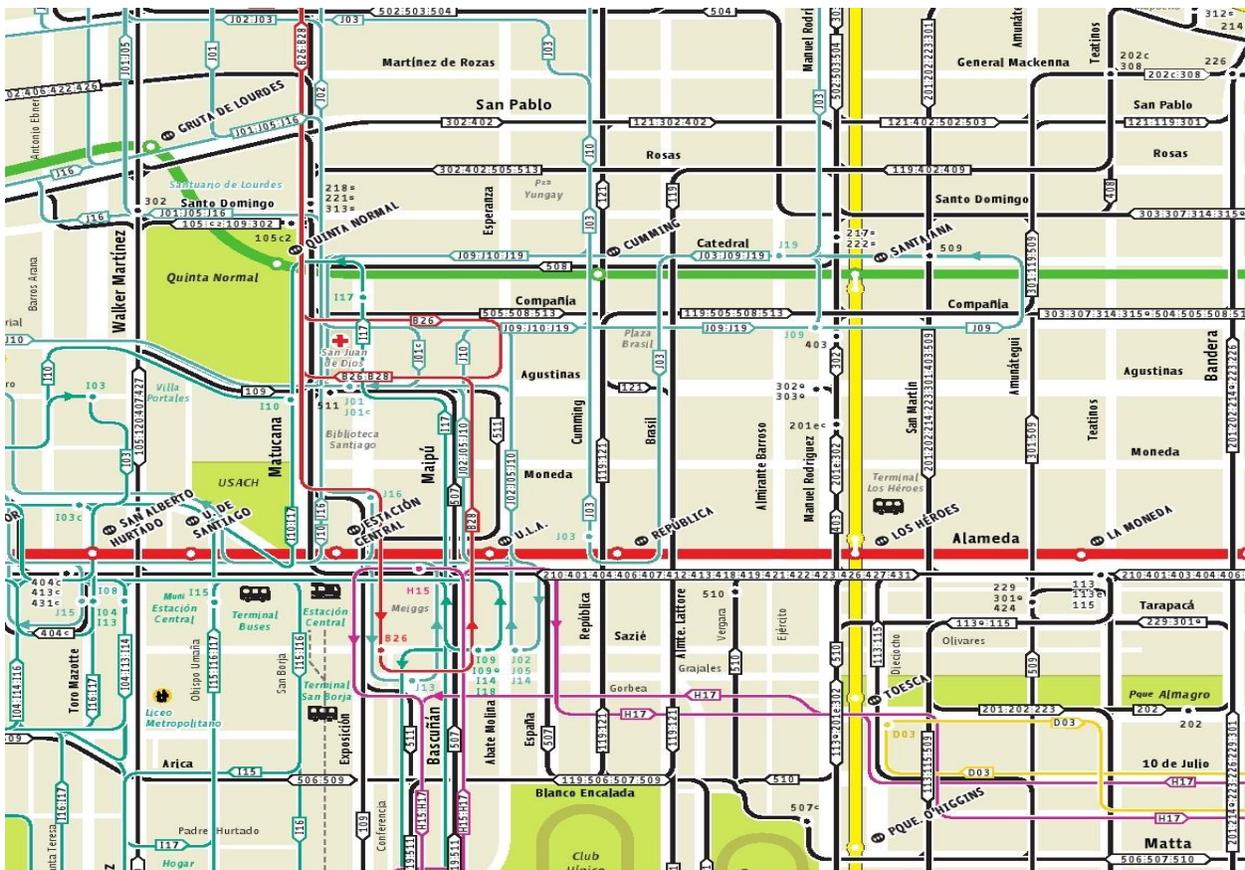
12.5% decrease. Even former president Ricardo Lagos, whose government oversaw Transantiago's design, was not immune from criticism. As a result, the sales of individual passenger vehicles rose dramatically, and those frustrated with bus travel became more dependent on the subway, overcrowding it and further reducing the efficacy of Transantiago. Although over time Transantiago has improved and users have returned, it did cause an increase in the number of passenger vehicles on the road and perhaps then the intensity of air pollution in Santiago. Below is a description of Transantiago's key sectors: bus service and subway service.

Bus Service: The bus service provided by Transantiago, colloquially known as *micros* is a unique and somewhat complex mix of routes. The simplified explanation offered here does not adequately explain the complexity of the system nor does it fully capture how frustrating it would have been to be presented with this system literally overnight with little in the way of education as to how it functions. For this reason an attached map of the bus and subway systems is presented herewith.

Essentially there are two types of bus services offered: *troncales* and *locales*. *Troncales* are designed for longer trips between different regions of the city. *Locales* however are designed for shorter trips, and are separated into ten regions within the city, comprised of several *comunas* per region. These less extensive routes feed the longer routes with passengers looking to cross entire sections of the city. I can offer anecdotal evidence to the complexity of this when, upon asking the woman with whom I was staying in Santiago how to take a bus from her house to the local elementary school where I was teaching, she replied by taking out a somewhat large folding map and navigating through the many routes until we found the right

one; it was only later that I realized that this was a map for one of the *locales* systems, meaning that there were nine other oversized maps similar to this one.

This system strongly reflects the deep ties that most feel towards their neighborhoods; an entire subsystem of the bus service is dedicated solely to moving residents to locations within their neighborhoods. However, this system also reflects the needs of many to daily commute from one end of the city to another. In many cities, such as cities in the United States, this system would be cumbersome and wholly inefficient; in Santiago it is a necessity. This is



This is a small section of Transantiago's map. Notice the complex bus routes, which are the small black, purple, yellow, and aqua lines that inhabit the map. The bold colored lines represent subway lines, and a quick glance at the subway map provided below will show the approximate relative size and location of this part of the map.

important to note because it highlights the inherent differences between cultures and societies and shows how outside analysis can at times be biased. While I do not dispute that it is possible

that my analysis is colored by my perspective as an outsider to this society, it is my intention to, as best as possible, present analysis that takes into account the socio-cultural intricacies that must be accounted for when performing this sort of analysis.

Subway Service:

The subway in Santiago, known colloquially as the *metro* is far and away the cornerstone of Santiago's public transit system, both before Transantiago and now. It was implemented under the Pinochet regime in 1975 (although plans for construction began in 1968 before Pinochet gained power), and initially only served Santiago's center. The second line was opened three years later, and currently it consists of 5 lines with a 6th line to be built in the near future. The metro services large portions of the city, and is extremely easy to navigate as it is based more or less on a grid system. Most lines run either north-south or east-west for the most part, although some lines deviate slightly from this pattern, especially line 5 which has a unique pattern. As the metro is run by Transantiago, it also requires users to use the *Bip!* smart card that is used on the busses. In order to facilitate a wider array of transit, most metro stations are connected in some way to another mode of transportation. For example there are usually if not always micro stations at or near each metro station. At several stations the metro station is connected to a terminal of long-ranges busses, such as busses that travel to the coastal cities of Viña del Mar and Valparaiso or cities further away. Because of this, the fare system is integrated using the *Bip!* card when transferring between metro and bus and vice versa, the rider receiving a discounted fare. The fare system consists of three fares, depending on the typical usage at the time: peak hours cost more than normal hours, and there are even

passengers line it in its entirety attempting to position themselves so that they will have the best shot at aligning themselves where the doors will appear.

When the train arrives and the doors open, passengers must try and fight their way onto the already crowded trains, almost spilling over with passengers already. There are times when the doors cannot properly close because passengers are not completely inside. This makes it especially difficult for the elderly and small children or people travelling with small children. In such cramped quarters, the metro has also become a den for pickpockets, who have an easier time slipping their hands into pockets or purses when the passengers are so cramped. Any trips taken during peak times are therefore extremely uncomfortable.

Passenger Vehicles:

When in Santiago, one will find that personal passenger vehicles (meaning vehicles for personal use, not taxis, colectivos, or busses) are ubiquitous throughout the city streets; nearly half of all Chilean vehicles operate in Santiago and passenger vehicles make up 83% of all vehicles in Santiago. It would be misleading to say that nearly everyone owned a vehicle; in fact the per capita vehicle ownership in Santiago specifically is 16% compared to 84% in all of the U.S. (Bauner and Laestadius 2003) However, one could argue that much of the U.S. was built to sustain a vehicle owning populace, whereas Santiago was not necessarily built to support an excessive amount of cars; this leaves the city streets congested and average Santiaguinos frustrated with the increased time it takes to travel to work.

Ultimately, air quality suffers as well, as traffic congestion keeps polluting vehicles on the roads for greater amounts of time. As was noted above, one of the main objectives of Transantiago was to increase usage of public transit and thereby lessen the stress traffic

congestion puts on the city's streets by essentially taking more passenger vehicles off the road. This would aid in improving air quality. However Transantiago, because it was designed so inefficiently and implemented so suddenly, actually enticed many to purchase passenger vehicles, causing a sudden spike in the amount of passenger vehicles on the road and therefore caused a decline in air quality. However, strides have been made in decreasing the amount air pollution produced by passenger vehicles. Two programs put into place by the government helped set the scene for Chile to join many other nations in requiring the use of automotive catalytic converters.

Automotive catalytic converters, also known as 3-way catalytic converters or simply catalytic converters, are devices designed to decrease the air pollution emitted from vehicles. Many may not be familiar with what a converter is or does, but if you've driven a car in the U.S. after 1983, you no doubt have used one. From a global context, the use of this technology can be traced back to the U.S. in the late 1960s. This was a time in the U.S. where many called for lower emission of pollution from automobiles, as did many other nations from around the world including other notable vehicle producing nations Japan and Germany. Because the U.S., Japan, and Germany were and still are the leading nations in automobile production, the actions they undertook to reduce vehicle emissions were critical in introducing this technology elsewhere around the world.

As for the U.S., the implementation and wide use of catalytic converters did not occur overnight. While the call for reduced emissions began in the 1960s, the U.S. did not require that new vehicles be equipped with catalytic converters until 1983, although it should be noted that California did require their use beginning in 1977, 6 years earlier. Japan followed and required

the use of the converter in 1978, although once again it should be noted that they did not impose this requirement on imported U.S. vehicles for fear that it might hurt trade between the two countries. Sweden required their use in 1989, although there had been vehicles that had been equipped with catalytic converters on the market since 1986.

Catalytic converters work to reduce carbon monoxide (CO), nitrous oxides (NO_x), and other hydrocarbons and volatile organic compounds (VOCs), all of which are major components of air pollution and are dangerous and unhealthy. 3-way catalytic converters are designed to address all three of these problems and are installed in every U.S. vehicle manufactured after 1983. For this reason they have become commonplace around the world and are largely non-existent in the conscious minds of most individuals who use them every day.

There are two main catalytic processes that occur: reduction and oxidation. The reduction catalytic process uses platinum and rhodium to reduce the nitrous oxide emissions. When nitrous oxides come into contact with these catalysts, the nitrogen atoms become stuck to the catalyst, leaving only oxygen (O₂) remaining to be emitted by the vehicle. The oxidation catalytic process works slightly differently, adding oxygen to CO and other hydrocarbons by burning them over platinum and palladium catalysts. This turns CO into CO₂, which although harmless in terms of immediate human health, has been proven to be a greenhouse gas and is integral in the process of global warming and global climate change. It also helps convert hydrocarbons into water (H₂O). Catalytic converters are relatively simple devices, relatively easy to integrate into vehicles, but are not without their limitations. For example, one problem is that it only works at a high temperature, a temperature not achieved immediately after starting a vehicle. There are solutions to this problem, but many are fraught with consequences that

render them difficult to implement. It should also be noted that, for catalytic converters to function, unleaded gasoline must be used.

To discuss how the catalytic converter was introduced in Santiago and Chile as a whole, it is necessary to discuss events that led up to and were integral in its introduction. I think it is important to note that Santiago, and Chile in general, is not a country known for fervent environmentalism; significant concern for the environment has only begun recently. For example, while the U.S. and many other nations around the globe developed an environmental conscience in the 1960s that became coalesced into a serious movement in the 1970s, Chile created a Ministry of the Environment in 2008, a ministry that has only recently (as of 2010) become fully operational. However Santiago has been concerned about the excessive amount of air pollution for decades.

While the newly founded Ministry of the Environment has only just become a powerful actor against Santiago's air pollution, Chile formerly used other ministries, such as Health or Energy to create and enact policies. There have been several decrees established by the Chilean government throughout the years to address air pollution. In 1961, Decree 144 outlined that any and all pollutants (including water pollutants) should be captured and eliminated. Within this decree it states that vehicles emitting visible smoke from the exhaust should be restricted from circulating in Santiago. While this decree was almost wholly ineffective because it lacked any sort of enforcement mechanism, it set up the basis for following decrees.

In the 1970s, the government began to establish norms for the amount of acceptable pollution allowed, although, like Decree 144, an absent enforcement mechanism left it without any teeth. However, in 1988, a huge step forward was taken as the government was able to

develop air quality indexes for gaseous fumes and particulate matter. These indexes became important in creating an enforcement mechanism that created effectual policies on mitigating air pollution. These indexes opened the doors for Decree 211, established in 1991, that oversaw the integration of 3-way automotive catalytic converters on Chilean vehicles.

Before Decree 211 is dissected and analyzed, it is important to discuss a policy enacted under the Pinochet administration in 1986 that became an indirect but extremely integral part of Decree 211. Under this policy, 20% of Santiago's vehicles were prohibited from being driven in all of Santiago. Once air quality indexes were developed, they were used to prohibit 20% of vehicles from driving in the downtown area during days that were deemed "critical" in addition to the 20% of vehicles that were prohibited from being operated that day. On "emergency" days, 40% of all vehicles were prohibited from being driven in all of Santiago. What is important about this policy was that, unlike previous policies that lacked a sufficient enforcement mechanism, this policy was enforced effectively. Vehicles were prohibited based on the last digit of their license plate. This was inconvenient for many people, and it actually enticed many wealthy residents to purchase a second vehicle with a different license plate number so that they would not be inconvenienced by this policy. It is important to note that most vehicle-owning individuals were wealthy and could afford to purchase a second vehicle, but that this still precluded middle-class individuals from escaping the inconvenience.

Decree 211 required that all new vehicles sold in Santiago and the other large coastal cities Viña del Mar and Valparaiso in 1992 and beyond must be fitted with a catalytic converter; furthermore under this decree all vehicles sold in the entire country would need to be fitted with catalytic converters in 1994 and beyond. Vehicles that were in good operating order could

also be equipped with catalytic converters. This policy only regulated new vehicles being sold, but not used vehicles. In order to lessen the stress on the enforcement mechanism and create an incentive for more operators to drive vehicles equipped with catalytic converters, Decree 211 exempted vehicles equipped with catalytic converters, identified by placing an official sticker in the windshield of the vehicle, from having to follow the abovementioned policy which restricted vehicle circulation. This program has been rather successful, due in large part to this incentive.

The push to create vehicles that polluted less by way of catalytic converter was aided by several factors. One reason this push was so successful is that it was implemented long after the technology had been adequately developed. Whereas nations like the U.S. and Japan led the way in developing these technologies, spending countless amounts of money in research and development in order to move the catalytic converter further down the learning curve, Chile benefitted by utilizing a technology that had been thoroughly vetted and improved upon. Furthermore, because these nations are home to large vehicle production companies, like Ford and GM in the U.S. and Toyota and Honda in Japan, they had created platforms for vehicles that would be equipped with the catalytic converters; it was actually more difficult for many of these companies to produce cars for Latin American nations where catalytic converters were not the norm, forcing them to backwards produce vehicles to be sold there. Once Decree 211 was introduced, these corporations were easily able to provide vehicles that fit the legislation. Lastly, there are no Chilean vehicle producing corporations, which ultimately meant that an automotive lobby, like the one that exists in the U.S., was virtually non-existent. Whereas the U.S. automotive lobby stood in the way of the development of catalytic converter, believing it

would cause undue hardship on car manufacturers, a Chilean counterpart did not exist, which left the path towards innovation relatively obstacle free.

POLLUTION FROM INDUSTRY AND THE IMPLICATIONS OF THE TRADABLE

EMISSIONS PERMIT PROGRAM

Because Santiago is the industrial center of Chile, Santiago's industrial sector is rather large. The air quality indexes that had been established in 1989 to quantitatively measure air pollution had worked effectively, and seemingly became the impetus for enacting policies to limit emissions. Vehicle related emissions, while constituting the majority of emissions, were not the only concern. Industrial emissions had become a very serious problem and many called for policies that would reduce emissions in the industrial sector. Decree 211, discussed above, became law in 1991, and a year later Decree 4, which aimed to limit emissions from Santiago's industrial sector, became law.

Decree 4 established a tradable permit system, colloquially known in the U.S. as "cap and trade" and which was extremely effective in the U.S. in reducing sulfur in the atmosphere that had caused acid rain. For Santiago, this permit system was specifically designed to limit the amount of total suspended particulates (TSP) emitted from large stationary sources, such as industrial boilers and ovens, as well as large residential and commercial heaters. While it was signed into law in 1992, it was not made mandatory until 1994. Programs like this are designed as free-market approaches to environmental problems. This type of approach is seen as, at least ideologically, dialectically opposed to command-and-control approaches.

Command and control approaches are undertaken by the government; they designate a specific procedure that must be followed; if this procedure is not followed, an enforcement

mechanism will force compliance. Decree 211 could be seen as a command-and-control approach because it outlined that all new vehicles sold in Chile must be fitted with a catalytic converter, although the strong enforcement mechanism was slightly augmented with an incentive approach; instead of imposing sharp fines on anyone that drove a vehicle without a catalytic converter, it lifted the 1986 vehicle circulation restriction on anyone driving a vehicle with a converter. For this reason it may not be classified as a pure command-and-control approach, but it lends itself as a great example as to how it is created and implemented and, at least in terms of vehicle importers, it acts as a strong command-and-control approach.

The tradable permit system established under Decree 4 has followed an interesting trajectory. Firstly, although the air quality indexes that were integral in developing policies to address excessive air pollution, they were only able to measure air quality for the whole city. Necessary infrastructure to measure regular emissions from each firm was not available. Therefore, instead of measuring the amount of pollution that each firm regularly emitted, they relied on proxy data by calculating the maximum amount that each firm could possibly emit, henceforth called emissions capacity. Insufficient measurement techniques would also cause further problems with this program.

Before I can address how insufficient measurement techniques created problems for Santiago's tradable permit system, it is necessary to describe how permits were allocated to each firm. Firms that were existent before the law was created were classified as existing firms, while firms that came into existence after the law was created were classified as new firms. There have been two procedures for allocating permits to firms: grandfathering and auctioning. When permits are auctioned, firms compete to purchase enough permits to cover their

emissions; if they find a way to reduce their emissions, they can then sell these permits to other firms that will exceed the amount of pollutions their permits allow them to emit.

Grandfathering is different in that, instead of allowing firms to purchase permits from the government, the government allocates permits to firms based on the amount their current emissions. New firms are not allocated any permits and must purchase them from existing firms. Santiago chose to use the grandfathering procedure.

If it would be too difficult to measure the emissions of each firm individually when the law went into effect, it stands to reason that the Chilean government had poor or absent historical records of emissions for each firm. Because of this, each firm was asked to provide their emission capacities to the Chilean government. This proved to be a process that greatly diminished the efficacy of the program. While the grandfathering procedure was seen as an incentive for firms to report their emissions levels, it enticed many firms to over-report their emission capacities in order to gain more emissions permits; this was further exacerbated by errors by the government in recording the capacities, where numbers were often incorrectly entered. Also, this meant that the “cap” aspect of “cap and trade” was not an explicit cap on total emissions but a cap on the potential emissions that a firm might emit. Also, unlike most programs which lower the cap at specified times, there does not seem to be a provision in Decree 4 that calls for this, but simply requires that emissions be capped at 1992 levels. One bright spot in this program was its ties to Decree 32, created in 1990. Decree 32 established a list of the largest polluters from the industrial sector. During days which were deemed “critical” or “emergency”, the polluters that comprised this list were forced to shut down operation for

the day. This was extremely frustrating for many firms and created an incentive to lower their emissions in order to halt the frequent interruptions to their productions.

Nonetheless, the program, despite its inherent limitations and shortcomings, became mandatory in 1994. One of the first problems the program encountered, much like many previous approaches, was that it lacked a strong enforcement mechanism. Enforcement was initially very weak, although it has gradually become stronger. The environmental objectives laid out in Decree 4 were not finally achieved until 1997, meaning that many firms were in noncompliance with Decree 4 for the first 3 years. However, it was not Decree 4 that was integral in the reduction of emissions levels, but another outside force. Soon after Decree 4 was made mandatory, Chile's eastern neighbor Argentina began exporting natural gas to Santiago.

Chilean industries benefitted greatly, as natural gas was both cheaper and "cleaner" than the coal and oil that Chilean industries had been forced to rely on prior. These firms began utilizing natural gas because it was economically expedient, and that this dramatically reduced their emissions was a fringe benefit. The tradable permits program established under Decree 4 became a non-issue and practically disappeared from public consciousness. Firms began to rely heavily on natural gas instead of creating innovative ideas for reducing emissions. Furthermore, because Decree 4 did not establish that the cap on emissions should be periodically lowered, there was no incentive to invest in research and development to further lower emissions in order to come into compliance with tighter regulation. Firms enjoyed a windfall that they had not anticipated would end. Unfortunately, the importation of natural gas from Argentina turned out to be a curse disguised as a blessing. Suddenly in 2004 Argentina was forced to halt exportation of natural gas in order to meet domestic demands. This left industrial firms in

Santiago reeling from the now increased cost of production due to increased energy costs.

Furthermore, because firms had not innovated to reduce their emissions, noncompliance with the regulation outlined in Decree 4 occurred almost immediately after the flow of cheap natural gas had stopped.

POLICY ANALYSIS

Before an analysis of the three abovementioned programs begins, it is important to discuss systemic issues that have contributed to government policies that have often times been mediocre in bringing about progress. It is important to note that one reason strong policies on mitigating air pollution have been relatively few is due to lack of a cohesive government authority on the environment, that is until recently. For example, environmental policies and programs were often times run through the Ministry of Health, a ministry that could not focus a significant amount of time or energy on air pollution policies and could not establish strong enforcement mechanisms or incentives. This fragmentation of governmental responsibility concerning air pollution and the environment at large meant that policies and programs that were created were at times incomplete. However, there is hope that the newly developed Ministry of the Environment can create solutions to these problems.

Furthermore, Chile's political history has had a profound effect on its ability to enact effective policies. The prolonged Pinochet regime, which was characterized by violent suppression of political dissidents, also brought economic prosperity to Chile. After the regime was voted out of power by the country's citizens, they were faced with the difficult task of how to move forward after 17 years of dictatorship. Many Chileans are content to denounce the violent actions taken under the Pinochet regime but value and continue to practice the

neoliberal economic reforms that were installed under his administration. The post-Pinochet years were dominated by left-leaning politicians who stood in opposition to Pinochet; I believe some of their success can be attributed to a backlash against the right which had supported the dictator. However, while left-wing politicians dominated but were relegated to maintaining more conservative economic policies and governmental policies, the Chilean political identity was still somewhat ambiguous. This ambiguity can allow for a wide range of policies to be created; it also forces these policies to adhere to sometimes contradictory schools of thought on enacting effective policies. However, as Chilean society becomes further and further removed from the Pinochet regime, it becomes easier for them to have discussions that are not tainted by their collective memories of Pinochet. Evidence of this process is the election of Sebastian Piñera in 2010, Chile's first right-wing President since Pinochet left office. A clearly defined political identity will help the Chilean government create and implement more effective policies.

Thus far three large scale programs have been created and implemented in Santiago in order to mitigate this serious problem and ensure that Santiago and its residents are not under threat. Santiago overhauled its mass transit and created Transantiago. It developed and implemented a tradable emissions permit program. It also developed a program to increase the amount of vehicles on the road equipped with automotive catalytic converters. These three programs were implemented with varying degrees of success and popularity, but what is important is that Chile is taking steps to address a serious problem.

Transantiago was developed with the specific goal of increasing usage of Santiago's mass transit system and thereby decreasing the number of personal passenger vehicles on

Santiago's continuously congested streets. Although it was largely unsuccessful, it did achieve some benefits for the city. Whereas before the city busses were independently owned, under Transantiago all busses would be consolidated. Before Transantiago, bus routes were largely inefficient; redundancies existed along busy thoroughfares and did not reach every area in the city. Furthermore, because each bus was independently owned and operators profited based on the amount of passengers they transported, busses would race dangerously down the streets in an attempt to beat other operators to crowded bus stops. These problems ceased under Transantiago.

However, in many residents' eyes, Transantiago was an abject failure from day one. Residents were especially frustrated because there had not been a strong campaign to educate them on how the new system would work. Essentially the program, which took years to create and perfect, was implemented overnight, leaving users confused and frustrated. This caused many users, overwhelmed by the new and extremely complex routes, to crowd the Metro, rendering it ineffective as well. Suggestions to improve this program would be to phase in Transantiago in a piecemeal fashion so as not to overwhelm users. Also a strong education campaign would be advisable.

Santiago also attempted to develop a tradable emissions permit program. This program was designed to address the pollution created by the industrial sector of Santiago, specifically the amount of total suspended particulates (TSP). This program, like the implementation of Transantiago, was not entirely effectual, although there were benefits to its implementation. One of the effective measures in this program was not a part of Decree 4 which created it, but was created by a previous decree. This decree penalized major polluters by compiling a list of

Santiago's largest polluters and interrupting their production during days that were deemed "critical" or "emergency" according to air quality indexes in Santiago. In decreasing their emissions, the largest polluters might halt the interruption of their production. It also, for the most part, established a structure that might have been effectual if it had not faced several disadvantages.

One main disadvantage that this program faced was that a strong enforcement mechanism was not put into place. The abovementioned incentive seems to be the only incentive to comply with the program. Another issue that plagued the program was poor measurement techniques that could not adequately measure how much each firm polluted quantitatively. Also, the cap on emissions did not tighten and thereby there was little incentive to further innovate in order to meet the forthcoming tightened regulations. However, what killed the efficacy of the program was the sudden ability to import a cleaner and cheaper energy source: natural gas exported from Argentina. Once the flow of cheap natural gas had halted, noncompliance with the program skyrocketed.

There are several ways in which this program could be improved. One suggestion, that incidentally could be applied to many of Chile's environmental policies, is to create a strong enforcement mechanism. Also, in order to encourage continued innovation, the cap on the level of emissions should be periodically lowered. However the largest problem that effected the implementation of this program does not have an easy solution. Because the natural gas that was suddenly available inexpensively reduced emissions; it would be counterintuitive to restrict its use because it had such a drastic effect. Placing a tariff on it, for example, might persuade industrial firms to continue to use dirtier energy sources like oil and coal. The

program can be seen as a cautionary tale for other nations that might be looking to implement a similar program.

By far the most effective program that was implemented in Santiago was the introduction of automotive catalytic converters. There were many reasons why it was effective. It, unlike many of Chile's environmental policies, was equipped with a sufficient enforcement mechanism. The incentive that allowed vehicles equipped with catalytic converters to circulate freely in Santiago is a great example about how an incentive can be added to a command-and-control policy to make it more palatable. Furthermore, adding catalytic converters to vehicles is relatively inexpensive and easy to do, especially because large vehicle producing companies had already developed platforms that supported fitting their vehicles with catalytic converters. In addition, this was a relatively safe program to utilize because other countries had already implemented it and moved the technology further down the learning curve.

It would be disingenuous to say that this was a perfect program. There seems to be an issue of equitability when implementing this program. When the program was in its infancy, new cars equipped with catalytic converters were expensive and only available to wealthy Chileans. Purchasing a converter and having it installed on a vehicle was also relatively expensive and only available to upper class citizens. Perhaps to further implement the program a subsidy could have been provided for individuals to fit their vehicles with converters, or perhaps even to purchase new vehicles by trading in their old vehicles, not unlike the "cash for clunkers" program offered in the U.S.

CONCLUSION

Santiago, Chile's capital and largest city, is a wonderful city. It is the cultural center of Chile, home to vibrant neighborhoods and countless cultural treasures. Santiago, because it is both the commercial and industrial center of Chile, has been integral in developing and maintaining Chile's stellar economic record. However, Santiago's inherent livability has been threatened by excessive amounts of air pollution, created in large part by Santiago's industrial sector as well as its transportation sector. Air pollution and its effects are worst during the fall and winter months when temperature inversion traps pollution in the basin in which Santiago sits. It threatens the health of its residents, particularly the very young and very old. Air pollution has become a serious problem that requires attention. Pragmatic and innovative solutions are needed to mitigate air pollution and its effects in Santiago.

It is clear that Chile has aimed to clean up its capital city by reducing air pollution, as evidenced by the three large scale programs it implemented to reduce air pollution. These programs have had varying degrees of success, but a recurring theme seems to be a lack of an adequate enforcement mechanism, even if an adequate incentive is offered. For example, while the tradable emissions program offered an incentive for companies to create innovative ways of reducing air pollution and thereby protecting them from interruption by regulators, poor monitoring infrastructure and weak enforcement left the program without teeth. Furthermore, it is important to enact policies gradually, after providing adequate levels of public education on said policies. Transantiago was hobbled by its sudden implementation without educating most of Santiago's residents on the modifications it would make to their daily commute.

Whether or not the program leans towards a free market approach or is from the command-and-control school of thought seems to be irrelevant. However, what is important I believe is for a clearly defined political identity to emerge as the legacy of Pinochet fades. It is important to note that, because of the policies implemented, progress has been made. Further progress is possible as long as pragmatic innovation is nurtured and implemented in a competent fashion. There is hope for Santiago as long as mitigating air pollution remains forefront in the collective mind of Santiago's residents and the government in Santiago maintains their vigilant stance against further degradation of Santiago's air quality.

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