The Relationship Between Economic and Environmental Dimensions of Sustainability on the Island of Montreal

by

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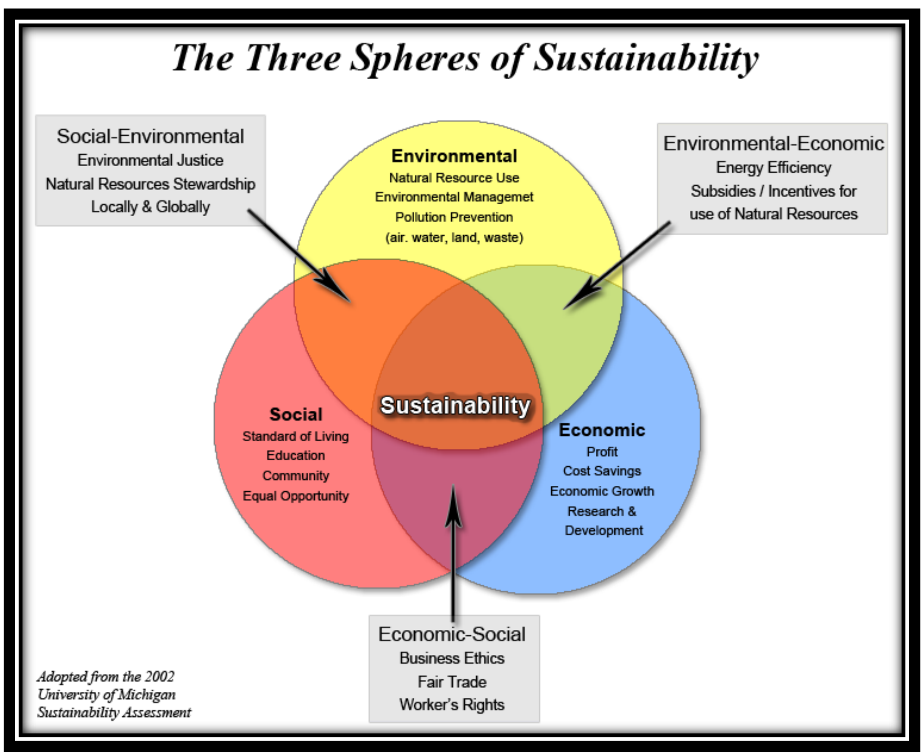
<u>ABSTRACT</u>

Sustainability's growing popularity amongst the literature, institutions and individuals since the coining of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987), contrasts with its blurry connotations, triggering endless semantic debates. In spite of its characterization as "ill-defined and diffuse area of study" (Leal Filho, 2000; Robinson, 2004; Whitley, 1984), the literature has reached a consensus on sustainability's "Triple Bottom Line" (Elkington, 1994) as inscribed into environmental, economic and social dynamics. Scholars have adopted different perspectives on the direction of the relationship between environmental and economic spheres (Wagner, 2001; Kahn, 2006), which explains the stance of this research toward inquiring the strength of this association at the Montreal scale. Twelve indicators of sustainability were confronted to correlation, regression and factor analyses, evidencing a linear negative relationship between sustainable practices and economic status on the island of Montreal, contrasting with the global findings and closing a literature gap at the local level.



CHAPTER I: INTRODUCTION

In 2008, the United Nations estimated that for the first time in history, more than half of the world's population lived in urban areas (UNFPA, 2007). This symbolic threshold resulted in a series of urbanization waves reaching a climax in the twentieth century, "that future historians will record as that century in which the whole world became one immense city" (Cox, 1966). Today, mainly as a consequence of developing countries' striking urbanization rates stemming from population depletion and the rural exodus phenomenon, almost 180 000 urban dwellers are added to the world urban population daily (UNCHS, 2001).

1.1 Humans/environment interaction

As shown by Jones (1991) who emphasized the positive correlation existing between urbanization levels and a nation's level of energy use and greenhouse gas emissions, this rapid urbanization process has had - beyond social and economic consequences – tremendous consequences on the environment. Deforestation, urban sprawl or the heat island effect are as many diversified examples born from urbanization severely hindering our environment. These challenges "symbolize everything that is inspiring and troubling about this era of rapid urbanization" (Hazel & Miller, 2006: 5) as they contrast with positively connoted urban agglomerations of economic, political and cultural paramount importance.

Of course, these impacts inevitably affect the world's populations, who experience different vulnerability levels to these environmental threats. Indeed, while developed nations contribute at least equally to strengthening the greenhouse effect through carbon emissions, natural disasters stemming from climate change affect their developing counterparts to a much greater extent. Additionally, natural disasters do not constitute the only challenge, as people need to face the direct consequences of the urbanization process: the development of slums at the periphery of mega cities host a population undoubtedly more exposed to child mortality, respiratory illness and other water-borne diseases, and furthermore subject to deviance and criminality compared to their urban counterparts.

1.2 Sustainability's Accepted Definition

These perilous interactions between humans and their physical environment push for a more respectful approach of urban dwellers in particular to the management of their environment. As pressure for economic profit has long overpowered the political agenda's concerns for environmental issues, the first genuine response originated from the Brundtland commission report coining the term 'sustainable development' as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Since then, sustainable development – and sustainability in general if we consider like Goodland & Daly (1996) or Clift (2000) that the former represents the process through which the latter can be achieved – has gained a new dimension to the point that Swart, Raskin & Robinson (2004) have inquired whether sustainability should be considered as an emerging science. In spite of blurry denotations nourishing endless semantic debates, sustainability unites the literature around a consensus on its triple bottom line (Elkington, 1994): an interaction between economic, physical and social dimensions.

The social dimension being "far more difficult to quantify than economic growth or environmental impacts and consequently the most neglected element of triple bottom line reporting" as expressed by Stephen McKenzie (2004: 8), this research focuses on the strength of the relationship between environmental and economic factors in achieving sustainability. Assuming that "human well-being cannot be sustained without a healthy environment and is equally unlikely in the absence of a vibrant economy" (Torjman, 2000: 2), focusing on economic and environmental realms will ultimately have social impacts that future studies can incorporate into the Triple Bottom Line's dynamics. Scholars have offered contrasting views on this association: while some have stressed the positive impact of environment regulation on a firm's social welfare and private benefits (Wagner, 2001), others have underlined the fundamental role that economic status plays in shaping environmental outcomes (Beckerman, 1992). As a result of this lack of consensus on the nature of the causal relationship between environmental and economic sustainability, this thesis will not seek to find any causation to this affiliation but rather inquire into the strength of the association between the two.

1.3 Literature Gap

As the literature has explored in depth the relationship between the economic and physical spheres, most of it focuses on the global level using countries as unit of analysis, leaving a literature and empirical gap at the local level. Moreover, if sustainability has recently turned into a trendy catchphrase used by a wide array of institutions and individuals, its achievement fundamentally relies on individuals and their everyday commitment toward the tackling of these environmental issues within an urban environment context: as put by Fricker (2001), "sustainability is as much a process of discourse and effort as it is a state". Research at the local level has attached great importance to physical facts explored in detail in the global literature, such as waste management, maintenance of biodiversity, water contamination, but has largely ignored people's daily incentives toward achieving sustainability. For example, if some scholars (Marsden, 2005; Litman, 2007) have created indicators evaluating transportation systems' sustainable performance, few initiatives have inquired into the extent to which individuals actually use these networks daily. Knowing more about these individuals' profile - including economic status - will therefore become useful in orienting future local and global policy towards enhanced environmental management. Electing Montreal as spatial framework of analysis appears particularly interesting for several reasons detailed in the following section.

1.4 The Montreal Context

Montreal presents an interesting profile amongst Canadian and world cities given its embedment in the Quebec province's French heritage and strongly affirmed identity; and the role it plays in the multicultural Canadian landscape as a leading economic, cultural and political center. Second most populated Canadian city after Toronto, Montreal is the home of world leading companies such as Royal Ban, Air Canada, ICAO or Bombardier and has increasingly turned this innovative spirit into sustainable initiatives and policies which have become the city's trademark. Montreal, home of the 2011 'Eco city' World Summit, has recently established itself as major instigator of urban agriculture under the form of food and rooftop gardens, as well as sustainable transportation through the launching of the Bixi program or the goal to reach 30% public transit use by 2031. Such initiatives are fostered by sustainability's trendy dimension, put forth by major urban centers as they compete for the 'global city status' and claim a spot in the world hierarchy of cities. Nonetheless, considering sustainability's utopian character and in more concrete terms, Montreal's fifth place on the Corporate Knights Magazine's ranking of Canadian sustainable cities; research underpinning people's sustainable practices will add to the growing field of sustainability.

These elements legitimize and structure the following research question: is there a correlation between environmental sustainability and economic performance amongst the Montreal island population?

This paper will first attempt to disentangle the notion of sustainability, placing emphasis on the physical and economic spheres of its triple bottom line and exploring the literature's perspective on their relationship. Another section will detail the different steps of the methodology, putting forth the different variables constitutive of the statistical analysis in light of the literature's insight on the process. A final section will expose the results of the analysis and offer interpretations potentially useful in future incentives toward the path to sustainability.

CHAPTER II: LITERATURE REVIEW

This section attempts to disentangle the ill-defined concept of sustainability, highlighting its different components and analyzing interactions between them. It also introduces previous initiatives from the scholarly literature at measuring sustainability, some of which inspired the choice of variables for this research.

2.1 What is sustainability?

2.1.1 Evolution of the concept

It is because most regional and global problems originate in cities, embodiments of man's need to impose itself on nature, that sustainability has gradually gained credit as a concept. The perception of the environment as an infinite supply of natural resources or the excessive pressure for economic profit, which overpowered the political agenda's preoccupation for environmental issues until the end of the twentieth century; hindered the popularization and belief in a respectful interaction between humans and their environment. The coining of the term 'sustainable development' by the report entitled "Our Common Future" in the context of the Brundtland conference (1987), emerged as the first genuine response to this striking lack of concern. This report stresses the necessity to achieve an economic system generating economic surplus while respecting the ecological basis for development; it has launched a global trend in the use of the term 'sustainability'. Indeed, this term has become ubiquitous within the scholarly literature as well as in various contexts of one's everyday life.

2.1.2 Why do we talk about it?

Sustainability is now put forward within the political sphere as a trendy electoral tool to obtain more votes. Major political parties incorporate ecological initiatives in their respective programs in order to attract Green Party voters as they run for the electoral victory. The concept is also omnipresent in policies from major world urban agglomeration competing for the 'global city' status, in order to attract international recognition and foreign investments. Montreal as part of the contenders makes no exception to this trend as shown by the launching of the $430 million Montreal 2025 plan (City of Montreal, 2011). This incentive toward the completion of 200 major projects aimed at consolidating Montreal's sustainable dimension is representative of the role played by this ecological trend in the competition for a spot on the world map.

Lastly, the concept of sustainability has become 'fashionable' in the marketing of consumer and manufactured goods destined to the public. Within the food industry, the concept of fair trade, wherein local producers receive a more substantial share of their production, is developing fast. People are now more inclined to spend more for goods obtained through sustainable means of production using natural fertilizers, hence minimizing the impact on the environment. This sudden attraction for these processes and goods more respectful of the environment has also been generalized to the manufacturing industry: Veleva, Hart, Greiner & Crumbley (2001) have developed the case of Interface Corporation, a large carpet manufacturer, whose first sustainability report in 1996 detailing its main incentives, helped improve the company's public image and create a competitive advantage through product/service differentiation.

2.2 Sustainability's triple bottom line

Ironically, if sustainability has recently turned into a catch-term wildly used by a wide range of institutions and individuals, the concept stays very blurry. Despite the extensive literature focusing on this "discussion for the expression of emotions and attitudes" (Solow, 1993), sustainability remains an "ill defined and diffuse area of study" (Leal Filho, 2000; Robinson, 2004; Whitley, 1984) subject to endless semantic debate. From a more radical point of view, Jacqueline de Chazal (2010) in her work on livability and sustainability considers that "not only do they remain undefined, livability and sustainability are indefinable". Part of the reason why sustainability remains so ambiguous in nature is that it encompasses several intertwined aspects, complementing each other and creating complex dynamics in which sustainability is inscribed. Nonetheless, the literature has reached a consensus on sustainability's 'triple bottom line', comprising economic, environmental and social dimensions.

2.2.1 The environmental perspective

While acknowledging the existence of the economic and social spheres, some scholars have placed exclusive emphasis on the environmental aspect. Kostas P. Bithas & M. Christofakis (2006) have justified this approach by underlining the “primary and irreplaceable role held by the natural environment in the functioning of urban systems, as well as in that of any other socio-economic system”, stressing the prominent role held by physical sustainability as keystone in the achievement of other kinds of sustainability. For example, Goodland (1995) has estimated that “there can be no social sustainability without environmental sustainability” considering that the latter supplies the conditions for the achievement of the former.

By approaching the concept from a physical perspective, scholars recognize the notion of limit to our environment’s capacity to face human exploitation, hence taking issue with the ‘frontier economics’ paradigm (Colby, 1991), which prevailed in most countries of the world until the end of the 1960’s. Frontier economics treated nature as an infinite supply of natural resources for the human benefit, capable of absorbing the by-products of human consumption, under the form of pollution or environmental degradation. Therefore the concept of ecological sustainability was highly inconceivable at that time, considering there was no real biophysical environment to be managed. Since the end of the 1960’s, concern for ecological preservation over the long run materialized by the Brundtland report has gained credit and is gradually gaining a new dimension.

In more practical terms, concerns have been raised about the measurability of environmental sustainability, arguing for its lack of empirical evidence - this point being explored in section 2.4 in light of previous attempts toward the grasping of this concept. In particular, scholars treating economic sustainability as focal point of their research appear to be the most active detractors to this physical approach.

2.2.2 The economic perspective

The economic approach to sustainability places emphasis on the ability of economic systems to support the human population over the long run. Solow (1993) has considered that if sustainability means anything more than a “vague emotional commitment”, it has to be a “generalized capacity to produce economic well-being” over an extended time-period. Economic sustainability hence appears much easier to quantify as it stands for some kind of economic wealth. Solow (*Ibid*) further believes that the only reason why natural resources or the natural environment in general are addressed is their role in the construction of the sustainable path allowing "every future generation the option of being as well-off as its predecessors". From an even more radical perspective, Pezzey (2004) justifies this economic approach by drawing a distinction between sustainability and 'environmental policy'. This distinction holds in the fact that quite similarly to the 'frontier paradigm' previously addressed, governments do not much believe in the imminent limits to substitutability of "human-made capital and knowledge for environmental resources" (*Ibid*) and hence do not treat environmental protection as the essence of sustainability policy. Economist Julian Simon (1996) has shared this vision in his book *The Ultimate Resource 2*, pointing out that humankind consistently managed to avoid the specter of Malthusian scarcity through resource substitution and technical ingenuity. Pezzey (2004) sees environmental policy as the result of the government's intervention, which encourage the internalization of environmental values often ignored by individuals. Sustainability by contrast, aims to achieve some social improvements in intergenerational equity for example, fostering a non-declining economy as well as encouraging both saving and investment.

By reviving to a certain extent the frontier economics paradigm, taking issue with Malthusian theory on resource scarcity and addressing natural resources as part of a broader economic chain allowing for the well-being of future generations, theorists on economic sustainability offer a drastically contrasting vision to the environmental perspective.

2.2.3 Relationship between the economic and environmental spheres

Although some authors have focused their research exclusively on one sphere of the triple bottom line, the common view acknowledges sustainability as an interaction of forces. The social dimension being much harder to quantify as expressed by McKenzie (2004), this research will explore the relationship between environmental and economic factors leading to sustainability. The nature of this relationship is very complex in nature; as some stress its bi-directional nature and others believe that one is a determining factor in the evolution of the other. In that prospect, Wagner (2001) has estimated that stringent environmental regulation (under the condition that it is efficient) can lead to win-win situations in which social welfare as well as the private benefits of firms operating under such regulations can be increased. A firm can base its marketing strategy on a sustainable production chain and exploitation of recyclable materials with very positive economic outcomes because people are increasingly sensitive to sustainable practices.

Similarly, in the context of the Millennium Development Goals, Solheim (2010: 100) has estimated that environmental sustainability is now a keystone in combatting poverty, claiming that "the fights against poverty and climate change must go hand in hand, or we will lose them both". More specifically, the depletion of natural resources, increased soil erosion, loss of soil fertility, unrestricted deforestation or restricted water supplies, contribute to diminish agricultural productivity, access to sanitation and valuable forest capital for economic development and environmental stability. Using natural resources equitably in a more sustainable fashion can therefore eradicate poverty in the context of developing countries (UNECA, 2010)

From the opposite angle, others have underlined the fundamental role that economic status plays in shaping environmental outcomes: from a radical point of view, Beckerman (1992) has estimated that "in the longer run, the surest way to improve your environment is to become rich". Similarly, Grossman & Krueger (1995) have considered increased wealth as a prerequisite for environmental improvements. While acknowledging some sort of interplay between the two spheres through the 'Kuznets curve', Matthew Kahn (2006) believes that after an economic threshold has been attained, pollution tends to decrease as more incentives toward a more sustainable development become more financially accessible. Adopting a more flexible perspective, the Yale Center for Environmental Law and Policy (2005) - while recognizing that a country's wealth and level of development is by no means the only driver of its performance and Environmental Sustainability Index score as shown by the very low rankings of Kuwait, Saudi Arabia and United Arab Emirates in spite of their important economic capital - estimated there is no doubt that economic conditions affect environmental outcomes.

Scholars in favor of the bi-directional relationship, believing that environmental and economic spheres fundamentally affect each other, have argued that economic growth that increases both resource use and waste emissions beyond the carrying capacity of the environment may make societies more sensitive to external shocks (Arrow et al. 1995). In return, the irreversible environmental consequences of consumption may mean that future generations will be offered fewer economic opportunities than present ones (Meadows et al. 1992). Others have estimated that wealth and environmental performance fundamentally go hand in hand and complement each other: plotting Columbia Universities' Environmental Performance Index against Fraser

Institutes' Economic Freedom of the World Index, the Frontier Center for Public Policy (FCPP, 2010) acknowledges that "environmental performance and economic freedom both correlate not only with each other but also with greater wealth".

This striking lack of consensus explains the thesis orientation toward evaluating the strength of the association rather than attempting to claim a precise direction of the relationship between economic and environmental spheres.

2.3 Can environmental sustainability be measured?

2.3.1 Challenges to the measuring of the concept

The highly ambiguous nature of the term sustainability makes its application in concrete situations, trying to measure it for example, empirically challenging: Fricker (2001) backs up this idea estimating that "as a concept, sustainability has captured our imaginations and aspirations, as a tangible and identifiable goal it eludes us". If economic sustainability appears somewhat easier to grasp if we consider that it stands close to the generalized capacity to produce economic well-being (Solow, 1993), the physical dimension appears much more difficult to address. Some scholars such as Esty, Levy or Srebotnjak (2005) have even raised concern whether environmental sustainability could be measured.

First of all, given sustainability's blurry denotations, there is a striking lack of common understanding of what is to be measured (Fricker, 2001). Few institutions have taken the responsibility of carrying the Bellagio Principles - guidelines established by a group of measurement practitioners and researchers in 1996, for the whole of sustainable development assessment process, including the choice and design of indicators, their interpretation and communication of the result – further. This absence of communication reveals impairing considering that the process of community sharing and interaction in itself – often more than the creation of indicators – is primordial in the grasping of the term leading to efficient and concrete incentives. In effect, the case of Sustainable Seattle developed by Alan Atkisson (1994) shows autonomous organizations fostering public participation in democracy often represent the most successful initiatives.

Another common argument against the measuring of environmental sustainability is its multidimensional character. The fact that its constituents are causally connected in several ways diminishes the likeliness of creating reliable and valid indicators, as developed by Yale (2005). For example, levels of environmental pollution can diminish the state of environmental systems, but also affect people and organisms adversely, while social and institutional capacity can intervene either in directly altering any of these phenomena, or in changing the nature of the causal connections among them. From a purely statistical perspective in the context of a regression analysis for example, this interconnection between the different indicators potentially leads to issues of multicollinearity likely to affect the results by invalidating – or wrongly validate - the statistical tests of significance that assume residuals are uncorrelated. In fact, this issue was problematic in this research, and is addressed in section 4.6 of the report.

From a similar perspective, the environment's coverage of an excessively wide range of issues from pollution to natural resource management, encompassing different time dimensions as processes are interlinked between past, present and future; is the final argument taking issue with the empirical grasp of environmental sustainability. As a result, the multiplicity and combination of different units (area, economic value or demographics) stemming from these numerous environmental spheres is likely to alter the validity of indicators.

Therefore sustainability's abstract nature of course, and its multidimensional character whereby many different environmental, economic and social spheres, and measuring units are combined, make its concrete application challenging. However a recent impetus for the creation of indicators as well as some characteristics of this research, have managed to overcome some of these obstacles.

2.3.2 Recent impulse on measuring environmental sustainability

The interest for sustainability born in the 1970's has been followed in recent years by a genuine impulse attempting to measure it. Sustainability's ubiquitous presence in political and commercial spheres in particular as an appealing catch phrase has led numerous countries, institutions and private firms into a similar path. Many private companies viewing economic and environmental/social performance as intertwined now address their sustainable corporate performance (SCP), providing a basis for business strategies and practices (Steg et al, 2001). Gerbens-Lennes (2003) develops the case of the Sustainable Corporate Performance in the context of the food production system, assessing the necessity to focus on energy, water and land to get a sense of the system's overall performance. Countries as well, are being attributed sustainability scores to cope with environmental goals such as air pollution thresholds imposed in the context of world protocols, such as Kyoto in 1997.

While various different methods have been adopted in measuring environmental sustainability, most of them rely on the creation of indicators, or variables helping to get an empirical sense of the term. The Consultative Group on Sustainable Development Indicators (CGSDI) in particular, has been active in producing a set of indicators spanning economic, environmental and social development objectives, therefore focusing on sustainable development broadly defined. Donella H. Meadows (1992) reinforces this constant need for more indicators: "We need many indicators because we have many different purposes—but there may be over-arching purposes that transcend nations and cultures, and therefore there may be overarching indicators."

Unfortunately, the CGSDI also embodies the downside of the indicator creation: while this group has provided a lot of guidelines concerning the choice of accurate and simple indicators inspired by the Bellagio Principles, the group is weakly institutionalized and provides little evidence of data collection, evaluation and aggregation methods as well as the analytic process. As a matter of fact, the broad horizon of environmental sustainability has lead to the creation of hundreds of indicators, some bringing more contribution than others on the matter: "the enormous number of indicators found in the literature generates too much data that often provide no additional knowledge on environmental sustainability" (Gerbens-Leenes, 2003).

Nonetheless, the pinpointing of individual indicators and their combination allows to some extent the aggregation of abstract concepts into one tangible measure. From the perspective of another field, the Human Development Index is a good example of the aggregation of several conceptual elements such as democracy, health or well being into one empirical measure.

All in all, although confronted to commonly advanced arguments against the measuring of environmental sustainability, past attempts have proven possible to come out with an empirical sense of the concept. The choice of the indicators at the local level for the purpose of this research has been inspired by the series of attempts developed below. While acknowledging the challenging aspect of the task, all aspire to provide a relative indication of a country's level of commitment and how close it stands to being on a sustainable environmental trajectory, adding global evidence to the limited database collection available on the subject.

2.4 How have others proceeded?

Now that we have identified the essential role of indicators in the process of exploring the strength of the relationship between environmental and economic sustainability, it is critical to assess what has already been done within the literature and institutions as benchmarking toward the choice of indicators in Montreal. While many indicators are flawed as the result of this recent race toward environmental sustainability's breakdown of data, the three following initiatives are institutionalized within the literature: the Environmental Sustainability Index (ESI), the Wellbeing Index and the Ecological Footprint. The similitudes and differences among them is representative of, and help breakdown sustainability's multifaceted character.

2.4.1 The Environmental Sustainability Index

The Environmental Sustainability Index (ESI) was created by the Center for Environmental Law and Policy at Yale University and provides a broad, policy-oriented approach to the concept on a short-term basis. The index encompasses several different dimensions regrouped into four core components and aims of action: i) a focus on environmental systems and the necessity to maintain them at healthy levels; ii) reduce environmental stresses and human vulnerability; iii) foster social and institutional capacity bringing about social patterns of skills, attitude and networks to offer effective responses to environmental challenges; and finally iv) develop global stewardship cooperating with other countries to deal with common challenges and reducing trans-boundary impacts.

These four components encompass 21 indicators considered to be the "fundamental building blocks" of environmental sustainability, equally weighted and aggregated to create the ESI. These 21 indicators are subdivided into a total of 76 underlying variables capturing different aspects of each indicator: air quality for example, is a composite indicator that includes variables tracking the concentration of nitrogen, sulfur dioxides and particulates. A total of 146 countries met the criteria for the inclusion into the ESI of 2005. The Markov Chain Monte Carlo simulation allowed the input of values where data gaps existed, especially in remote countries where data collection is not a priority. The result of this aggregation process is the ranking of these 146 countries, from Finland with an ESI score of 75.1 to North Korea with a score of 29.2. The ESI-based analysis reveals that some of the critical determinants of environmental performance are low national population density – therefore not necessarily anti-urban as the focus is at the national scale - economic vitality and quality of governance, some of which "have long been identified as theoretically important". Hence these results tend to support the literature's correlation between environmental and economic performance at the global level.

In my opinion, the main asset of the ESI is while narrowly placing emphasis on the environmental dimension and physical facts targeting pollution and emissions, it still addresses the economic dimension through the Private Sector Responsiveness (indicator 17), the political through Global Stewardship (indicator 19, 20, 21) and the human aspect through Environmental Health (indicator 12). This large approach angle provides an accurate sense of environmental sustainability's broader picture and embedment into other economic, social and political dynamics. Nonetheless, I believe that the ESI still omits an important dimension of environmental sustainability: it gives limited attention to attitudes and incentives from the population's everyday life habits and commitments to environmental protection. This approach would have complemented ground facts about physical waste and emissions, although it might be difficult to achieve in the context of a global study where the project's leaders rely on databases available, probably highly limited in remote areas of the globe. Yale (2005) supports this idea, highlighting that the quantitative basis is stronger in OECD countries than in many low-income nations especially in Africa and Asia.

2.4.2 The Environmental Performance Index

Many have been inspired by the ESI, including the 2006 Environmental Performance Index (EPI), developed by the Center for International Earth Science Information Network (2010) and standing close to its predecessor in the analytic process of the different variables, although indicators are slightly different and less numerous. The study also targets 163 countries instead of 146. EPI is divided into two core components: ecosystem vitality and environmental health. Another difference with the ESI stands in the aggregation of different variables, achieved through the following weighting scheme: the ecosystem vitality encompasses 25% of climate change, 4.167% of agriculture, 4.167% of fisheries, 4.176% of forest, 4.176% of biodiversity and habitat, 4.167% of water effect on ecological system and finally 4.167% of air pollution effect on the ecosystem as well. The environmental Health component encompasses 25% of environmental burden of disease, 12.5% of air pollution effects on humans, and 12.5% water effects on humans. Inconsistencies between the two indexes in the choice and aggregation of indicators results are reflected in the final ranking identifying leaders and laggards in the field. EPI’s top five is composed of New Zealand, Sweden, Finland, Czech Republic and the UK, against Finland, Norway, Uruguay, Sweden and Iceland for the ESI. In both indicators, Canada is fairly well ranked with a sixth position in the world hierarchy following the ESI criteria and an eighth position for the EPI. However, the top five position of the UK in the EPI ranking, highly contrasts with the 65th rank measured by the ESI, evidencing the existence of wide gaps between the two hierarchies.

If the works of Yale or the EPI have many points in common, other scholars have come up with original methods to measure environmental outcomes.

2.4.3 The Wellbeing Index

Robert Prescott-Allen’s Wellbeing Index (Allen, 2001) that encompasses both ecological and human measures has much in common with the ESI, including the aggregation of a series of thematic indicators into one broader index and the choosing of countries as the basic unit of analysis. The quantification of sustainability in a broad range of environmental areas such as water and air quality, biodiversity and resource-use results in the creation of an overall indicator, which combined with human outcomes results in the Wellbeing Index. Allen has introduced new methods of combining individual variables into one thematic indicator. He uses non-linear relationship in the calculation of inland water quality for example: the score for this particular variable is calculated as the "average score of drainage basins in each country, each basin score being the lowest of six indicators, oxygen balance, nutrients, acidification, suspended solids, microbial pollution, and arsenic and heavy metals." (*Ibid*) These methods avoid the common problem of a country performing well because good scores on one component average out low scores on another component.

The main difference with the ESI holds in the method of aggregation: indicators are attributed relative rankings in terms of 'importance' whereas the ESI attributes equal weights to all indicators. This point is subject to controversy as people have underlined its lack of transparency in the determination of the weighting scheme of the Wellbeing Index. Another subject of criticism is the lack of precision in the spatial unit of analysis chosen to compute the indicator. As a matter of fact, the local air quality index for Brazil is constructed as an average of air quality data for five cities, which are probably not precisely representative of Brazil's local air quality. Therefore if the Environmental Wellbeing Index "makes key contributions to the field of sustainability indicators, much work clearly remains to be done" (ECSP Report, 2002). Indeed if it opens new perspectives on the combination of variables to better grasp the underlying patterns and dynamics, the ambiguous methods of weighted aggregation, issues of precision and scale, and the automatic focus on countries as unit of analysis, hinders to some extent the reliability of this index.

2.4.4 The Ecological Footprint

The Ecological Footprint developed by Mathis Wackernagel (Wackernagel, 1998), measures the degree to which a given country is living within its ecological means. Put differently, the ecological footprint is an "area based indicator, which quantifies the intensity of human resource use and waste discharge activity in relation to a region's ecological carrying capacity" (*Ibid*). This indicator differs substantively from its counterparts as it aggregates the consumption of natural resources within a country in terms of land area that is estimated to require the support of such consumption. The total land area of the country then divides this measure of ecological footprint given in hectares per capita. Therefore countries whose ecological footprint is larger than their actual area are considered to be consuming beyond a sustainable level. Of course, in order to achieve global sustainability, the sum of all regional footprints must not exceed the total area of the biosphere. There are two explanations to this situation where a country's impact exceeds its carrying capacity. First, the population receives resources from elsewhere and disposes the waste outside of its area. The second alternative is that the population depletes the area's natural capital stocks. Thus the Ecological Footprint also raises issues of scale, inscribed into sustainability's dynamics, as some cities may be sustainable at the local scale but not globally, by placing unsustainable demands on natural resources elsewhere and exporting emissions and waste to other regions (Bithas, 2006).

A total of six ecologically productive variables have been used for analytic purposes: crop land, pasture, forest, ocean covers, built-up land and energy. For each category, the total area representative of the component on the face of the Earth was divided by the global population, which resulted in an attribution of 0.25 hectares of crop land, 0.6 ha for both pasture and forest, 0.5 ha of ecologically productive sea space and finally 0.03 ha of built up space per 'global citizen'. These numbers take into consideration the attribution of 12% of global space for biodiversity conservation – what Noss and Cooperrider (1994) have considered insufficient to preserve biodiversity over the long run. As an example, the calculations for the US have shown an ecological footprint of 8.49 ha per US citizen, which is equivalent to five times the world average of 1.7 ha. In general, out of the 52 countries analyzed by Wackernagel, only ten have citizens that consume less than the amount available on a worldwide per capita basis.

All in all, this indicator is original in that it reverses the analytic process that many have come across, attempting to determine human carrying capacity as the number of people that can be supported by a given area: on the contrary, the Ecological Footprint estimates the area of the earth's surface required to support a given population.

I personally find this indicator particularly interesting as it distinguishes itself from most previous attempts, both area-based approach to human consumption and impact on sustainability, but also by investigating a single dynamic of triple bottom-lined sustainability, placing emphasis on environmental sustainability rather than a broader measure incorporating economic/social and institutional aspects as well. Nonetheless The Ecological Footprint could have included more factors other than resource depletion, perhaps exploring already existing patterns of commitment to environmental sustainability across the world. Also, this measure does not really take into account different levels of development and their effects on 'sustainable' policies and facilities. Although Americans have an ecological footprint five times superior to normal, they might have an enhanced access to recycling facilities and renewable energies compared to Indian citizens, whose direct impact on the environment is inferior however constant as they have restricted means to tackle these issues. In that prospect a weighted system could have added another dimension – targeting attitudes and access to resources induced by development level instead of solely focusing on physical facts.

In spite of its originality, which initiated a genuine breakthrough in the literature on environmental sustainability indicators, the Ecological Footprint Index cannot be applied in the context of my research given the restricted variation within the Montreal sample population.

2.4.5 Synthesis of sustainability's global indicators

Overall, it is clear that this new interest for ecological matters has been accompanied by an authentic trend seeking to measure this 'fashionable' concept of sustainability using empirical methods. Most attempts, including incentives from the Consultative Group on Sustainable Development Indicators (CGSDI), consist of finding indicators that best describe and potentially grasp environmental sustainability, aggregating them into indexes. If this method remains common to most indexes, aggregation methods differ from one study to another: when the wellbeing and environmental performance indexes use weighting schemes ranking underlying variables in terms of prominence, the ESI and the ecological footprint attribute equal weights to all indicators. Another source of distinction between studies in the wide panel of indicators, some incorporating social and institutional dimensions, as shown by the substantial share of variables targeting quality of governance and the ESI's results evidencing its prominent role in the achievement of sustainability goals. The angle and precision of approach then, but also the mixing of analysis units, ranging from the calculation of oxygen balance in drainage basins at the national scale, to ecological footprint measured in hectares per capita, highlights once again sustainability's multifaceted character making it empirically challenging to create a standard universal index.

2.5 Cities and sustainability

If we can now consider that it is possible to measure sustainability in its environmental dimension, the following section approaches the concept of sustainability at the city level: what changes from the national scale? What elements are being looked at? A closer look at citywide indicators and the sustainability of cities in general, enlighten these questions.

2.5.1 City-wide Indicators

One can address the sustainability of cities by focusing on urban ecology, considering that the latter allows a better understanding and therefore plays a role in its achievement. Similarly to sustainability, urban ecology holds blurry denotations, as the link between the 'urban' and ecological dimension has not clearly been established within the literature. Niemelae (1998) has shown that "biodiversity of urban habitats is poorly documented in many cities, and thus baseline information is scarce". On a similar note, Collins (2000) underlines the fact that "ecologists have hardly rushed to the city: a mere 0.4% - 25 0f 6157 – in the nine leading ecological journals in the past five years dealt with cities or urban species". Still, the need for a privileged understanding of urban ecology, has become urgent: Odum (1997) has estimated that a typical city daily transforms into heat about 70 times more usable energy per square meter than a close non-human equivalent to a city - an oyster reef.

If we can consider that urban ecology stands for the interaction of ecological organisms within an urban setting, and the urban threats that these organisms have to face, the ecological footprint appears as a relevant indicator of the sustainability of cities. As Wackernagel (1998) has undertaken the same approach at the country level, the transition between the global and local scales requires some adjustments, explored in section 3.1 of this report. The study from the Maine Economic Growth Council and the Maine Development Foundation exemplifies this ecological footprint measure locally: this measure, showing the links between the environment, economy, and society, connects the health of the fish stocks with the economy of the fishing industry, and therefore the stability and sustainability of lifescapes based on this industry. Sustainable Measures, a company offering consultative services to governments, businesses and non-profits to better shape sustainable communities, has created several guidelines to more understandable, relevant, reliable and based on accessible data indicators. The estimation of total residential, commercial, industrial and proportion of recycled waste indicator, created by the Sustainable Community Roundtable of the South Puget Sound region in the state of Washington, follows these guidelines. Similarly, the evolution of the number of pedestrian friendly streets in Richmond, British Columbia, encompassing dynamics of transportation, health, environment and society has also been inspired by the work of Sustainable Measures. Targeting transportation, the Transportation Research Board (TRB, 2008) and scholars such as Marsden (2005) and Litman (2007) have come up with specific indicators falling into distinct categories: travel activity, traffic risk, noise pollution, accessibility or land use impacts.

It appears clear that while resting on different scales thus implying somewhat different indicators, the global and city scale place emphasis on physical indicators: waste disposal, pollution, access to drinkable water, air quality. This is where this project brings something new, as the focus on individuals and the relationship between commitment to sustainability and economic status allows the exploration of peoples' attitudes to a greater extent: while focusing on transportation and voting behavior, a wide array of possibilities such as involvement in community organizations, recycling behaviors, open space for future studies to exploit this new indicator of sustainability.

If the study on city wide indicators has justified the scope of this research by pinpointing the lack of understanding between the 'urban' and 'ecological' dimensions and identified a new category of sustainability indicators relying on individuals and their cognitive behavior toward the issue, the next question that comes to mind is: are cities considered sustainable? A negative answer would justify the scope of this study aiming for enhanced awareness and policy directed toward the daily achievement of sustainability. In fact, both perspectives have been adopted on the matter.

2.5.2 Cities are by nature unsustainable

Partisans of the social dimension of sustainability in particular have claimed that cities are by nature unsustainable, underlining the overemphasized character of the economic and ecological spheres as source of marginalization for the 'people'. Don Mitchell (1997) has placed emphasis on a growing concern and recurrent theme in urban social geography addressing the ‘privatization’ of public spaces, becoming increasingly inaccessible to people often placed at the margin of society such as the homeless or mentally/physically disabled. From a similar perspective, Oluf Langhelle (1999) has viewed social justice, humanistic solidarity and concerns for the world’s poor as equally relevant, yet often marginalized from most decision instances’ agenda. The rise of political ecology in recent years is inscribed in this dynamic rising against the unsustainable nature of urban environments, victims of the interplay between environmental and economic forces. Scholars have adopted several distinct approaches to political ecology, looking at how the different spheres interact from a Marxist point of view, ‘Third World’ position and feminist.

Swyngedouw & Heynen (2003) have been influenced by the Marxian perspective when examining the relationship between capitalist urbanization processes and environmental injustices at different scales, stressing the role of urban, political and environmental processes in advantaging some social groups while negatively affecting others: the gap between marginalized social groups and the capitalist elite is likely to be increased by the exposure and vulnerability of the “urban underclass” toward processes of ecological change.

Similarly, Raymond Bryant (1998) places emphasis on the Third World context as he seeks to disentangle the prominent role played by politics and the capitalist-driven economy in shaping the causal relationship between human-environment interactions and the spread of environmental degradation. The illustration of his theories by the ‘scientific forestry’ example, promoting forestry as progress in order to assure a long-term timber production in the name of the ‘greater social good’, emphasizes the discourse put forward by the political and economic elites to justify these unequal patterns of human use of the environment.

Ariel Salleh (2009) in her book *Eco-Sufficiency and Global Justice: Women Write Political Ecology* has pursued a distinct approach to urban political ecology by drawing a parallel between gender oppression and degradation of the environment. In her opinion, the continuity between social and gender oppression on the one hand, and environmental degradation on the other, remains rooted in the fact social oppression in the past has been supported by ideologies targeting “less human” social groups closer to nature. By focusing on the imposition of reforestation schemes in the Kyoto protocol that affect the fertility of soils, biological diversity and provoke the displacement of communities encouraging women to get involved in the sex trade industry to survive, she offers a rather pessimistic vision of the future dynamics of social/gender inequalities and environmental degradation under a capitalist economic system.

In brief, most branches of political ecology highlight the unsustainable nature of cities, bringing about the pervasive effect of the capitalist economic system on the production of unequal social and ecological landscapes, as well as highlighting the widening nature of the gap between capitalist elite and the urban underclass. Political ecology seeks to challenge the 'natural' dimension of 'natural hazards' by stressing the enhanced vulnerability of the poorest toward processes of ecological change and increased occurrences of such catastrophes. Despite exposing a rather pessimistic vision of the future, the interest of Salleh (2009) for the progressive emergence of global justice movements since the beginning of the 21st century challenging the "undemocratic and eco-destructive logic of capital accumulation at all costs", as well as the mentioning of the potential role of planning in increasing the likelihood that attention will be focused on the issue by Swyngedouw and Heynen (2003), still provides grounds for hope. Indeed, the view that cities are relatively and in absolute terms sustainable, has gained credit within the literature.

2.5.3 Cities can be considered sustainable

Urban planning's more concrete approach to urban sustainability contrasts with the political ecology's position by supporting the idea that cities are (at least relatively) sustainable. By stating that "the connections between urban planning and public health are not new", Northridge (2003, 118) underlines the capacity of cities to interact with their natural environment in a healthier and sustainable way. Just as poor structural establishments such as slums act as vectors for diseases, successfully planned urban realms can limit pollutions levels and foster public health. In fact, the principle asset of cities is that they provide density, contrary to their traditional and nowadays controversial counterparts, suburbs. Suburbs emerged at the end of the 19th century as result of, among others, improved commuting facilities, downtown real estate prices preventing people from owning a home and as a desire to escape the ills of the city. These elements catalyzed the launching of the urban sprawl phenomenon. While the advantages related to quality of life and wellbeing commonly associated with these quieter, cleaner and safer neighborhoods cannot be contested, today's exacerbating ecological problems require us to rethink our patterns of resource consumption and energy use. As a matter of fact, suburbs have turned into car-dominated environments where social interactions and active transportation are constrained by the necessity to own and utilize a car. On the contrary, cities require fewer infrastructure networks per person and in turn decrease resource and energy needs. Urban environments also promote active modes of transportation such as cycling and walking. Higher densities allow for more services (groceries, corner stores, restaurants) to be provided in a smaller area decreasing the distance people need to travel and thus promoting these active means of transport. Thus urban environments have the potential to be more sustainable in terms of energy and resource consumption, as well as offering opportunities for socializing and personal lifestyles. In his book "Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier and Happier", Edward Glaeser (2011) synthesizes all the elements above and makes the apology of urban environments. By showing that New Yorkers are less prone to heart diseases and cancer compared to the nation as a whole and that city dwellers consume on average 40% less energy than their suburbanites counterparts, he accentuates on the sustainable aspects of cities.

Yet the magnitude of global urbanization rates is alarming and if cities are relatively more sustainable than suburban agglomerations, their absolute energy consumption and pollution emissions leave pessimistic hopes for future generations, thus standing in contradiction with sustainability's definition. This trend is reflected in the number of mega cities, urban agglomerations exceeding ten million inhabitants, which escalated from one in 1950 (New York) to 21 in 2011. These places of "metabolic interactions" (Swyngedouw & Heynen, 2003) exhibit striking contradictions as economic, social, political and cultural centers of paramount importance, nonetheless facing 'mega-challenges' struggling to strike a balance between economic competitiveness, social equity and the tackling environmental issues.

Along these lines, while the urban planning sphere acknowledges cities are relatively more sustainable than suburbs, others view cities as socially and environmentally unsustainable, when the economic dimension depends more on the urban center's characteristics such as world location and demographics. Shi & Singh have even put restrictions on the prospects of planning, considering that "while the theory that connects the built environment to health and well-being is intuitively plausible, we still have a long way to go in collecting sufficient empirical data to make convincing appeals for planning and policy changes by the weight of the evidence" (2011: 98). This urges for the shaping of a new relationship between urban dwellers and their environment. Considering the intricate interplay between environmental, economic and social forces, it is likely that enhanced environmental awareness will bring successful change within each dimension, bringing answers to political ecology skepticism. Knowing more about individuals and what drives them to commit to daily actions that make a difference should help orientate future policy making, which constitutes the first element legitimizing this study.

2.6 Legitimization of this research

As I have searched the literature on sustainability indicators, it seems clear that most attempts have concentrated their effort on the global scale, using countries as units of analysis, with Gross Domestic Product (GDP) as a global economic indicator. On the contrary, little attention has been paid to the local scale and to the identification of locally relevant aspects to environmental sustainability. As stated by Mark Roseland (2000: 74), "while there has been considerable attention in recent years to thinking globally (e.g. the Montreal Accord on stratospheric ozone protection, the Rio 'Earth Summit', the Kyoto Summit), relatively little attention has been devoted to examining local activity within this global context". In fact, the limited attempts by cities at grasping environmental sustainability have resulted in similar patterns and indicators observed at the global level, placing exclusive emphasis on physical facts rather than behaviors. My thesis is therefore useful in that prospect as it seeks to correlate seven variables believed to capture environmental sustainability dynamics on the island of Montreal, and economic performance expressed as two distinct proxies. To some extent, this research will therefore add a local dimension to the empirical data already existing in the field.

Moreover, despite the recent popularity of indicators and indexes, "most indices have not generally been accepted for actual decision-making because of measurement, weighting and indicator selection problems" (Bartelemus, 2001). Esty (2002) shares this vision, considering that "plagued by widespread information gaps and uncertainties, environmental policymaking has often been based on generalized observations, best guesses, and ‘expert opinion’ – or, worse yet, rhetoric and emotion”. Living in an era of numbers where most realms have increasingly become data-driven, this thesis will make environmental management more quantitative, empirically grounded and systematic, and hopefully strengthen environmental problems at the Montreal policy level (Yale, 2005).

CHAPTER III: METHODOLOGY

We have seen that this study could add to the field of sustainability by fulfilling the constant need for empirical results and introducing a local aspect to the vast literature placing emphasis on the global level. Indeed, if many studies have explored the connection between a country's economic achievement and environmental performance, little attention has been drawn to this relationship at the municipal level. The literature gap concerns both broader dynamics such as the relationship between the environmental and economic aspects of sustainability and the interaction between the urban realm and its intrinsic ecological organisms. While challenging to measure at first glance, a recent impetus on the calculations of indicators has allowed the empirical grasp of environmental sustainability. Economic sustainability on the other hand, remains more straightforward as it is synonymous with the creation of wealth. The methodology section outlines the choice of indicators representative of Montreal, which first entails a series of adaptations from the global indicators.

3.1 Local vs. Global variables

The transition from a global focus to a local scale analysis involves some changes in the process of selecting relevant indicators. First and foremost, the local scale opens new perspectives compared to its broader counterpart as it allows for greater precision, a narrower focus in the data and the creation of indicators that would not be possible to include globally, especially targeting attitudes and behaviors. Data concerning the use of sustainable means of transportation to go to work for example, would not be as relevant and available at the country scale, in part because this factor is of little value to developing countries which prefer to concentrate on tangible economic development and fail to value its connection with enhanced environmental conditions. The sample would therefore be highly restricted given these countries' specific interest for more 'traditional' indicators.

On the other hand, relevant global indicators lose some of their validity on the island of Montreal for pure geographic purposes: exposure to environmental hazards for example, is probably the same across Montreal if we consider the extent of the phenomena and the total size of the island. From a similar perspective, the local scale entails lesser variance among the population, so that variables that are relevant globally may become useless in the running of statistical analyses. Given the economic distribution across the city and general level of development of a ‘Northern’ metropolis, access to drinkable water or undernourished population surely are relevant in a comparative study between Canada and Bangladesh for example, however these variables lose their validity at the local level.

Thus this local scale perspective allows for a privileged access to more precise datasets tackling new spheres of demographics analysis. This finer scope of analysis features two distinct aspects of environmental sustainability: one targets the individuals in particular, trying to get a sense of people’s ‘environmental concern’ and commitment toward environmental issues on a daily basis; the other focuses more on the physical facts, such as pollution and its impacts on the population’s health. The combination of the two is believed to provide an accurate sense of environmental sustainability at the local level. Despite Bossel (1999: 12) who considers that “GDP is now mainly a measure of how fast resources are squandered and converted into money flows, irrespective of their effect on society – hardly an indicator of national wealth and well—being” GDP has been consistently used by the literature as an indicator of economic achievement at the global scale. Considering the difficulty to come up with an exact local equivalent and the fact that it places emphasis on enterprises inputs and outputs rather than individuals, economic achievement was measured using individuals’ income as well as rent and real estate values, expressed through six different variables.

3.2 Primary vs. Secondary data

Overall, the approach pursued based on secondary data under the form of existing datasets instead of surveys or personal data collection, appears to be the most suitable for this research. As only limited research has focused on the local level, this study stands in conjuncture with the global literature and other methods would have simply been unrealistic or flawed the purpose and outcome of the analysis. The reliance on existing datasets from various academic databases, institutions and individuals allowed the access to a wide array of data, from pollution levels to voting behaviors and economic status. Of course, some challenges remained concerning unit of analysis or date of release, which are described in section 3.5, but these datasets suit best the inquiry of correlation between environmental and economic sustainability. On the contrary, the gathering of my own data through field research – through surveys for example - would have been unrealistic in terms of the study's temporal and spatial frameworks (552 census tracts) so the results would probably have been less representative of sustainability's multifaceted character and of the population on the island of Montreal.

3.3 Variables

A total of thirteen variables, spanning two environmental and two economic proxies were selected to be part of the statistical analysis. They were inspired by the availability of data on the island of Montreal, by the global literature on indicators (physical facts); others were adapted to the local level (economic status and real estate patterns) and lastly some introduced a genuine breakthrough in the literature (attitudes, initiatives). Four variables address directly the literature gap on individuals' commitment toward sustainability: use of sustainable means of transportation to go to work (public, walking, bicycling) and Green Party votes. Additionally, if public transportation or bicycle use reflects attitudes of people on their way to work, the magnitude of use also results from a genuine will from the city to promote these kinds of transportation by developing adequate and efficient infrastructures (metro lines, reserved bus lanes, bicycle paths). These four variables therefore capture peoples' initiatives but also the city's policies tailored toward fostering these initiatives. Montreal has successfully managed to incorporate these policies into its vision with the launching of the Bixi in 2009 or the STM's award as best American Public Transportation Association in 2010. The other environmental variables target health and pollution variation across the island through incidence of respiratory diseases, lung cancer and NO_2 concentration. Some would expect little variation within the island given its relatively restricted size as well as its lower pollution concentrations than Toronto or other large US cities such as Chicago, New York and Philadelphia (Ontario Ministry of the Environment, 2006), yet Gilbert et al (2005) have shown ambient air pollution does vary spatially in Montreal. Once again, variables targeting health (lung cancer incidence and respiratory mortality) were consistent with the literature on the matter, as many indicators have been interested in death or diseases causes related to environmental issues. Their aggregation at the CLSC region level

(Centre Local de Services Communautaires) required some data transformation, in order to adapt them to the census tract level.

Traditionally measured through Gross Domestic Product globally, economic performance was measured through two broad indicators - income levels and real estate values – expressed as five different variables. Production of wealth was measured as average family income, number of households with yearly income inferior to $10 000 and number of households with yearly income superior to $100 000. Property values were described as average gross rent, whereas the variable "number of people spending between 30 and 99% of income on rent" integrated both income and rent proxies. The integration of 'extreme' variables both in terms of income and property values, permitted greater variation in the data and often resulted in sharper and more straightforward findings. All variables were obtained from the Canadian Census Analyzer for the year 2006, consistent with other datasets. All variables are displayed in the following Table.

Table 3.3: Environmental and Economic Variables Constitutive of the Statistical Analysis

Variable name	*Unit of variable*	*Date of collection*	*Data source*	*Spatial unit of analysis*	*STATA code*
Green party votes	% Total	2006	"Elections Canada, 2006"	Precincts	*weightedgr*
Public transit	Count	2006	"Canadian Census Analyzer, 2006"	Census tracts	*weightedpu*
Walking	Count	2006	Idem	Census tracts	*weightedwa*
Bicycling	Count	2006	Idem	Census tracts	*weightedbi*
NO_2 concentration	Particles/ Billion	2005 - 2006	"Crouse, 2009"	Census tracts	*no2concent*

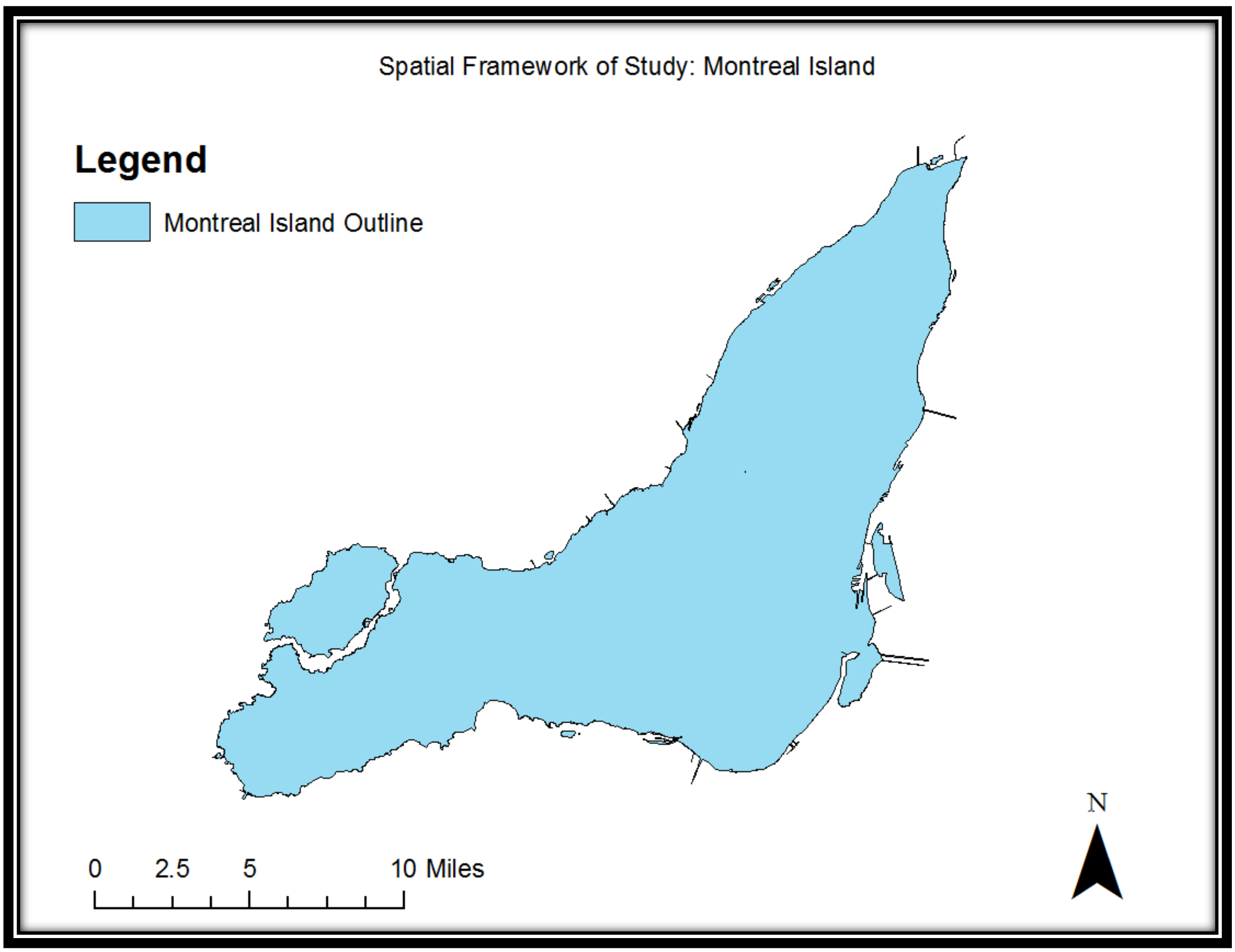
Lung cancer	Index	2001 - 2005	"Carrefour Atlas Santé, 2005"	CLSC	*lungcancer*
Respiratory mortality	Index	2001 - 2005	"Carrefour Atlas Santé, 2005"	CLSC	*respmortal*
Average family income	Dollars	2006	"Canadian Census Analyzer, 2006"	Census tracts	*averagefam*
Households with income > $100 000	Dollars	2006	Idem	Census tracts	*house-100000*
Households with income < $10 000	Dollars	2006	Idem	Census tracts	*househ-10000*
Tenant occupied households using 30-99% of income on rent	Count	2006	Idem	Census tracts	*tenantoccu*
Average gross rent	Dollars	2006	Idem	Census tracts	*averagegro*

3.4 Data Transformation

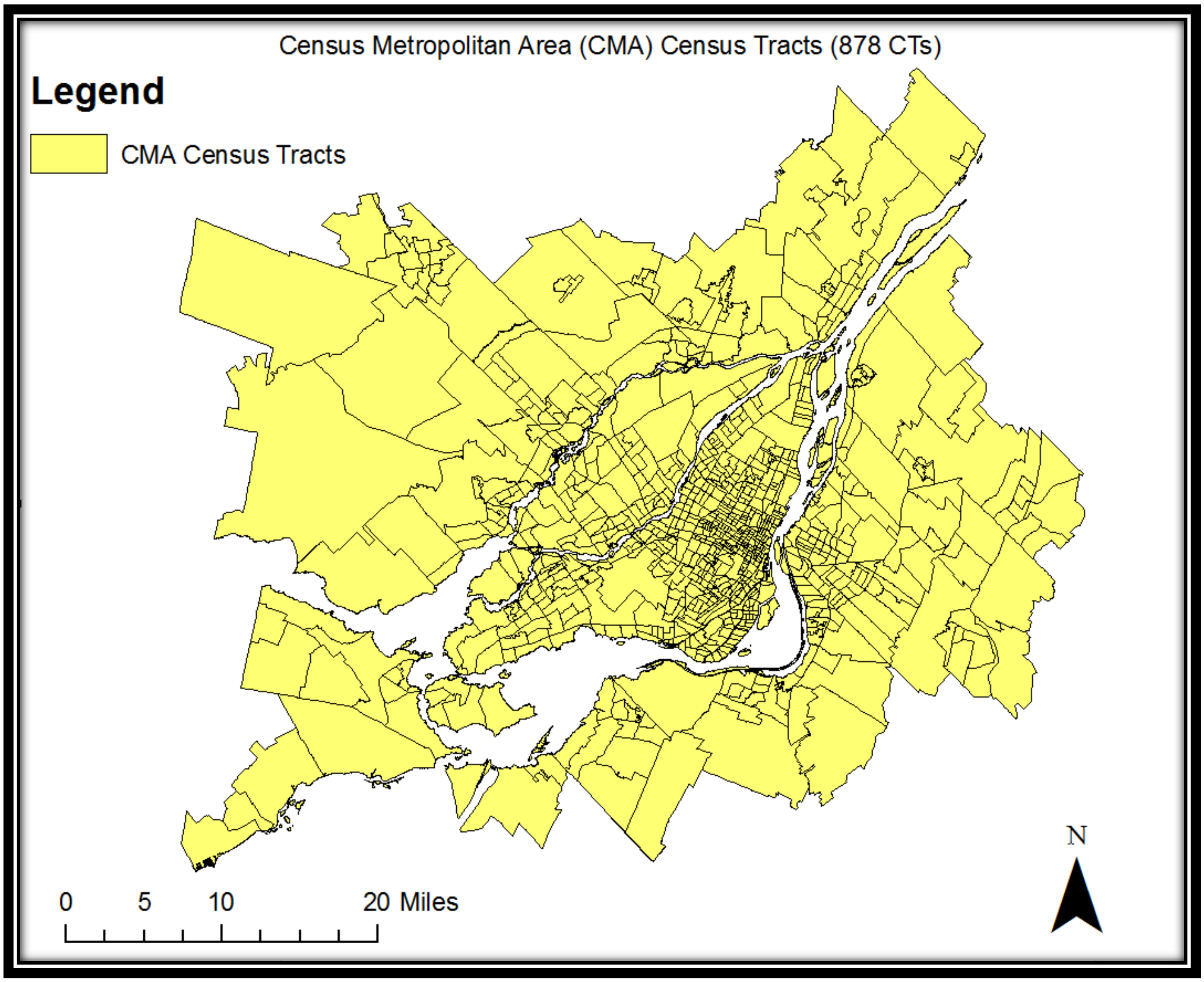
The first step to data transformation concerned the spatial framework and aggregation unit chosen for analytical purposes, which had to be processed into a more coherent entity as being constrained by the availability of the data. As a matter of fact, the census tracts file was obtained for the entire Montreal Census Metropolitan Area (CMA), which comprises the entire island but also Laval and other minor urban agglomerations such as Longueil. Two elements constituted sufficient incentives to solely focus on the Montreal island not the whole CMA: first in terms of voting patterns, the island delimitates exactly 18 federal electoral ridings, which was convenient for the aggregation of Green party votes. Furthermore, data provided by Dan Crouse was given for 501 census tracts from the 2001 census, all of which were strictly situated on the island. The

ArcMap software was used to obtain the final list of 'island census tracts': after the CMA shapefile was input into the program, the 'clip' function achieved through spatial file of the island obtained on the TRAM website, helped select and isolate census tracts of interest. As a result of this data processing, out of the 878 CMA units (Statistics Canada, 2006), 552 were localized on the island. The following maps display the Montreal Island contours (Map 3.3a; the CMA's census tracts (Map 3.3b), as well as the result of GIS manipulation: census units situated on the island (Map 3.3c).

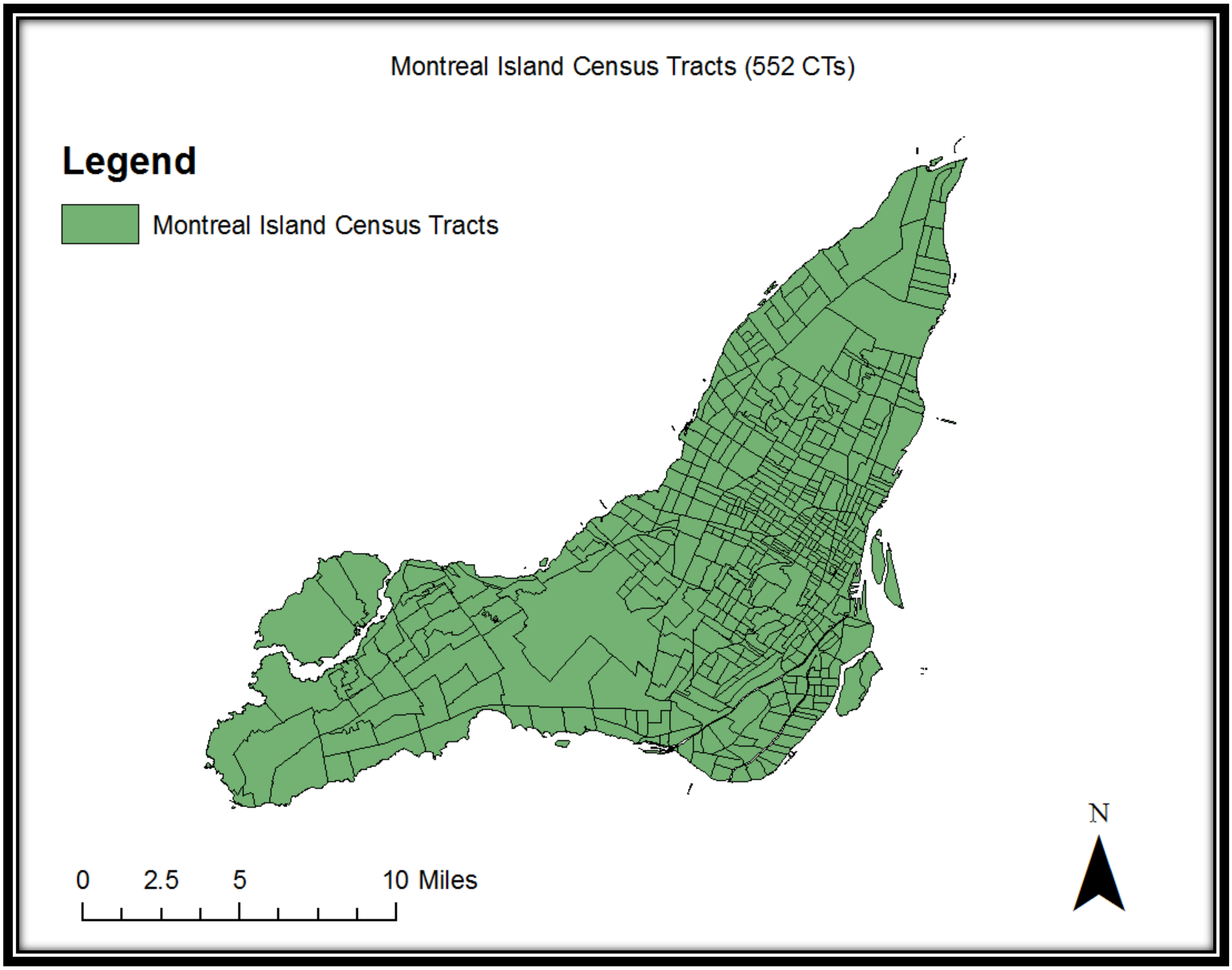
Map 3.3a: Spatial Framework of the study: Montreal Island



Map 3.3b: Census Tracts situated in the Census Metropolitan Area (CMA)



Map 3.3c: Census Tracts situated on Montreal Island



If most variables were relatively straightforward to input into the statistical software as already available at the census tract level, the fact that voting patterns were either offered at much finer (precincts) or broader (federal electoral ridings, Centre Local de Services Communautaires region - CLSC) scales entailed some data transformation. The voting results were downloaded from the Elections Canada website for the eighteen federal electoral districts on Montreal Island. These results were available at the 'precincts' level, an aggregation unit of approximately six residential blocks, and were obtained through the "pollresults_resultatsbureau" format, providing an entry for each candidate by polling station and including information on who the candidate is, the candidate's political party, and the voting results for that candidate at a particular poll. The first step of data processing consisted in a spatial join linking the CMA census tracts layer to the precincts layer. The spatial join was achieved through the 'ONE TO ONE INTERSECT' matrix resulting in the aggregation of several precincts into one census tract. This method had some imprecisions addressed in the following section, considering that precincts and census tracts do not exactly overlap. Alternative methods included a centroid matrix or an area-based transformation calculating the percentage of precincts present in each census tracts, but these were not necessary since the number of precincts falling into each census tract was sufficient enough to mitigate the imprecisions. Key attributes Federal District Number and Polling Stations were useful in providing a green party votes number for each precincts. The weighted average of these precincts green party votes was then calculated – given that precincts have different populations and therefore cannot be attributed the same weight – in order to obtain a unique indicator for each census tracts.

If the voting data necessitated an adaptation from a fine unit of analysis (precincts) to a somewhat broader one (tracts), the processing of the health variable measuring diseases with environmental causes involved an inverted transformation. Indeed, the diseases indicative of environmental causes were available at the CLSC level, therefore less precise than census tracts. The same process was undertaken, using a 'ONE TO ONE INTERSECT' matrix spatial join to associate one CLSC with several census tracts. Consequently, the same indexes for diseases indicative of environmental causes were repeated several times, causing precision issues. Nonetheless, the range of index values or cancer prevalence on the island still revealed statistical patterns and correlations in the analysis.

Additionally, Dan Crouse's study on landscapes of inequality in Montreal (2009) was based on data targeting NO_2 concentrations collected over three seasons between 2005 and 2006. If the consequences of this discrepancy are again expected to be minor, the fact that results were overlaid onto the 2001 census tract pattern is more problematic. Census tracts' spatial organization evolves as population growth and patterns change over time. Comprising a population ranging from 2500 to 8000, census tracts are divided in two distinct units as the population threshold is attained. For example census tract 4620570.0 (where 462 stands for the Montreal CMA code) is likely to evolve into 4620570.1 and 4620570.2 as the first exceeds 8000 people. Given that the census tracts' general spatial organization doesn't change but rather two units are created from a single one, the original 2001 value was adapted to both 2006 entities. Once again, this interpolation induces minor changes in the elaboration of the final dataset.

Lastly, the process of building maps displaying the spatial distribution of each variable necessitated data transformation on ArcMap. The Excel file could not be joined to the spatial file because the 'key', or common variable to both documents (census tracts identification number – CTUID), presented different data types: "string" on the GIS software and "double" in the Excel file. I added a field to the attribute table of the census tract spatial file labeled as "CTUID_Double" and adapted all string values to this field using the Field Calculator. The joining of the two tables could then be operated, adapting all environmental and economic scores to their respective census tract, enabling the elaboration of maps. Maps included in Appendix A add a visual component to statistical testes as they show distribution of the different variables' scores on the island.

3.5 Data Limitations

The first limitation to my study concerned precisely this disparity in spatial units of analysis. As mentioned above, some datasets were available at precincts or districts aggregation level, and therefore needed to be standardized into census tract in order to fit the analysis. Although precincts, tracts and districts boundaries revealed overlapping contours to some extent, the process of aggregating finer units into broader entities through the 'ONE TO ONE INTERSECT' matrix entailed some loss in precision in the final results. From a similar perspective, the fact that diseases indicative of environmental causes was incorporated into the research at the district level – considering data revealed inexistent at a finer unit of analysis – involved some lack of precision. As a matter of fact, there are 20 districts for 552 census tracts on the island of Montreal.

Another source of limitation regarded disparities in the years wherein data was collected. In order to be temporally consistent with the calculation of correlation between environmental sustainability and economic performance and be able to convey results about a particular year, datasets needed to derive from a specific year. In that prospect, although most datasets dated back from the year 2006, two variables were representative of other years. The data targeting diseases and their causes was collected over a four-year period from 2001 to 2005, therefore likely to differ somewhat from 2006 results exclusively. However, if the final statistical results might have been slightly affected by this discontinuity in the data, the impact is expected to be negligible given the slow evolution of the phenomena which is likely to be relevant and observable at the decennial level and certainly not within a two or three years span.

The final challenge to the validity of the statistical results stemmed from the multiplicity of units involved in the study, displayed as percentages, absolute counts and ranging from particles per billion to votes and dollars. This issue was brought up in the Yale (2005) report as common argument against the feasibility of empirically grasping sustainability. If the ESI index used already aggregated measures such as GDP or populated land areas as denominators, which allowed controlling for this wide array of units, my study did not make use of these standardized measures. Nonetheless, the fact that this study did not involve creating one aggregated index but rather considered variables individually, both in the data collection and statistical analysis where variables were correlated and regressed in pairs, lessened the issue and differentiated it from the ESI and other indexes encompassing more than 50 intertwined variables.

CHAPTER IV: RESULTS AND INTERPRETATION

This chapter first addresses the statistical tools at my disposition and how they can contribute to answer the initial research question: what are their specificities? What can we expect to see if there is a strong association between sustainability's economy and environment? Subsequent sections display the statistical results and seek to interpret them in light of the preceding description of different tools' potential and their comparison with the global scale findings.

4.1 Statistical background

Contrary to most global indices, all variables are not aggregated into an index but rather considered individually. As this research seeks to evaluate the strength, rather than inferring the direction of the relationship, two different tools were originally planned to support statistical tests: Pearson's correlation tests and regression analysis. In the first case, the correlation coefficient is the main indicator of the strength of the association between two or several variables. A value of '1' indicates a perfect positive association and '-1' a perfect negative association. For the second test, the coefficient of variation for each individual variable, as well as the overall 'R-squared' (R^2) providing the percentage of variation in the dependent variable explained by the independent variable(s). In both cases, the higher the critical value, the higher the association between environmental and economic sustainability.

Nonetheless, correlation and regression analyses differ in that they do not treat underlying patterns and influences equally, which in the case of sustainability and its multidimensional character is critical to address. Correlation and simple regression analyses incorporate underlying patterns driving the variation in the variables into the final results, which in some cases can undermine their validity if variables are highly interconnected. Multiple regression analysis on the other hand, is not subject to underlying patterns as it considers the variation of a single indicator, all other variables held constant. In fact, given that all variables are somewhat interconnected, the study was subject to issues of multicollinearity (described in section 4.3 of the report) which urged for a way to control for these intrinsic patterns as in some cases, multiple regressions gave different results from single regressions: Factor analysis in STATA, reducing the original data from a large number of variables to a restricted number of underlying factors appears as a solution to aggregate environmental and economic indicators into broader categories, targeting specific dimensions and therefore less prone to be interrelated.

In brief, Pearson's correlation, simple and multiple regressions and Factor analysis constituted my tools to investigate the relationship of interest and answer the research question. The next section outlines the results of correlation and regression analyses, confronting environmental and economic variables to each other.

4.2 Statistical results and interpretations

4.2.1 Results

The results of the first sets of statistical tests are displayed in the following tables (pages 39 and 40). Table 4.2.1a shows the correlation coefficients (black) and regression R^2 (green), resulting from the confrontation between environmental and economic variables. A star (*) indicates that the relationship is significant at the 95% confidence level.

Table 4.2.1b shows the signs of the coefficients stemming from the multiple regression models (using each environmental variable as dependent and economic variables as independent), the color code indicating similar (black) or different (red) directions compared to Table 2. A star (*) indicates that the coefficients are significant at the 95% confidence level. Appendix B displays all statistical testes with greater precision.

Table 4.2.1a[1]: Results of the preliminary correlation (coefficients) and regression (R^2) tests between environmental and economic variables

	Green Party	*Public Transportation*	*Walking*	*Bicycling*	*NO_2*	*Lung cancer*	*Resp. mortality*
Avg. family income	-0.1112 0.0103*	-0.4181 0.1731*	0.0088 0.0020	-0.0892 0.0059*	-0.1373 0.0168*	-0.3030 0.0899*	-0.1136 0.0108*
> 100 000	-0.3907 0.1509*	-0.4857 0.2343*	-0.1901 0.0341*	-0.2309 0.0513*	-0.31 0.0942*	-0.3573 0.1258*	-0.1947 0.0359*
< 10 000	-0.1629 0.0245*	0.2732 0.0727*	0.2330 0.0523*	0.0383 0.0006	0.20 0.0379*	-0.0057 0.0021	0.0473 0.0001
30-99% income on rent	-0.2928 0.0838*	0.1656 0.0254*	0.0300 0.0012	-0.0786 0.0041	0.1038 0.0087*	-0.0389 0.0006	-0.0616 0.0017
Average Gross rent	-0.1220 0.0128*	-0.3424 0.1154*	0.1262 0.0138*	-0.0687 0.0026	-0.0352 0.0009	-0.3216 0.1015*	-0.1018 0.0083*

[1] Considering that simple regression models and Pearson's correlation analysis gave the same results in terms of direction of the relationship, the Table focuses on indicators of its strength, correlation coefficients and R^2, which explains the absence of regression coefficients.

Table 4.2.1b[2]: Results of the multiple regression models and comparison of the coefficients direction with Table 2

	Green Party	*Public Transportation*	*Walking*	*Bicycling*	*NO_2*	*Lung cancer*	*Resp. mortality*
Avg. family income	+*	-	+*	+	+	-	+
> 100 000	-*	-*	-*	-*	-*	-*	-*
< 10 000	+	+*	+*	+*	+*	-	+*
30-99% income on rent	-*	-	-*	-*	-	-	-*
Average Gross rent	-	-*	+*	+	+*	-*	-
R^2	0.2658	0.2815	0.1859	0.0689	0.1349	0.1612	0.0461
Prob > F	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.001*

[2] The Regression Models were conducted with each environmental indicator as dependent variable (left of the model) and economic indicators as independent variables (right of the model). The signs of the coefficients were then compared to the single regression analysis using a color code: similar direction in black and opposite direction in red.

4.2.2 Interpretations

Despite clear trends concerning the relationship between income and the local achievement of sustainability, the results were not as strong as expected after review of the global literature. Section 4.5 explores possible reasons explaining these weak coefficients.

With regards to attitudes, the relationship between income and green party votes seemed to follow a bell-shaped curve: the strong negative association between Montreal's lower income population (spending from 30 to 99% of income on rent) with a negative correlation coefficient of - 0.29 and highest income stratification ("number of households with income > $100 000") with a negative correlation coefficient of – 0.39, suggested a fairly high association between the environmental variable and its economic counterpart at extreme ends of the income distribution. Running the regression between "number of households with income > $100 000" and Green Party voting, the R^2 of 0.1509 advanced that the variation in the former explained 15% of the variation in the latter. The negative sign of the coefficient (- 3090.879) indicated an important drawback of these opposed income categories from Green Party voting. Average income and average gross rent display mitigated values, correlation coefficients respectively equal to 0.11 and 0.12 with green party voting, showing much weaker patterns of association. There are several potential explanations for these results.

The voting process has complex dynamics as explored by Lieske (1989): how many votes can be gained from newspaper wards? What is the influence of incumbency? How important are the personal qualifications of the individual candidates? These are as many questions explored by Lieske (*Ibid*) attesting of the difficulty to grasp voting behavior inscribed in other human science fields such as psychology or sociology. Nonetheless extreme income situations can act as incentives to vote for a party that better reflect one's economic interest. If one spends between 30 and 99% of income on rent, leaving restricted margin to invest in other goods such as food, it is legitimate that this person's voting behavior will attempt to fulfill this gap through a party encouraging social equality, such as 'Québec Solidaire' for example. The achievement of sustainability becomes secondary to personal economic concerns, just as lesser off countries prefer to concentrate on economic development strategies rather than commitment to sustainable indicators because the direct connection between an improved environment and economic outcomes is not always obvious. Similarly, Montreal's highest income population may want to elect a party privileging liberal policies aimed at fostering their capital. The Green Party traditionally defends social measures, so higher income earners might therefore direct their votes toward the Quebec Liberal Party for example.

While these interpretations by no means attempt to categorize voting behavior on economic standards nor defend/undermine political parties, the results attest for some kind of trend targeting extreme income situations which might act as incentives in the context of an election. In fact, similar findings were inferred concerning the use of sustainable means of transportation.

Overall, public transportation use was the most strongly correlated with economic status among the other sustainable means of transport – which is not surprising considering bus and metro are the easiest and most common ways of commuting publicly all year long in Montreal's varying weather. The strong negative coefficient (- 0.49) associated with "number of households with income > $100 000", as well as average family income (- 0.42) corroborate the previous findings that as people get wealthier, they increasingly turn their backs toward indicators of sustainability commitment. The running of a simple regression model between "number of households with income > $100 000" and public transit use resulted in an R^2 of 0.2343, showing variation in the former explained 23% of the variation in the latter (coefficient is equal to – 1815.027). The regression between average family income and public transit use resulted in similar results, with a 17% explained variation and a coefficient of – 280883.3. On the other side of income distribution, the positive coefficients associated with tenants spending 30-99% of income on rent (0.17) and household income < $10 000 (0.27) are coherent with the previous findings. It is interesting that these findings applicable for public transportation more generally apply to walking and bicycling as well. As a matter of fact, all sustainable means of transportation (public transit, walking, bicycling) are negatively correlated with "income > $100 000" (coefficients respectively equal to – 0.49, - 0.19 and – 0.23), and all positively correlated with variables indicative of lower incomes such as income < $10 000 (coefficients respectively equal to 0.27, 0.23 and 0.04).

These results show that higher incomes – while being able to choose between polluting cars or a fairly efficient sustainable transit network in Montreal – elect the former solution and take their own vehicles to go to work. However, lower incomes' adoption of more sustainable commuting habits does not necessarily reflect their own choice toward the achievement of sustainability: some just cannot afford an individual vehicle, while others are constrained by the escalating oil prices and therefore don't have the choice but to use sustainable means of transportation to go to work.

In terms of attitudes, it is clear that environmental concern and the achievement of sustainability is inversely correlated with income: as people get richer, they tend to ignore the Quebec Green Party – perhaps because of its traditional social dimension – and turn their backs to sustainable means of transportation, privileging the use of their individual car. These results stand in line with a study from the US Bureau of Labor Statistics which showed that households with an annual income comprised between $5000 and $10 000, spend on average around $2000 on their individual car against $7000 for households with income equal to $70 000 (BLS, 2000). If the other environmental variables do not capture attitudes, the confrontation with the economic variables suggested patterns of pollution and respiratory disease spatial distribution. Once again, while coefficients remained low, their signs made intuitive sense and allowed to distinguish trends.

Negative coefficients describing the relationship between average family income and NO_2 concentration across the island, respiratory mortality and lung cancer index (respectively – 0.14, - 0.11, - 0.30) show that richer people tend to live in less polluted areas and are therefore less subjects to respiratory diseases such as lung cancer. This inference is verified by the correlation test with the richest variable (> $100 000), which shows even greater coefficients (- 0.31, - 0.2, - 0.36) and attests of a negative linear relationship. Additionally, variables indicative of real estate and rent patterns converged in the same direction: average gross rent was negatively correlated with NO_2 concentration (- 0.04) and with all health variables as well. On the contrary, the variable representative of people spending 30-99% of income on rent was positively correlated (0.10) with pollution levels in the island. More generally on the other side of the income distribution, the relationship between income < $10 000 and NO_2 concentration as well as respiratory mortality was positive (0.20 and 0.05). The association between the economic variable and lung cancer was very weak but negative. These results suggest that wealthier people have more possibilities to choose where to live and select nicer and less polluted areas, whereas poorer people do not have this option and follow low rent zones. Some of these low rents are situated in old industrial areas susceptible to be more polluted than others. As a result, people with a lower income appear to be more vulnerable to respiratory mortality, as shown by the positive correlation coefficient associated with the number of households with income inferior to $10 000 annually (0.04). Less wealthy citizens may also have a limited access to health care and specific treatments for lung cancer for example.

Sticking to sustainability's accepted definition, these results suggest that poor people live in more polluted areas of the city, and they are therefore more exposed to diseases due to environmental causes. While this would suggest that they are being less sustainable, the restricted spatial framework of study entails some distance to take with this reasoning. Study limitations, including issues of spatial framework are addressed in section 4.6 of the report.

4.3 Factor Analysis

4.3.1 Why proceed to Factor analysis?

Simple regression models were performed between each economic indicator and all environmental variables, giving analogous results – in terms of strength and sign of the relationship - as the correlation analysis. Nonetheless, some multiple regression models, ignoring underlying dynamics, came in contradiction with the original findings, urging for a way to control these inconsistencies stemming from multicollinearity. For example, as the Green party votes variable was negatively correlated with income, the multiple regression model indicated that all other variables held constant, for each increase in Green Party votes, average family income also increased by a coefficient of 86786.73. The multiple regression model with income > $100 000 nonetheless displayed results coherent with the correlation analysis with a negative coefficient of -1346.153. This inconsistency highlighted the fact that all variables – environmental and economic - are in fact correlated with each other, as they capture similar patterns. Indeed, we can consider that NO_2 concentration is driven by urban density, concentrating polluting factors within one restricted space, just as a dense urban environment equally facilitates all kinds of sustainable means of transportation. Density then, among other factors, is responsible for multicollinearity amongst environmental variables.

4.3.2 Election of proxies

The first step of the Factor analysis is the attribution of an Eigen score, determining the number of Factors or broader categories chosen for each sustainability dimension. A sudden drop in Eigen values, or an Eigen score of 2 is commonly used as rule of thumb to elect the number of proxies believed to provide an accurate sense of environmental dynamics. The first factor scored an Eigen value of 2.7 and the potential second and third factors respectively scored values equal to 1.0 and 0.2. Theoretically, as the drop occurs between the first and second factors, only one proxy should be adopted for environmental variables. Nonetheless several factors encouraged me to deviate somewhat from the theory: considering that all variables that I had originally pinpointed as “attitudes” scored high within the first factor, I decided to create a proxy for voting and transportation behavior, aggregating Green Party voting, public transportation, walking and bicycling to go to work together. As I was simply going to regroup all other “physical facts” targeting pollution and health into another proxy, I realized that the health variables scored negatively in the second factor, standing in contradiction with the NO_2 concentration. As they probably captured distinct variations, “health” and “pollution” therefore became two different proxies, the first incorporating respiratory mortality and lung cancer, and the second considering NO_2 concentration individually.

The same process was achieved for the economic variables. The first Eigen score of 2.5 was selected to be part of the analysis as the drop in values occurred before the second Eigen score of 1.2. However given the variability in the economic variables in terms of units (counts, dollars) but also the fact that they covered the whole scope of income distribution, from people earning less than $10 000 annually and spending 99% of income on rent, to households with an annual income superior to $100 000, I decided to include average values capturing income and real estate/renting patterns. “Average family income” and “average gross rent” were therefore selected to constitute the proxy for economic variation across the island in the factor analysis. A proxy called “economic” was created after these two variables and confronted to environmental aggregated variables. In order to verify that multicollinearity was indeed controlled for through factor analysis, average family income and average gross rent were first considered individually against attitudes, health and pollution indicators.

4.3.3 Results of the Factor analysis

Table 4.3.3a displays the results of the simple regression (R^2, green) and correlation (coefficients, black) among different proxies.

Table 4.3.3b shows the results of the multiple regression model using a single indicator for economic variables and three indicators for environmental ones (coefficients and R^2). A star (*) indicates that the regression coefficients are statistically significant at the 95% confidence level.

Table 4.3.3a: Results of the simple correlation and regression analyses between aggregated variables

	Attitudes	Diseases	Pollution
Avg. family income	-0.1722 0.0296	-0.2258 0.0472	-0.1373 0.0168
Avg. gross rent	-0.1258 0.0136	-0.2335 0.0488	-0.0352 0.0009
Economic	-0.1657 0.0265	-0.2555 0.0603	-0.0958 0.0071

Table 4.3.3b: Results of the final multiple regression model between aggregated variables

	Attitudes	Diseases	Pollution
Economic	-0.0555622	-0.2047145*	-0.014785
R^2	0.0661	0.0661	0.0661
Prob > F	0.0000*	0.0000*	0.0000*

4.3.4 Interpretation of the results

The results of the factor analysis mainly corroborated the correlation and simple regression findings. As a matter of fact, the three environmental proxies were negatively correlated with average family income (respectively -0.17; -0.23 and -0.14) and average gross rent (respectively -0.13; -0.23 and -0.04), underlining the fact that as people get richer, they perform lower compared to less wealthy individuals for the chosen indicators. As expected, similar findings were inferred when dealing with the single proxy for economic performance, aggregating the previous two variables into a single one. Negative coefficients of respectively -0.17, -0.26 and -0.10 suggested, like most other tests, a fairly high negative relationship between the economic and environmental spheres of sustainability.

Factor analysis was elected as a way to control for multicollinearity across variables, undermining the statistical results by showing contrasting patterns between simple correlations and regressions and multiple regression models (as shown by Table 3), considering the variation of a variable, all other variables held constant. The aggregation of variables into broader categories aimed at reducing interrelations amongst them. As environmental variables were reduced to three different proxies and economic to a single one, the running of the multiple regression model with "economic" as dependent and "attitudes", "health" and "pollution" as independent variables resulted in similar results to simple regression and correlation associations: all three coefficients were negative, witnessing the decrease in attitudes, pollution and health as income increased, consistently with trends observed from the beginning. The fact that only average family income and average gross rent were chosen to constitute the economic proxy probably played a role in controlling for multicollinearity, considering that fewer variables were involved and therefore less likely to be interconnected.

If the results are consistent throughout the study, messages have different weights if we consider some study limitations, explored in further details in section 4.5. Issues of spatial framework entailed to take some distance with the results suggesting that as people get wealthier, they tend to live in less polluted areas of the city, and are therefore less prone to cardiac and respiratory diseases. In effect, if this assumption can hold at the global level given the important spatial framework involved, the relationship is more ambiguous at the Montreal scale: a polluted area of the city can have its source is other parts of the city or within the greater CMA since NO_2 levels fluctuate with air currents. If one can conceive that richer people have the possibility to elect nicer, less polluted areas closer to mountain neighborhoods such as Outremont or Westmount then these results make intuitive sense. This research does impose a causal relationship since this remains to be confirmed at a greater, more relevant spatial scale. Attitudes concerning transportation use and voting patterns, while being driven by factors other than simple commitment to sustainability such as urban density or access to transportation networks, are believed to show a much clearer association with economic patterns and stay relevant at the local scale. In effect, if accessibility or density undoubtedly affects public transportation use, the different means covering a large scope of distances (people can walk for short distances to work, bicycle for longer ones and use public transit for important distances) somewhat controls for this underlying pattern.

In short the main outcome of the study targets attitudes: for the indicators chosen (many others can be used for further research), there is a fairly strong linear association between environmental and economic dimensions of sustainability. The next section considers this finding in relation with the global appreciation of this relationship.

4.4 Relation with the global trends

It is interesting that the statistical results mostly displayed dissimilarities with the global literature in terms of relationship income/sustainability. The negative relationship between economic achievement and environmental concern stands in opposition with Grossman and Krueger’s (1995) view summarized in Beckermann’s sentence: “in the longer run, the surest way to improve your environment is to become rich”. Higher omniscient instances (UN, Kyoto protocol) incentivizing countries into sustainable paths do not exist at the local level, so richer people are not pressured into sustainability.

In addition, the wealthy do not tangibly benefit from positive backlash effects of their daily commitment to sustainability, contrary to international firms which can build a customer basis and enhance their image through such policies. From this perspective then, Wagner’s view (2001) that stringent environmental regulations can lead to ‘win-win’ situations resulting in economic profit cannot apply at the local level. Indeed if well-off people do not get penalized from their lack of involvement, nor do poorer people benefit economically from their sustainable habits.

The bell-shaped relationship between income and pollution levels defended by Matthew Kahn (2006) – while to some extent applicable to the association between green party votes and income – does not seem to accurately represent the general trend which appears more linear. Indeed, the results do not seem to make sense of that specific income threshold by which profit suddenly allows a better management of pollution and better sustainable path.

In brief, this local study contrasts in all points with the global literature: if from an economic point of view, richer people do achieve sustainability by producing economic wellbeing, they fail from an environmental perspective. This linear relationship opposes the structural models proposed by several global theorists and opens new perspectives for further studies on the matter, as this research acknowledges certain limitations that can be controlled for in the future.

4.5 Study Limitations

As already stated, although most coefficients showed underlining trends which made intuitive sense, they were much weaker than expected after such establishment of clear links between income and environmental sustainability in the global literature.

First and foremost, the restricted variation of data across the island is a major factor in explaining these flaws. As a city competing for global status, the chosen variables did not vary as much as they would through a comparison among countries with different levels of development. Underdeveloped countries have striking income disparities while most of Montreal's income distribution is concentrated around the median (see income distribution graph). The 4.48% score of the Green Party in 2006 federal elections, reaching a historical peak of popular vote in 2008 (6.80%) and thus the relative restricted number of partisans, makes it difficult to obtain important disparities across the island. This obstacle is aggravated by the choice of census tracts as spatial units of analysis: it provided precise information on the spatial distribution of variables, but it also mitigated variation as 'hotspots' of Green Party votes are likely to be broken down given the 552 island census tracts.

The restricted spatial framework also made physical attributes such as pollution or disease rates less valuable at the local level compared to the global scale. Indeed, while a country's level of development can be accounted responsible for its pollution – and therefore unsustainable practices - at the global scale, the spatial framework entails much more complex dynamics at the local level preventing such straightforward association: pollution of a certain neighborhood can originate in the neighborhood itself, in which case locals are responsible for these emissions and act in an unsustainable manner. However some polluted zones of Montreal can find their roots in other parts of the city, transported through air corridors. Nonetheless, the incorporation of these variables in the model still highlighted the (feeble) correlation between lower incomes and census tract pollution as well as respiratory disease incidence.

Another downfall of the study stands once again in sustainability's abstract nature and the attempt to grasp some aspects of it through variables that cannot grasp it in its entirety. It remains challenging to capture attitudes as other parameters have to be taken into consideration other than income: family influence, education, relations network are as many factors that can influence a well off individual to vote for the green party and commit to sustainability daily, or a poorer person into voting for a party whose environmental preoccupations are remote from other priorities. Variables used are believed to provide a general trend of the distribution of sustainable practices across the island, not induce narrow judgmental values or categorize people because of their voting behavior. As the Green Party suffrage has remained constant since 2007 (3.85% at general elections) and sustainable practices inevitably multiplied as the result of enhanced awareness campaigns and its new 'fashionable' dimension, voting behavior – and other variables - is not the ultimate indicator of sustainability. Similarly, sustainable transportation use can be driven by environmental awareness but also by many other factors such as population density and patterns of transportation networks resulting from city planning strategies. These attitudes have also other aspects such as recycling, involvement in organizations promoting urban agriculture for example, which are harder to seize compared to transportation or voting data and would require a political and institutional push toward census data and survey completion.

Additionally, as much as sustainability fundamentally relies on choice and conviction, it also relies on a person's capability to achieve it. Therefore it might be useful to focus primarily on variables depicting high incomes, as they have the possibility to choose between different transportation and following the trend, deliberately elect their own vehicles as primary solution. Poorer people on the contrary may commit to sustainability by making use of public transportation not by choice but rather by constraint because they cannot afford escalating oil prices or the ownership of a car. Hence it is more by focusing on richer stratifications' demise of sustainable principles rather than poorer classes' apparent attachment to these principles that this research is valuable.

These two main points setting limits to the reach of the study fall into a broader category of ecological fallacy, major obstacle to any research making inferences at the individual level, based on aggregate data for a group. Indeed, this aggregation of data may conceal some variations existing at a finer scale and invisible at the Montreal island scale because these variations are being balanced out by others. This ecological fallacy is worsened by the fact that some variables were available at the CLSC level, entailing some loss of precision and therefore expanding the generalizations made for the populations concerned. Also, the fact that the variables chosen were driven by other factors as well, and that many other variables capturing sustainability dynamics could have been included make these generalizations for the Montreal island population subject to flaws. Nonetheless, the recognition of limitations stemming from ecological fallacy, and the choice of census tracts as unit of analysis – arguably the finest unit of analysis in terms of data availability and accessibility – reflect the objectivity of the study and desire to open perspectives built around these limitations, to better investigate this relationship between environmental and economic spheres of sustainability.

CHAPTER V: CONCLUSION

On a personal note, this research allowed me to connect my past discovery of sustainability in an urban context through urban agriculture, my present studies in urban systems and incorporating sustainable principles into a future planning or design oriented profession. The writing of the GEOG 381 essay on sustainability's Triple Bottom Line fostered this desire to know more about this catchphrase everyone knows about, yet highly abstract and poorly defined. The research question inquiring into the strength of the relationship between the environmental and economic spheres of sustainability, sought to disentangle this ill-defined concept, subject to contentions within the literature: like Wagner (2001), Solheim (2010) has underlined the environment's role as keystone in triggering positive economic outcomes, Beckerman (1992) and Grossman (1995) have estimated that the best way to achieve environmental sustainability is to become rich.

Environmental sustainability, standing at the core of this study, is challenging to measure. The multiplicity of units and time frames involved, and the capturing of similar variations, makes it prone to issues of multicollinearity. Nonetheless, a recent impetus based on the creation of specific indicators of environmental sustainability, has sought to get an empirical sense of the term. Wackernagel's Ecological Footprint (1996) at the global level and the Transportation Research Board's transit indicators using cities as unit of analysis, are examples of these initiatives. Most variables and indicators have one point in common: they focus on the physical dimension of sustainability, targeting waste management, pollution levels and their effect on health; little or no effort has been accomplished to pinpoint attitudes and what drives citizens to commit to sustainability.

My dataset therefore included a mix of traditional indicators, variables adapted from the global scale to the local level, and others believed to capture attitudes, although they also depended on other factors such as density or public transportation accessibility.

After running correlation, regression and factor analyses, the message delivered concerning attitudes rather than more ambiguous pollution and health dynamics, was clear: there is a fairly strong negative linear association between environmental and economic spheres of sustainability where attitudes are concerned. In other words, as people get wealthier, in spite of having the choice between the polluting car solution and sustainable means of transportation, they tend to elect the former alternative and turn their backs to the Green Party. On the other side of the income distribution, poorer people may privilege sustainable means of transportation and Green Party voting, but this may happen because they cannot afford the ownership of a car and oil prices, not by genuine concern for sustainability. Thus economic sustainability is strongly connected to, but is not a precondition, to the achievement of environmental sustainability, nor does it stand as a consequence of sustainable practices on the island of Montreal. These results contradict the global findings as a whole.

There is still much work to accomplish on sustainability, its relationship with economic and social realms. Notwithstanding the limitations of this study, it opens much space for improvement, opening new horizons for research on sustainability. Future studies will have to find a balance between both extreme scale levels, countries as unit of analysis and Montreal Island's restricted area of 500 km^2, maybe inquiring the economic/environment relationship at the domestic scale, using Canada's provincial system or using an even finer scope, French 'départements' system. This compromise would allow to access 'finer' variables such as sustainable modes of transportation accessible at the local scale, while gaining variation in the data. Variables targeting pollution levels and health would also become more relevant as a polluted area is less likely to originate from another source. A balance of scale therefore allows combining advantages of both scales, controlling for their respective flaws. Issues of multicollinearity would be mitigated, as underlying patterns would link variables in a less evident way.

Of course, other variables could be incorporated into the model, trying to capture other aspects of sustainability, such as prevalence of urban agriculture which could be obtained for major urban centers within the perimeter of interest. Making use of environmental incentives to attract suffrage nowadays, political instances could widen the scope of census information, including more questions targeting sustainable practices, so that variables grasping precise incentives such as recycling or involvement in environmental groups could be included in the model even at a broader scale. From a similar point of view, the running of surveys fulfills the same purpose.

Finally, as this research fundamentally relies on individuals, future inquiries would also concentrate on local and broader enterprises' behavior, calculating the actual payback of ecological incentives at a finer level than country, or internationally.

These initiatives could be precious in tailoring enhanced approaches to better grasp the interactions between the environmental, economic and more obscure social spheres of sustainability's triple bottom line as these interplays stand at the core of human adaptation to global challenges, "without compromising the ability of future generations to meet their own needs" (WCED, 1987).

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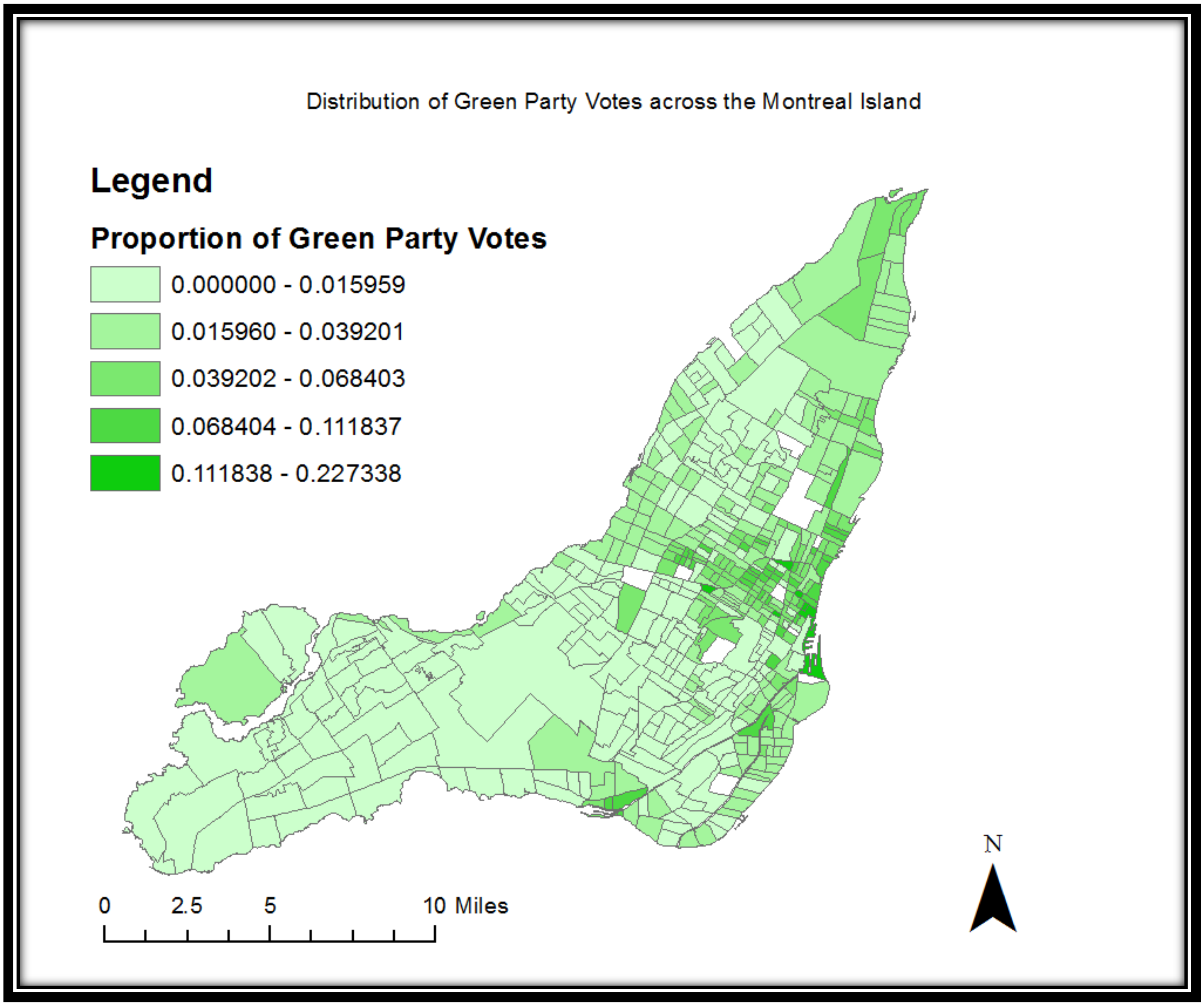
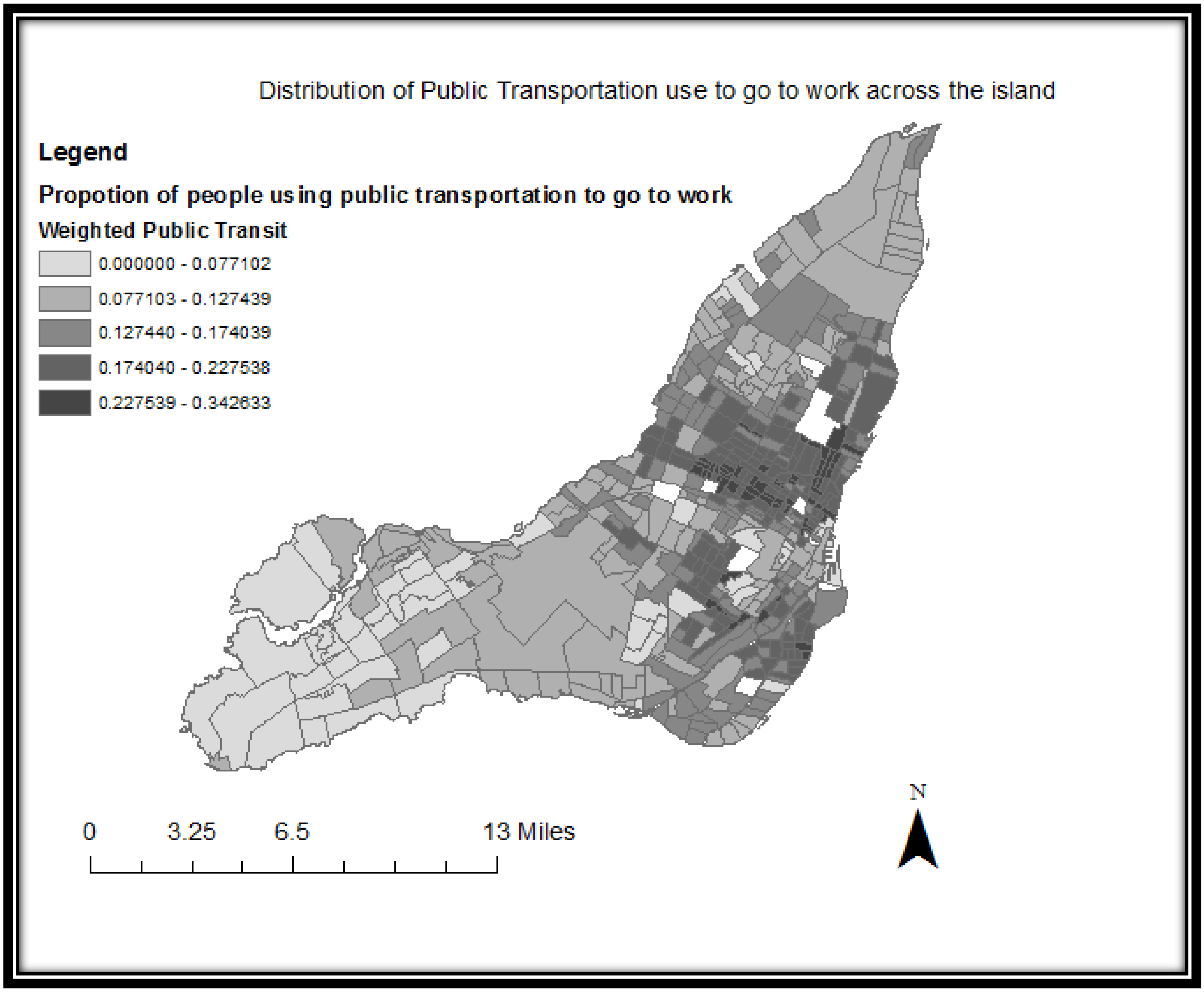
Appendix A:

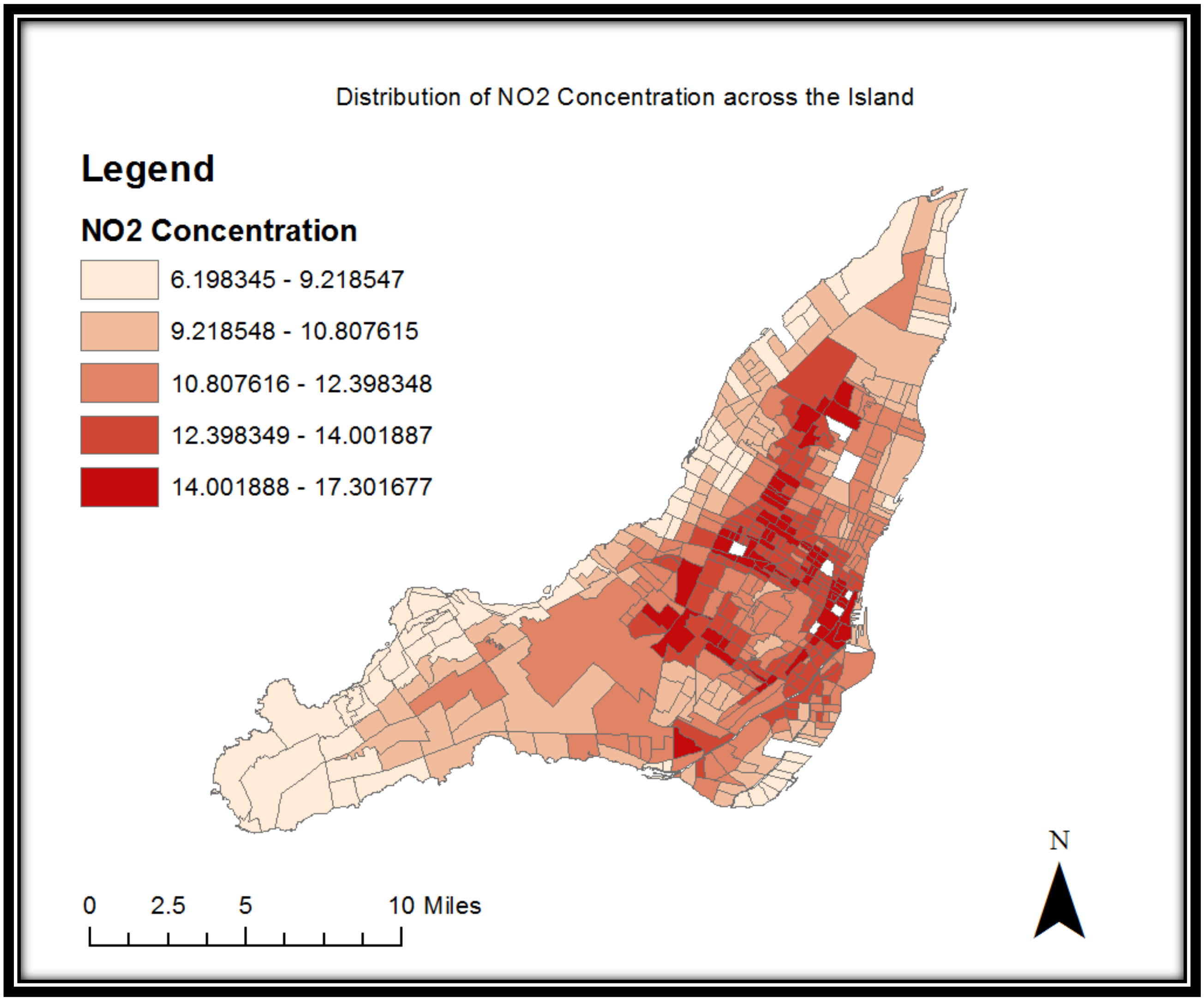
Map 3.5a: Distribution of Green Party Votes across the Montreal Island:



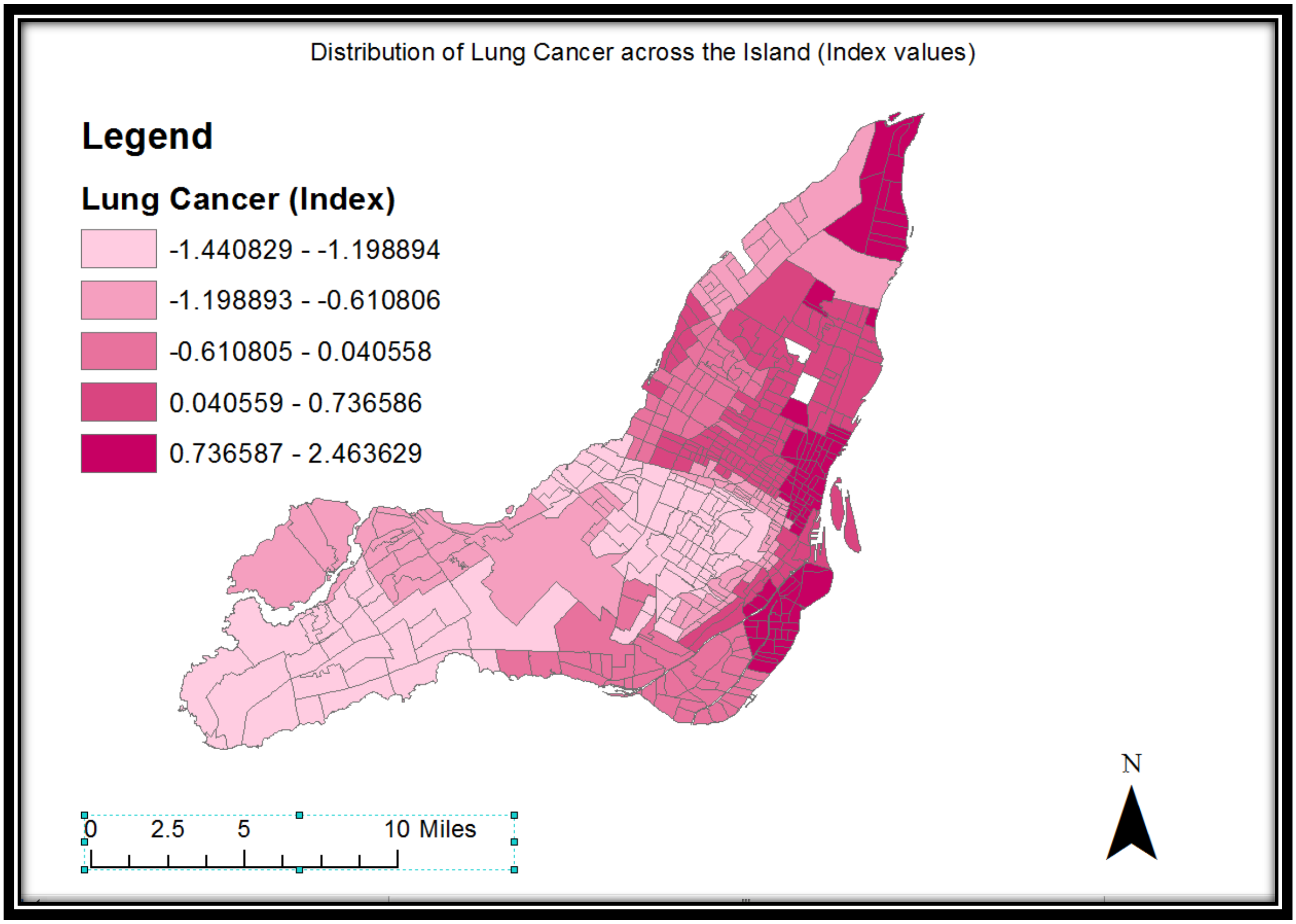
Map 3.5b: Distribution of Public Transportation behavior across the Montreal Island:



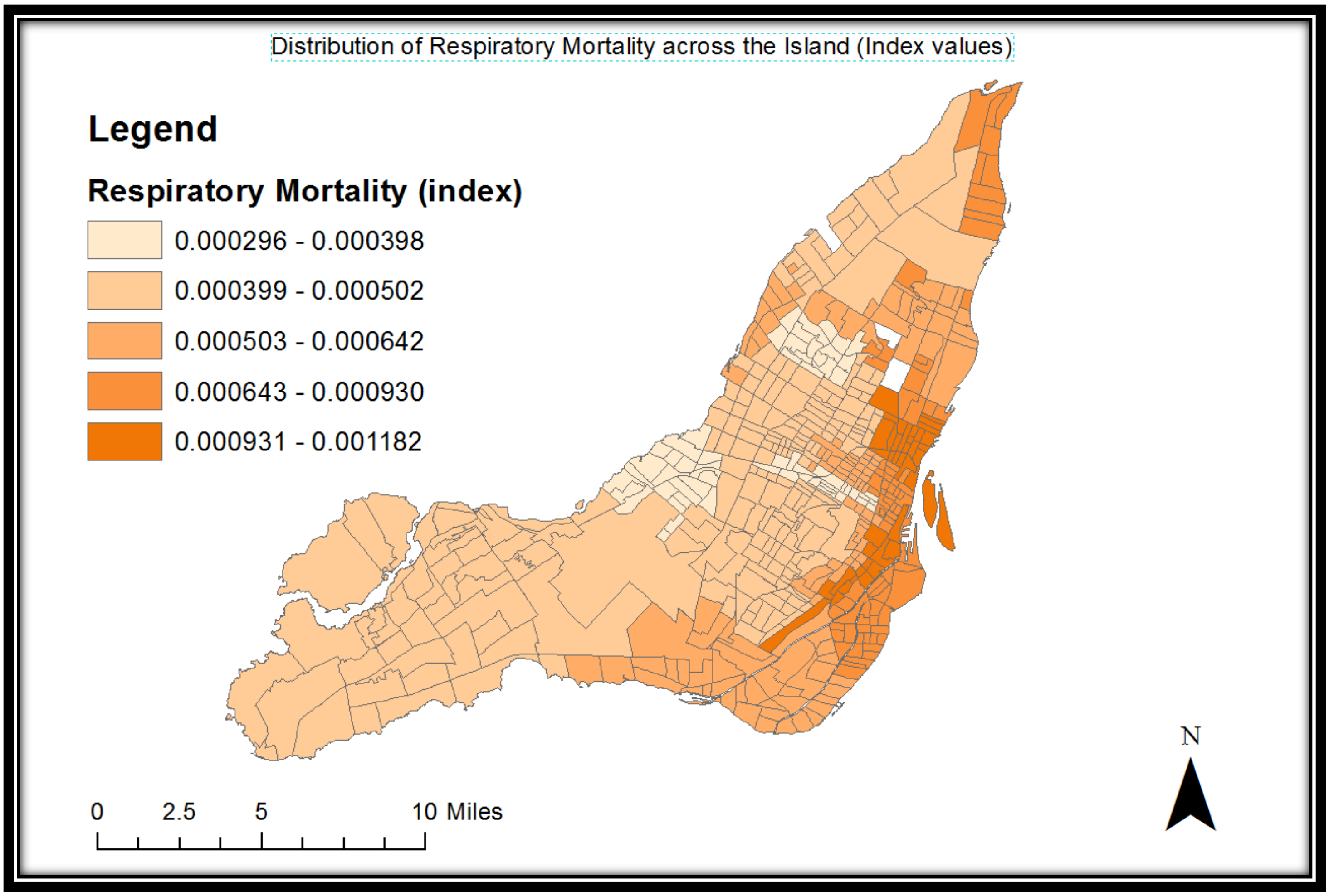
Map 3.5c: Distribution of NO2 Concentration (particles/bn) across the Montreal Island:



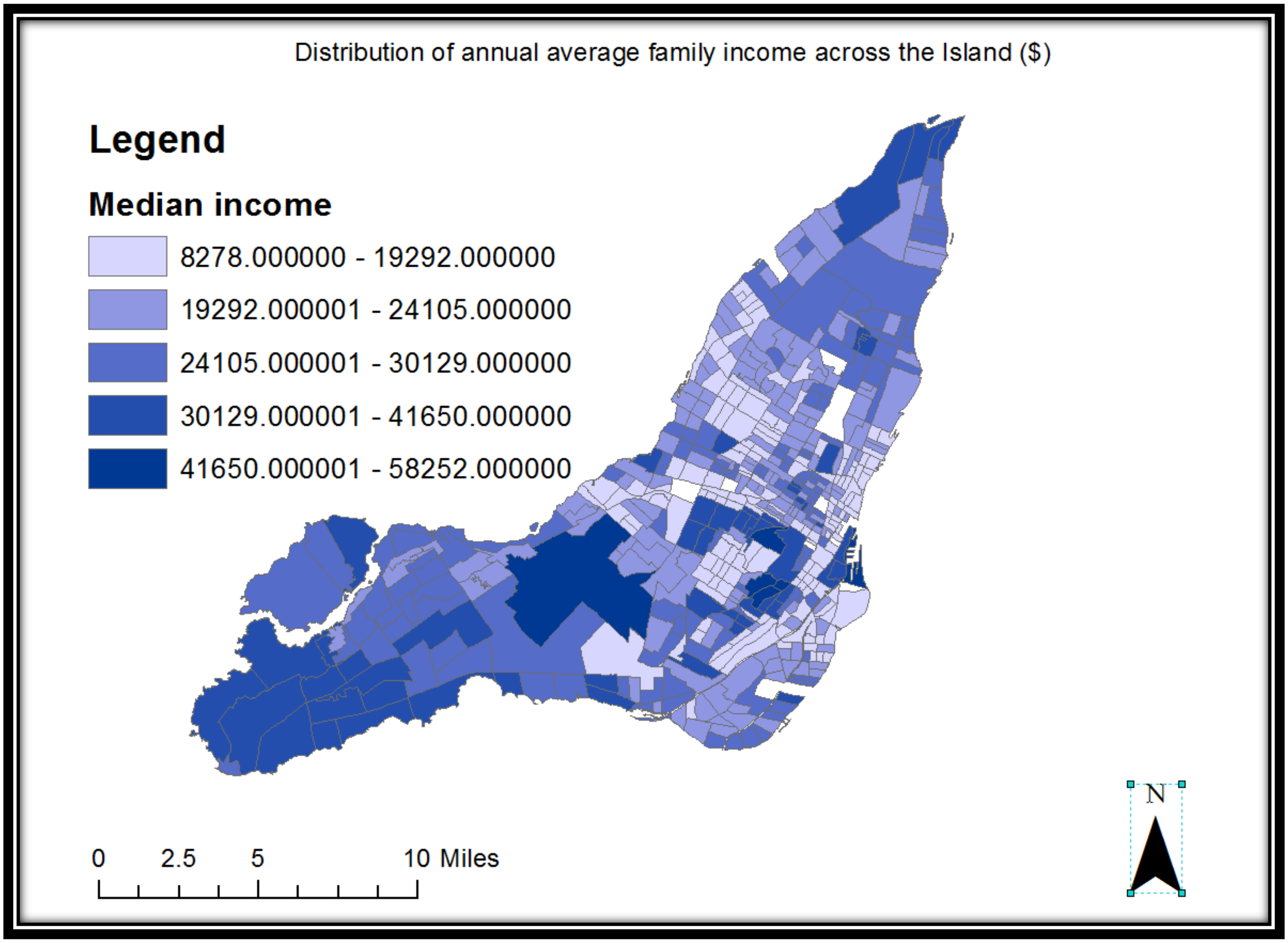
Map 3.5d: Distribution of Lung Cancer (Index values) across the Montreal Island:



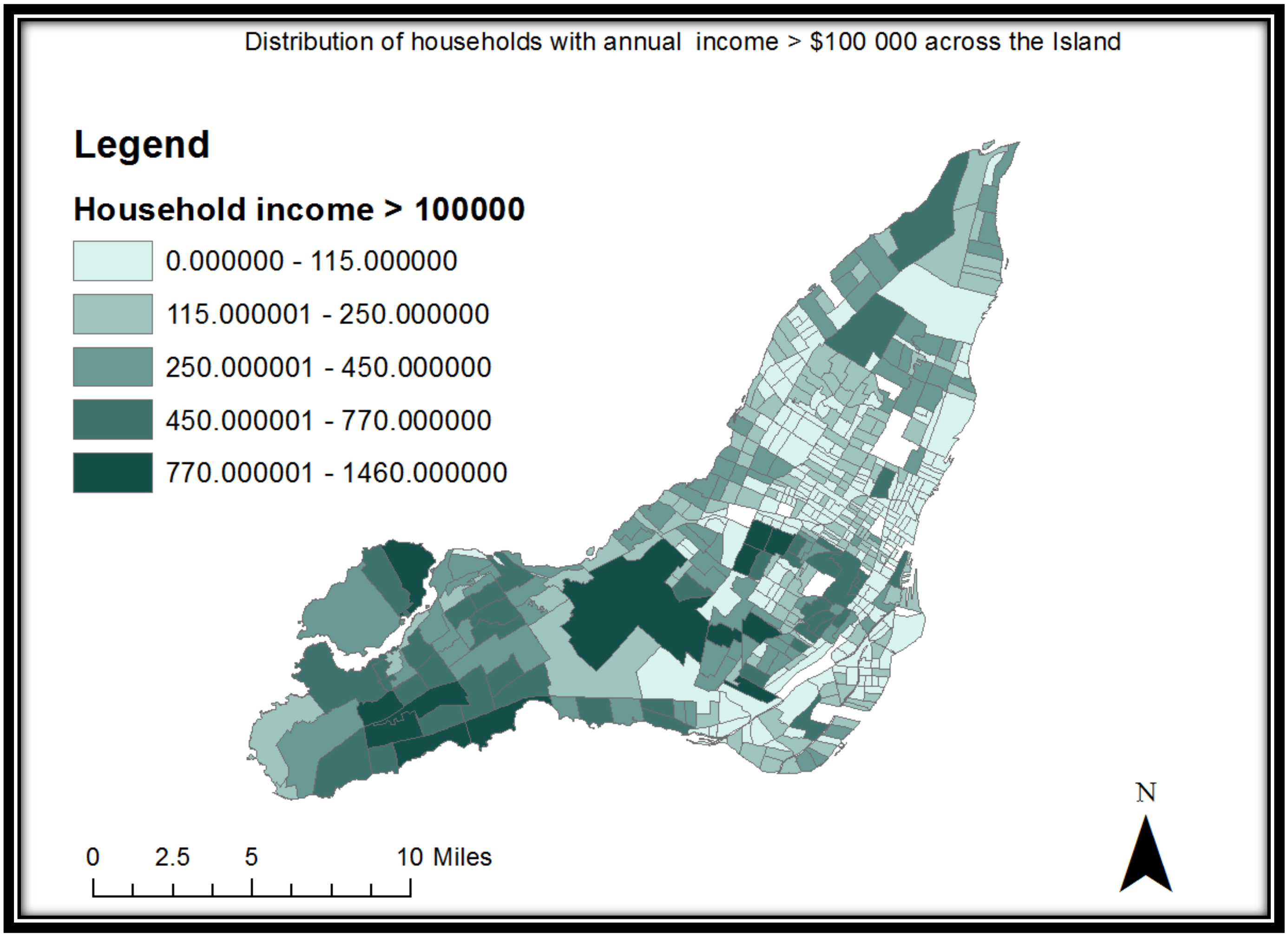
Map 3.5e: Distribution of Respiratory Mortality (Index values) across the Montreal Island:



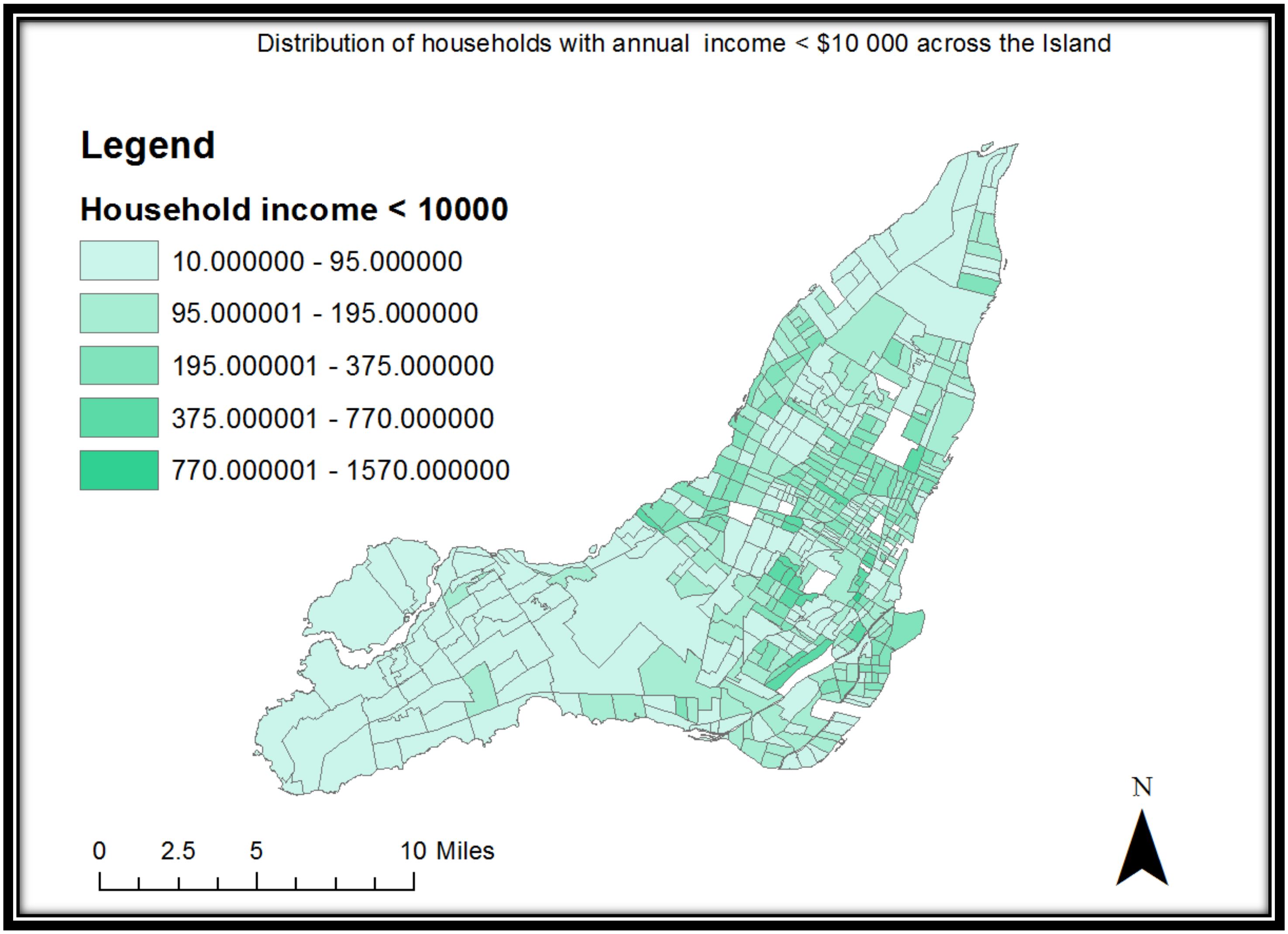
Map 3.5f: Distribution of annual Average Family Income ($) across the Montreal Island:



Map 3.5g: Distribution Households with Income > $100 000 across the Montreal Island:



Map 3.5h: Distribution Households with Income < $10 000 across the Montreal Island:



Appendix B1: STATA tables of simple regression and correlation tests

Green Party voting to Economic variables:

```
. corr weightedgreenparty averagefamilyincome householdincome100000 householdinc
> ome10000 tenantoccupiedspending3099ofinco averagegrossrent
(obs=475)
```

	weight~y	a~fami~e	h~100000	ho~10000	tenant~o	averag~t
weightedgr~y	1.0000					
averagefam~e	-0.1112	1.0000				
house~100000	-0.3907	0.6605	1.0000			
househ~10000	-0.1629	-0.2977	-0.1755	1.0000		
tenantoccu~o	-0.2928	-0.3007	-0.1007	0.7328	1.0000	
averagegro~t	-0.1220	0.6075	0.4553	-0.1711	-0.1095	1.0000

Public Transportation to Economic variables:

```
. corr weightedpublictransit averagefamilyincome householdincome100000 household
> income10000 tenantoccupiedspending3099ofinco averagegrossrent
(obs=475)
```

	weight~t	a~fami~e	h~100000	ho~10000	tenant~o	averag~t
weightedpu~t	1.0000					
averagefam~e	-0.4181	1.0000				
house~100000	-0.4857	0.6605	1.0000			
househ~10000	0.2732	-0.2977	-0.1755	1.0000		
tenantoccu~o	0.1656	-0.3007	-0.1007	0.7328	1.0000	
averagegro~t	-0.3424	0.6075	0.4553	-0.1711	-0.1095	1.0000

Walking to Economic variables:

```
. corr weightedwalking averagefamilyincome householdincome100000 householdincome
> 10000 tenantoccupiedspending3099ofinco averagegrossrent
(obs=475)
```

	wei~king	a~fami~e	h~100000	ho~10000	tenant~o	averag~t
weightedwa~g	1.0000					
averagefam~e	0.0088	1.0000				
house~100000	-0.1901	0.6605	1.0000			
househ~10000	0.2330	-0.2977	-0.1755	1.0000		
tenantoccu~o	0.0300	-0.3007	-0.1007	0.7328	1.0000	
averagegro~t	0.1262	0.6075	0.4553	-0.1711	-0.1095	1.0000

Bicycling to Economic variables:

```
. corr weightedbicycling averagefamilyincome householdincome100000 householdinco
> me10000 tenantoccupiedspending3099ofinco averagegrossrent
(obs=475)
```

	wei~ling	a~fami~e	h~100000	ho~10000	tenant~o	averag~t
weightedbi~g	1.0000					
averagefam~e	-0.0892	1.0000				
house~100000	-0.2309	0.6605	1.0000			
househ~10000	0.0383	-0.2977	-0.1755	1.0000		
tenantoccu~o	-0.0786	-0.3007	-0.1007	0.7328	1.0000	
averagegro~t	-0.0687	0.6075	0.4553	-0.1711	-0.1095	1.0000

NO_2 concentration to Economic variables:

```
. corr no2concentration averagefamilyincome householdincome100000 householdincom
> e10000 tenantoccupiedspending3099ofinco averagegrossrent
(obs=469)

             | no2con~n a~fami~e h~100000 ho~10000 tenant~o averag~t
-------------+------------------------------------------------------
no2concent~n |   1.0000
averagefam~e |  -0.1373   1.0000
house~100000 |  -0.3100   0.6771   1.0000
househ~10000 |   0.2000  -0.2972  -0.1967   1.0000
tenantoccu~o |   0.1038  -0.3044  -0.1168   0.7331   1.0000
averagegro~t |  -0.0352   0.6162   0.4771  -0.1799  -0.1137   1.0000
```

Respiratory mortality to Economic variables:

```
. corr respmortality averagefamilyincome householdincome100000 householdincome10
> 000 tenantoccupiedspending3099ofinco averagegrossrent
(obs=475)

             | respmo~y a~fami~e h~100000 ho~10000 tenant~o averag~t
-------------+------------------------------------------------------
respmortal~y |   1.0000
averagefam~e |  -0.1136   1.0000
house~100000 |  -0.1947   0.6605   1.0000
househ~10000 |   0.0473  -0.2977  -0.1755   1.0000
tenantoccu~o |  -0.0616  -0.3007  -0.1007   0.7328   1.0000
averagegro~t |  -0.1018   0.6075   0.4553  -0.1711  -0.1095   1.0000
```

Lung cancer to Economic variables:

```
. corr lungcancerindex averagefamilyincome householdincome100000 householdincome
> 10000 tenantoccupiedspending3099ofinco averagegrossrent
(obs=475)

             | lungca~x a~fami~e h~100000 ho~10000 tenant~o averag~t
-------------+------------------------------------------------------
lungcancer~x |   1.0000
averagefam~e |  -0.3030   1.0000
house~100000 |  -0.3573   0.6605   1.0000
househ~10000 |  -0.0057  -0.2977  -0.1755   1.0000
tenantoccu~o |  -0.0389  -0.3007  -0.1007   0.7328   1.0000
averagegro~t |  -0.3216   0.6075   0.4553  -0.1711  -0.1095   1.0000
```

Appendix B2: STATA tables of multiple regression models

Green Party voting (dependent) to Economic variables (independent):

```
. reg weightedgreenparty averagefamilyincome householdincome100000 householdinco
> me10000 tenantoccupiedspending3099ofinco averagegrossrent

      Source |       SS       df       MS              Number of obs =     475
-------------+------------------------------           F(  5,   469) =   35.32
       Model |  .101472617     5  .020294523           Prob > F      =  0.0000
    Residual |  .269492568   469  .000574611           R-squared     =  0.2735
-------------+------------------------------           Adj R-squared =  0.2658
       Total |  .370965185   474  .000782627           Root MSE      =  .02397

------------------------------------------------------------------------------
weightedgr~y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
averagefam~e |   9.73e-08   4.37e-08     2.22   0.027     1.13e-08    1.83e-07
house~100000 |  -.0000642   6.74e-06    -9.52   0.000    -.0000774   -.0000509
househ~10000 |   4.86e-06   .0000129     0.38   0.707    -.0000206    .0000303
tenantoccu~o |  -.0000396   7.38e-06    -5.37   0.000    -.0000541   -.0000251
averagegro~t |  -8.90e-07   7.30e-06    -0.12   0.903    -.0000152    .0000135
       _cons |   .0475643   .0047394    10.04   0.000     .0382512    .0568774
------------------------------------------------------------------------------
```

Public Transportation (dependent) to Economic variables (independent):

```
. reg weightedpublictransit averagefamilyincome householdincome100000 householdi
> ncome10000 tenantoccupiedspending3099ofinco averagegrossrent

      Source |       SS       df       MS              Number of obs =     475
-------------+------------------------------           F(  5,   469) =   38.14
       Model |  .480480023     5  .096096005           Prob > F      =  0.0000
    Residual |  1.18174488   469  .002519712           R-squared     =  0.2891
-------------+------------------------------           Adj R-squared =  0.2815
       Total |  1.66222491   474  .003506804           Root MSE      =   .0502

------------------------------------------------------------------------------
weightedpu~t |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
averagefam~e |  -1.06e-07   9.16e-08    -1.16   0.248    -2.86e-07    7.40e-08
house~100000 |   -.000096   .0000141    -6.81   0.000    -.0001238   -.0000683
househ~10000 |    .000101   .0000271     3.73   0.000     .0000478    .0001542
tenantoccu~o |  -.0000163   .0000155    -1.06   0.292    -.0000467    .0000141
averagegro~t |  -.0000326   .0000153    -2.13   0.034    -.0000626   -2.55e-06
       _cons |   .1962643   .0099246    19.78   0.000     .1767621    .2157665
------------------------------------------------------------------------------
```

Walking (dependent) to Economic variables (independent):

```
. reg weightedwalking averagefamilyincome householdincome100000 householdincome1
> 0000 tenantoccupiedspending3099ofinco averagegrossrent

      Source |       SS       df       MS              Number of obs =     475
-------------+------------------------------           F(  5,   469) =   22.64
       Model |  .170365491     5  .034073098           Prob > F      =  0.0000
    Residual |   .70580576   469  .001504916           R-squared     =  0.1944
-------------+------------------------------           Adj R-squared =  0.1859
       Total |  .876171251   474  .001848463           Root MSE      =  .03879

------------------------------------------------------------------------------
weightedwa~g |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
averagefam~e |   1.51e-07   7.08e-08     2.14   0.033     1.24e-08    2.91e-07
house~100000 |  -.0000664   .0000109    -6.09   0.000    -.0000878   -.0000449
househ~10000 |   .0001532   .0000209     7.32   0.000     .0001121    .0001943
tenantoccu~o |  -.0000509   .0000119    -4.26   0.000    -.0000744   -.0000274
averagegro~t |   .0000549   .0000118     4.64   0.000     .0000316    .0000781
       _cons |   .0027469     .00767     0.36   0.720    -.0123248    .0178187
------------------------------------------------------------------------------
```

Bicycling (dependent) to Economic variables (independent):

```
. reg weightedbicycling averagefamilyincome householdincome100000 householdincom
> e10000 tenantoccupiedspending3099ofinco averagegrossrent

      Source |       SS       df       MS              Number of obs =     475
-------------+------------------------------           F(  5,   469) =    8.01
       Model |  .010465646     5  .002093129           Prob > F      =  0.0000
    Residual |  .122549693   469    .0002613           R-squared     =  0.0787
-------------+------------------------------           Adj R-squared =  0.0689
       Total |  .133015339   474  .000280623           Root MSE      =  .01616

------------------------------------------------------------------------------
weightedbi~g |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
averagefam~e |   2.89e-08   2.95e-08     0.98   0.327    -2.90e-08    8.69e-08
house~100000 |  -.0000211   4.54e-06    -4.63   0.000      -.00003   -.0000121
househ~10000 |   .0000214   8.72e-06     2.45   0.015     4.22e-06    .0000385
tenantoccu~o |   -.000015   4.98e-06    -3.02   0.003    -.0000248   -5.24e-06
averagegro~t |   1.90e-06   4.92e-06     0.39   0.700    -7.78e-06    .0000116
       _cons |   .0157612    .003196     4.93   0.000     .0094809    .0220414
------------------------------------------------------------------------------
```

NO_2 concentration (dependent) to Economic variables (independent):

```
. reg no2concentration averagefamilyincome householdincome100000 householdincome
> 10000 tenantoccupiedspending3099ofinco averagegrossrent

      Source |       SS       df       MS              Number of obs =     469
-------------+------------------------------           F(  5,   463) =   15.60
       Model |  289.845459     5  57.9690918           Prob > F      =  0.0000
    Residual |  1720.88284   463  3.71680958           R-squared     =  0.1441
-------------+------------------------------           Adj R-squared =  0.1349
       Total |   2010.7283   468  4.29642798           Root MSE      =  1.9279

------------------------------------------------------------------------------
no2concent~n |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
averagefam~e |   5.73e-06   3.61e-06     1.59   0.113    -1.37e-06    .0000128
house~100000 |  -.0041509   .0006062    -6.85   0.000    -.0053421   -.0029597
househ~10000 |   .0034783    .001048     3.32   0.001     .0014189    .0055376
tenantoccu~o |  -.0004856   .0005995    -0.81   0.418    -.0016638    .0006926
averagegro~t |   .0013404   .0005968     2.25   0.025     .0001675    .0025133
       _cons |   10.84435    .383514    28.28   0.000     10.09071    11.59799
------------------------------------------------------------------------------
```

Respiratory mortality (dependent) to Economic variables (independent):

```
. reg respmortality averagefamilyincome householdincome100000 householdincome100
> 00 tenantoccupiedspending3099ofinco averagegrossrent

      Source |       SS       df       MS              Number of obs =     475
-------------+------------------------------           F(  5,   469) =    5.58
       Model |  1.2446e-06     5  2.4891e-07           Prob > F      =  0.0001
    Residual |  .000020927   469  4.4620e-08           R-squared     =  0.0561
-------------+------------------------------           Adj R-squared =  0.0461
       Total |  .000022171   474  4.6775e-08           Root MSE      =  .00021

------------------------------------------------------------------------------
respmortal~y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
averagefam~e |   2.49e-11   3.85e-10     0.06   0.948    -7.33e-10    7.82e-10
house~100000 |  -1.78e-07   5.94e-08    -3.00   0.003    -2.95e-07   -6.17e-08
househ~10000 |   2.68e-07   1.14e-07     2.35   0.019     4.41e-08    4.92e-07
tenantoccu~o |  -1.88e-07   6.50e-08    -2.89   0.004    -3.16e-07   -5.99e-08
averagegro~t |  -1.80e-08   6.43e-08    -0.28   0.780    -1.44e-07    1.08e-07
       _cons |   .0006609   .0000418    15.82   0.000     .0005788    .0007429
------------------------------------------------------------------------------
```

Lung cancer (dependent) to Economic variables (independent):

```
. reg lungcancerindex averagefamilyincome householdincome100000 householdincome1
> 0000 tenantoccupiedspending3099ofinco averagegrossrent

      Source |       SS       df       MS              Number of obs =     475
-------------+------------------------------           F(  5,   469) =   19.22
       Model |  76.1055813     5  15.2211163           Prob > F      =  0.0000
    Residual |  371.513204   469  .792139028           R-squared     =  0.1700
-------------+------------------------------           Adj R-squared =  0.1612
       Total |  447.618785   474  .944343429           Root MSE      =  .89002

------------------------------------------------------------------------------
lungcancer~x |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
averagefam~e |  -1.46e-06   1.62e-06    -0.90   0.369    -4.65e-06    1.73e-06
house~100000 |  -.0010876   .0002502    -4.35   0.000    -.0015791   -.000596
househ~10000 |  -.0003984   .0004801    -0.83   0.407    -.0013419    .000545
tenantoccu~o |  -.0002772   .0002741    -1.01   0.312    -.0008158    .0002613
averagegro~t |   -.000955   .0002711    -3.52   0.000    -.0014878   -.0004223
       _cons |   1.086907     .17597     6.18   0.000     .7411194    1.432694
------------------------------------------------------------------------------
```

Appendix B3: Results of the Factor Analysis

Aggregation of "Attitudes" variables:

```
. factor weightedgreenparty weightedpublictransit weightedwalking weightedbicycl
> ing
(obs=477)

Factor analysis/correlation                        Number of obs    =      477
    Method: principal factors                      Retained factors =        2
    Rotation: (unrotated)                          Number of params =        6
```

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	1.63401	1.58790	1.2300	1.2300
Factor2	0.04611	0.18949	0.0347	1.2647
Factor3	-0.14338	0.06491	-0.1079	1.1568
Factor4	-0.20829	.	-0.1568	1.0000

```
    LR test: independent vs. saturated:  chi2(6)  =  456.11 Prob>chi2 = 0.0000
```

Factor loadings (pattern matrix) and unique variances

Variable	Factor1	Factor2	Uniqueness
weightedgr~y	0.6546	0.0754	0.5658
weightedpu~t	0.5618	0.1225	0.6694
weightedwa~g	0.5547	-0.1534	0.6688
weightedbi~g	0.7630	-0.0433	0.4159

Aggregation of "Health" variables:

```
. factor lungcancerindex respmortality
(obs=477)

Factor analysis/correlation                        Number of obs    =      477
    Method: principal factors                      Retained factors =        1
    Rotation: (unrotated)                          Number of params =        1
```

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	1.34320	1.52444	1.1560	1.1560
Factor2	-0.18124	.	-0.1560	1.0000

```
    LR test: independent vs. saturated:  chi2(1)  =  413.61 Prob>chi2 = 0.0000
```

Factor loadings (pattern matrix) and unique variances

Variable	Factor1	Uniqueness
lungcancer~x	0.8195	0.3284
respmortal~y	0.8195	0.3284

Aggregation of "Economic" variables:

```
. factor averagefamilyincome averagegrossrent
(obs=475)

Factor analysis/correlation                        Number of obs    =      475
    Method: principal factors                      Retained factors =        1
    Rotation: (unrotated)                          Number of params =        1

    --------------------------------------------------------------------------
         Factor  |   Eigenvalue   Difference        Proportion   Cumulative
    -------------+------------------------------------------------------------
        Factor1  |      0.97649      1.21494            1.3231       1.3231
        Factor2  |     -0.23845            .           -0.3231       1.0000
    --------------------------------------------------------------------------
    LR test: independent vs. saturated:  chi2(1)  =  218.04 Prob>chi2 = 0.0000

Factor loadings (pattern matrix) and unique variances

    ---------------------------------------
        Variable |  Factor1 |   Uniqueness
    -------------+----------+--------------
    averagefam~e |   0.6987 |       0.5118
    averagegro~t |   0.6987 |       0.5118
    ---------------------------------------
```

Simple Correlation Analyses between aggregated variables:

```
. corr attitudes disease no2concentration averagefamilyincome averagegrossrent
(obs=469)

             | attitu~s  disease no2con~n a~fami~e averag~t
-------------+---------------------------------------------
   attitudes |   1.0000
     disease |   0.3742   1.0000
no2concent~n |   0.5178   0.1119   1.0000
averagefam~e |  -0.1722  -0.2258  -0.1373   1.0000
averagegro~t |  -0.1258  -0.2335  -0.0352   0.6162   1.0000


. corr economic attitudes disease no2concentration
(obs=469)

             | economic attitu~s  disease no2con~n
-------------+------------------------------------
    economic |   1.0000
   attitudes |  -0.1657   1.0000
     disease |  -0.2555   0.3742   1.0000
no2concent~n |  -0.0958   0.5178   0.1119   1.0000
```

Multiple Regression model between economic (dependent) and environmental (independent) variables

```
. reg economic attitudes disease no2concentration

      Source |       SS       df       MS              Number of obs =     469
-------------+------------------------------           F(  3,   465) =   12.04
       Model |  20.5452028     3  6.84840095           Prob > F      =  0.0000
    Residual |  264.416336   465  .568637281           R-squared     =  0.0721
-------------+------------------------------           Adj R-squared =  0.0661
       Total |  284.961539   468  .608892177           Root MSE      =  .75408

------------------------------------------------------------------------------
    economic |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   attitudes |  -.0555622   .0523413    -1.06   0.289    -.1584171    .0472926
     disease |  -.2047145   .0433408    -4.72   0.000    -.2898826   -.1195465
no2concent~n |   -.014785   .0197627    -0.75   0.455    -.0536203    .0240503
       _cons |   .1661156    .233605     0.71   0.477    -.2929365    .6251677
------------------------------------------------------------------------------
```