Urban Journeys Unveiled: A Study of Work Commutes among the Montreal Disadvantaged

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ABSTRACT

The planning and provision of equitable urban transportation services is critical to ensure both equitable societies and sustainable urban forms. To achieve these, planners and decision-makers must acknowledge the diversity of issues resulting from the heterogeneity in socio-demographic segments. While the transportation needs of these groups are comparable within social strata, they greatly differ across them. The goal of this dissertation is to determine the level to which these differences exist and investigate the elements that engender them at the individual level. The analysis, conducted in various demographic segments in the Montreal census metropolitan area, is based on econometric models of commuting modes and distances, which have been developed using 1996 Canadian Census data.

SOMMAIRE

La planification et l'offre de services de transport urbain équitable sont des éléments pivots autant dans le maintien de la cohésion sociale que dans l'élaboration de politiques axées sur le développement durable. Ces objectifs dépendent en grande partie de la mise en place de structures décisionnelles sensibles à l'hétérogénéité des groupes sociaux. En effet, bien que les besoins en transport soient similaires à l'intérieur d'un même groupe, ils varient sensiblement à travers les couches sociales. Le but de cette dissertation est de déterminer l'étendue de ces différences et d'isoler les attributs qui les engendrent au niveau de l'individu. Cette analyse, menée sur divers groupes démographiques dans la grande région de Montréal, est basée sur des résultats de modèles économétriques de choix modaux et de distances de déplacement, développés à partir de données désagrégées du recensement de 1996.

Chapter 1 Introduction

1. Background

"I always avoid prophesying beforehand because it is much better policy to prophesy after the event has already taken place."

Sir Winston Churchill

Predicting travel demand and behaviour after they have occurred is certainly an ingenious albeit impractical modus operandi. In the real world, the complex task of travel demand modeling (TDM) relies on the analysis of multiple variables including current trips, route choices, timing of departures, transportation modes... Much of the work done in the field of travel demand modeling, both in research and in actual practice, is about just that: predicting and most importantly understanding people's behaviour of mode and route choices and transferring this knowledge through transportation policies onto the planning of liveable cities.

The complexity associated with predictive work (such as TDM) requires transportation professionals to rely on a four-step analytical framework that addresses an exhaustive array of issues from the genesis of a trip to its choice of path and from the trip mode(s) to the timing and duration of trip. In this four episode procedure of trip generation, trip distribution, mode split and traffic assignment, this thesis finds its place in the third section of the planning process, the mode split procedure.

Much of the work presented in the modeling part of this thesis (or at least the theory behind it) is based on almost four decades of research in econometric theory. Particularly notable is the research work of Daniel McFadden on linking economic theory of consumer choice with transportation decision-making processes, which has resulted, among other things, in the formulation of the widely used multinomial logit model, with applications beyond the travel analysis domain, in fields as diverse as marketing, sociology or medicine. The theory on which this thesis so deeply relies has also been honoured by the 2000 Nobel Price in Economics for Dr. McFadden.

The mode choice decision for our morning commute is simultaneously logical and hard to predict. Logical because it is only the end result of a decision process fuelled by various influencing factors, both at the personal and trip level: the commuting distance, cost

of trip, whether the trip is a chained-trip or without any stop, the number of cars in the family, its income, the urban form. The list is endless. And this is in essence what defines the unpredictability of mode choice. The job of a transportation planner is to reconcile the information available about the attributes of the trip, the trip-maker and its urban form (the deterministic part), quantify and model these so as to minimize the effects of random factors and spontaneous decisions (the stochastic part).

The analysis conducted in this study particularly focuses on demographic groups whose incomes can barely cater for primary needs, or groups whose racial identities have traditionally been considered to put them as a disadvantage. For the majority of us, commuting is second nature, an inseparable part of our urban experience: the distance between home and work is a bus trip away; five minutes by car separate us from the grocery store; hopping in a cab will get us to the meeting in no-time.. Yet, there is a segment of the population for whom commuting entails a lot of planning, an astounding budget of money and time and sometimes a great deal of discomfort. While I view my transit trip as a picturesque occurrence in my day, smiling at the thought of missing my train but tirelessly waiting for my bus, for a disabled or poor person, this experience can be frustrating and even painful. Similarly for a single mother who can not afford a car, carrying the groceries while keeping an eye on her toddler may be an unpleasant exercise. These people for whom commuting requires a greater effort than from the rest of the population are known as the transportation-disadvantaged groups (TDGs). This dissertation focuses on three sub-groups: single mothers, visible minorities and the poor.

Equitable transportation services are important in order to provide people with equal access to opportunities. Through moving and reaching new destinations, going to a job, attending social events, people enrich their lives and expand their knowledge. Transportation is the fundamental link between segregation and opportunities, between isolation and community. Because of its very nature, it raises the issue of equity. How do the transportation-disadvantaged people travel in Montreal? What are their travel patterns? What modes do they use? Are their needs met? These are some of the issues I will be discussing in this dissertation. In a preliminary part (chapter II), we will be reviewing the current literature on transportation issues faced by the transportation disadvantaged. Chapter III raises the issue of data collection, its importance in the field of empirical research and the type and quality of transportation-related data we have in Montreal. We will then discuss how single

mothers, the poor and visible minorities travel in Montreal (chapters IV, V and VI), both in terms of commuting modes and distances. We will analyze how their socio-economic attributes and lifestyles influence their commuting patterns in two chapters (VII and VIII) where the reader will also find a multinomial logit model of mode choice (chapter VII) and an ordered logit model of commuting distance (chapter VIII). The econometric theory behind these models is presented in the very next paragraph. This dissertation will end with concluding remarks on our findings, policy implications and next steps and direction for subsequent research.

Chapter 2 Literature review

1. Transportation and Social Capital

The issues of equity and transportation, and its connection to social inclusion have shifted transportation from a mere need (as a derived demand) to a social right. Kenyon et al. (2003) have hypothesized that the lack of mobility could contribute to social exclusion along what they have coined the "dimensions of exclusion" (political, personal, societal...). The needs for transportation are the same for every segment of the population, poor or rich. In the USA, Cervero et al. (2002) have eloquently sketched this common reality of American workers' daily lives and showed that the intricate process through the urban world suffers no segregation of social status: "low-skilled workers need access to cars for the same reasons high-salaried workers do-to drop their kids off at daycare centers in route to work, the desire to reduce time spent commuting [..], the availability of free parking".

If and when transportation is the causal factor of exclusion, it is essential to address the issue. Some scholars have argued that transportation alone was unlikely to resolve the issues of exclusion that it has exacerbated: "A 're-balancing of the scales' between transport and social exclusion may not, by itself, provide a fully satisfactory solution to mobility-related exclusion" (Kenyon et al.). They have posited the hypothesis that "virtual mobility", the access of goods and services through the internet, could enhance access to opportunities by "increasing access rather than increasing mobility". Above and beyond the need for access to opportunity, mobility has been argued to increase social capital and as such, is viewed as an essential component of daily lives. Urry (2002) argues on the other hand, that virtual mobility will never replace "co-presence", this sense of proximity concomitant to physical presence. It is through the analysis of why people travel that one is to understand how good a substitute of mobility virtual mobility can be.

Along with exclusion, social policies have tried to address the poverty issue. In a discussion of anti-poverty strategies, Hughes (1995) assesses that there are only three approaches to halt the prevalence of poverty in urban areas: move poor people to job-rich

neighborhoods[1], create more jobs where poor people live or provide transportation infrastructures that enable poor people to commute to their jobs. This last approach, which acknowledges the crucial role of transportation in the lives of the poor, is probably the cheapest and most feasible solution and naturally the one advocated by many researchers (Hughes, 1995; Wachs and Taylor, 1998), and should be at the heart of any anti-poverty strategy.

2. Transportation and the Employment of the Transportation Disadvantaged

Individuals facing a transportation disadvantage for work trip purposes are the poor, most of whom rely on welfare aid for daily subsistence. And they are all the more disadvantaged that recent reforms both in the US and the Canadian welfare system have switched their focus from helping individuals with welfare provision to moving them rapidly to the job market, or in the words of Wachs and Taylor (1998), while "the purpose of welfare was to eliminate poverty, the purpose of welfare reform is to eliminate welfare". Although this enterprise is quite honourable in theory, in practice, scholars and researchers alike have voiced their concerns as to the suitability of the transportation measures taken to ensure a smooth transition into the labour force (and transportation is only one aspect of the problem). And inevitably, the Canadian debate over whether these groups should be encouraged to move from welfare to work has produced much dissonance from researchers. While some have embraced the "workfare" school of thought (Schaffer et al., 2001), others have voiced reservations vis-à-vis the cost-effectiveness of such programs and their potential and established that these policies only stand as symbols of good faith from politicians (Evans, 1993). Independent of their position with respect to workfare policies, researchers agree that the success of these are in great part dependent on whether current transportation infrastructures and policies will cater to the needs of welfare recipients. In the U.S., these reforms have even implemented various transportation-specific subsidies through the welfare-to-work grants, access-to-jobs program (granting interest-free loans for car

[1] The most popular example of this type of programs is the Gautreaux Assisted Housing Program in Chicago. The idea of the program was to move African-American families from the inner-city to a largely white neighborhood in the suburbs, in the hope that closer to the opportunities characteristic of the suburbs, these families would improve their quality of life.

purchases) and even the more general Temporary Assistance for Needy Families (Blumenberg, 2002).

The purpose of this dissertation is not to argue the validity of workfare programs but rather discuss the transportation needs of those on welfare who are looking for a job. And empirical research shows that these needs are real: in a study of employment barriers faced by single mothers in an Urban Michigan County conducted by Danzinger et al. (1999) the authors have found that, of the 753 black or white single mothers surveyed, about half of them reported no access to a car, or not having a driver's license. Their study hypothesizes a set of 14 barriers single mothers face in the search of a job, while transitioning from welfare to work. Among the single mothers studied, 44.6% of them have either no car and/or no driver's license. The authors point out that at the national level, only a meager 7.6 % of all women are faced with this barrier, which emphasizes the prevalence of this phenomenon among single mothers. Their model further shows that, for an African-American single mother, aged between 25 and 34, with a child less than 2 and who's been on welfare for 7 years, the probability of working 20+ hours a week (and hence remaining on the welfare program) is only 67%, a drop of almost 15 % when compared with a woman with the same profile but not faced with the transportation barrier. The surprising finding of their study is that the transportation barrier issue affects white single mothers more than it affects Afro-American ones (56.1 % vs. 35.8%), a finding significant at p=0.05.

This phenomenon is not exclusive to single mothers, but rather affects the majority of poor. Quoting OPCS[2] data (2000), Bostock shows that in the UK, only 30% of low-income households have access to a car, compared to 70 % for those with average or above average income.

3. Distance and the Spatial Mismatch Hypothesis

The mid and late sixties in the US have seen a steady suburbanization of low-skill jobs traditionally held by the black population. While these jobs previously abundant in the central city have slowly moved to the peripheral ring of the urban core, affordable residences for the black population have not. For the black population entrapped in the central city, this phenomenon only exacerbated the already existing differences in travel patterns between the

[2] Office of Population, Censuses and Surveys (UK)

white and the non-white population and materialized for the black population in longer work commutes. This argument, referred to in the literature as the spatial mismatch hypothesis, was first proposed by Kain in 1968. Several studies and decades later, the spatial mismatch hypothesis originally describing a racial phenomenon was generalized to describe a social problem, mainly affecting the transportation needs of low-skilled poor workers vs. a more white-collar skilled labor force. It is this generalized hypothesis, although not called by name, which has been the basis for justifying most of the reverse commuting programs in the US, such as the Job Access Program through TEA-21 (Blumenberg, 2003).

Gordon et al. refute the spatial mismatch theory. According to the authors who base their study on the 1977, 1983-4 National Personal Travel Survey, the data show no evidence for the SMH, as posited by Kain and others. They find that trips made by both suburban and metropolitan workers are comparable, if not similar. The same holds for trips made by white and non-white workers. The only difference found concerned trips made by women which were found to be significantly shorter. But the authors argue that this phenomenon could be the result of the attributes imputable to the traditional role of women as primary caregivers, whose distance from home is to be minimized at all times. Furthermore, the authors argue that shorter trip distances experienced by women could also be the result of spatial homogeneity of the jobs they traditionally hold (secretarial, administrative) and were not to be used as evidence in favor of the spatial mismatch hypothesis.

Do longer commutes and the presence of a car improve the chances of employment? The debate echoes many dissonances. Using data from 306 unemployed job seekers in Scotland, McQuaid et al. (2001) have found that even the presence of a car would not influence the willingness of these job seekers to travel further (the finding was insignificant in their maximum likelihood model). On the contrary, Vandermissen et al. (2001) have proposed models to show that better accessibility to jobs by car, and longer commutes have enabled women to participate at higher levels to the workforce by increasing the work trip length and by widening the area of potential job search.

4. The influence of Gender, Marital Status and Income on Women's Travel Patterns

The influence of gender on both commuting modes and distances has received much attention from feminist researchers and urban geographers alike, with recurrent findings that

women are less likely to drive a car than men and more likely to travel shorter distances . Several theories have tried to explain this phenomenon (for an extensive review, see McDonald, 1999 and Law, 1999). Two of these theories will briefly be discussed here.

The first hypothesis suggests that shorter trips among women are largely due to gender-attributable inequalities in earned income- that is, women travel shorter distances because they earn less money than men. These inequalities have ramifications both in the labor force and in the non-working population: in the labor force, gender discrimination in wages attribution has been widely evidenced and studies have shown that men do indeed earn more than women for comparable occupations. In 1980, women were making almost 40% less on each dollar earned (US department of Labor as quoted by Hanson and Johnston, 1985); among the unemployed, single mothers constitute one of the poorest segments of the population. Quoting Labor Markets Trends, the Gender Audit report reveals that 70 % of lone mothers earn less than 50% of the median income. In 1998, an overwhelming 83 % of American welfare recipients *were* single mothers (Department of Health and Human Resources as quoted by Blumenberg, 2000). In 1999, more than 40% of these single-mother led households lived below the poverty threshold, a rate three times greater than the rest of the country (Mills and Hazarika, 2003). And the trend is on the rise as an ever increasing number of households are led by single-mothers. In a study of new travel patterns displayed by women, Rosenbloom indicates that in the span of twenty years, the percentage of American households led by single mothers increased by 10%. These households constitute almost a quarter of all families in the US (Rosenbloom, 1996). In Quebec, a very similar trend is observable. Between 1986 and 1996, the percentage of single parent households (among families with at least one child) increased from 21 to 24 % (Shee, 1991; Thomas and Boudart, 1999 as quoted by Vandermissen et al, 2001).

The second theory proposes that women shorten their trips as a means to cope with household responsibilities. While some researchers have showed that single women experienced on average longer trips than married women, others found that there was no correlation between the marital/parental status of women and their commuting patterns. Elliot and Joyce (2004) have found that commute times of women with and without children were comparable. In their single-women category, the ones with children had slightly longer commutes (30.2 min vs. 29.2 min) whereas in the married women group, the ones without children had somewhat larger one-way commute times (25.3 min. vs. 24.8 min). However,

these differences were not as dramatic as the ones that occurred when differences in just the marital status were observed. The authors found that the marital status created a greater gap between married women who spent less time commuting than their single counterparts (24 min. vs. 29 min.). These results are consistent with the ones found by Preston et al (1999). They found that marriage, then children help reduce the commute time of women. On the other hand, Hanson and Johnston's data (1985) tell another story. Although they find that married women travel a lesser amount of time than their single counterparts, the difference was not found to be significant. As a whole, their study found no evidence to support the gender-role/shorter trips hypothesis.

When and where gender differences in the commuting pattern of women have been found, on-going debates have failed to definitely resolve whether these differences were the result of personal decisions or imposed circumstances. Some scholars have argued that women's shorter trips were the result of choices but others think it is the effect of constraints. Blumenberg challenges the notion that trip distances are an indication of employment barrier. (Low-income) women make shorter trips, and shorter trips have been linked to lower wages. Some scholars have therefore suggested that longer work commutes would capitalize in higher wages. But Blumenberg argues that shorter commutes are a result of women's personal choice, which would rather trade longer commutes (and incidentally higher wages) for a job closer to home, where they often carry the most weight in the household responsibilities.

Using the 1995 NPTS, Murakami et al. have shown that in the US, two-thirds of single mothers' trips are shorter than 3 miles. They have also shown that for income above the low-income threshold, less than one percent of all trips taken in a private car were conducted in a car that did not belong to the household. For low income households, this statistic is nine times greater. For low income single parent households (often led by single mothers), the proportion is a staggering 17 percent. Their statistics are also compelling regarding auto-ownership in the single-parent household. The average number of cars in such families is 0.72 cars. When single-parent households have a car (about 36 % of them don't), it's on average 10.8 years old. Households receiving some kind of welfare compensation allocate 10% of their expenditures to transportation.

Bostock has showed that for some single mothers motorized ways of transportation are not even an option: "While many walk to work for pleasure, for the poor, walking is their

primary form of transport", especially for women trying to save on public transportation costs. Although some of them have relatives with access to a car, and though half of them live close to their relatives, they will only ask a ride in case of a medical emergency. Even food shopping is limited to areas within walking distance.

5. Visible Minorities

Differences in commute times and commute modes, especially between the Black and White populations in the USA, are the legacy of years of segregation and arguable transportation policies that further increased the divide between these ethnic groups. The post World War II transportation policies in the US highly favoured the construction of highway projects, while allocating little to no money to public transportation. These policies made minorities particularly vulnerable because the highway infrastructure developed only catered to the needs of those who could afford to drive (in the 50's, this already excluded a great deal of minorities), and secondly, because these highway structures disrupted minority neighbourhoods where they were primarily built because of low land prices (Sanchez et al. 2003). These pro-highway policies, through uncontrollable growth of the urban core (a phenomenon known as urban sprawl), have engendered in many US cities very low densities which prohibited then and still do today, the effectiveness of public transit, a mode on which poor population so heavily relies. As a result of several decades of such policies, the transit rate in most US cities rarely exceeds 10%.

Historically, transportation in the US has always been a tool to segregate the White and Black population. In the late nineteenth century, the *Plessy v Gerguson* trial, by convicting a Black rider for using a white-only railway car, gave birth to the *separate-but-equal* policy, establishing that the two groups would receive similar services in different facilities (Sanchez et al., 2003). In actual facts, those services were both unconstitutional in theory and did not uphold the rights of the Blacks in practice. Decades later, in the 60's, civil rights activists successfully fought for the rights of the Black Americans so they could enjoy the same rights as the White population. One often cited such right is the provision to the Black community of decent transportation services. One of the most famous episodes of this movement is the Montgomery Bus Boycott, in 1955, following the arrest of Rosa Parks, an African American who refused to give up her bus seat to a White passenger. The (successful) boycott of public transit in the city was intended to give Black commuters the right to ride in the same section

as the White commuters. Naturally, transportation infrastructures were also the symbolic canal through which freedom riders chose to ensure the enactment of the 1960 Supreme Court decision to end discrimination and racial segregation in the use of public facilities (King, 2000). By riding in all sorts of modes, whites and non-whites alike traveled the southern states of the United States traditionally more segregationists, to convey the message that racial discrimination was no longer acceptable in the provision of public services, and especially public transit.

While discrimination is officially frowned upon today, and is probably less of a concern in Canada than in the US, much of the disparities between minority and non-minority groups are still very present. Using PUM data for 1990, Krovi and Barnes' study (2000) on travel patterns of people of color indicates that minorities' commute times (Asians and African American) are at least 20% longer than those of the Whites. They hypothesize that these differences may be due to differences in mode choices. Within minorities, it was also found that Hispanics traveled the shortest time. Comparable patterns among the Whites and Hispanics are hypothesized to result from the presence for these groups of close-to-home employment opportunities. Contrary to Krovi et al., Giuliano's study (2000) found that Asians travelled the shortest, both in terms of distance and time. Her research work, based on NTPS data, reveals however that a geographic dimension contributed to the exclusion among racial groups: within central cities, Whites and Asians traveled less in terms of commuting time than Hispanics and Blacks, which gives partial credence to the hypothesis formulated by Krovi and Barnes' on the influence of mode choice.

Visible minority indicators are very good predictors of auto-ownership (Doyle and Taylor, 2000). In the USA, Doyle and Taylor have found that young men and women had comparable rates of licensing. Therefore, the authors suggest that the analysis of transportation patterns must be must account for both sex *AND* race, as most of the differences can not only be explained by differences in gender; for example, they find, using NTPS data, that longest commutes are not just done by people of color, but by women of color. Whether in the suburbs or in the central cities, McLaffery and Preston have shown that one reason why women of color were so prone to long commutes was their heavy reliance on transit for trips dictating motorized modes of transportation: reverse commutes and intra-suburbs trips. For both these types of trips, the rates for Black women in New York were found to be three times greater than those for White women.

6. Transit vs. Private Mobility

Researchers unanimously agree on the necessity of decent transportation for employment purposes and all other daily activities. Cervero (2002) has elegantly voiced this agreement among researchers by qualifying transportation as the " *to* component of welfare-to-work". However, there is much debate as to what modes and conditions qualify as acceptable. While some strongly advocate personal mobility, others denounce its use, invoking environmental concerns.

In an attempt to reduce the social disparities partly imputable to inappropriate transit infrastructures, policy-makers have been urged to increase the government participation in transit funding. This effort, it is hoped, will increase the frequency and the quality of the service, the number of routes and the overall serviced population. But for the daily long commutes that characterize low-skill worker journeys to work, is transit a viable option? A work trip by transit for workers trying to reach their job destinations in the suburbs is often synonymous with multiple routes, egress and waiting times, one or multiple connections, the nearest transit stop far from home, the access point at the other end of the trip even further. In quantifiable terms, this reality has been described to represent transit journeys of 20 to 40 minutes longer than other modes (McLafferty and Preston, 1997). Quoting a report by the Bureau of Transportation Statistics, Blumenberg and Manville cite the example of Boston, where 98% of the welfare-recipients respondents acknowledged living within a quarter mile radius from a transit stop, when in fact 70% of the entry-level jobs they could qualify for were in the suburbs (Lacombe, 1998). Blumenberg points out that many transit systems charge flat rates independently of the length of the trip. This clearly disadvantages women as they travel shorter distances. She advocates for different policies in different neighborhoods.

For Cervero (2000), private mobility could really be what separates people on welfare from a job. Cervero et al. (2002) have found an associative relationship between owning a car and finding a job (and staying off welfare). Their multinomial logit model on Californian data show that controlling for other factors, the odds of finding a job was thirteen times greater for a person who owned a car compared to a person who did not own one, all else being equal. The use of data for two different time periods (91-92, 94-95) have also enabled

them to show that conversely, the probability of getting a job was reduced when a person who owned a car no longer did.

Macek et al. have echoed this sentiment. Using the 1995 NPTS survey (N>5,000), they fitted an OLS model to the New York data and found that people using transit commuted 37.4 min longer than people using a private vehicle, all else being equal. Their binary probit model estimated the probability of being employed and showed that longer commutes and reliance on transit decreased the chances of an individual of being employed.

Similarly, Blumenberg (2000) has argued that certain conditions would warrant the use of personal mobility over transit for job seekers on welfare, essentially because of the distance factor. She criticizes actual policies that encourage single mothers, through subsidies and various aid programs, to commute long distances to low-wage employment centers. More specifically, she posits that the temporality of these subsidies programs will negatively weigh on the attractiveness of these jobs, and that single mothers will stop traveling these long distances; furthermore, that these long distances should not be encouraged because single mothers are the sole provider for their families and that more of their time should be spent at home, not commuting.

Taylor and Ong (1994) found that the interaction between transportation and space would best be described by a transportation mismatch. On average, their study shows that black workers have similar if not shorter commuting distances, but longer commuting times, even when controlling for residential areas and commuting modes. This phenomenon has been explained by the authors by a higher dependence of the black population on transit: "blacks were three times more likely than whites to commute by transit, and transit commute times averaged 75 % longer than driving alone"

Transit has also been showed to increase the odds of working. In a study of labor participation in Portland and Atlanta, Sanchez (1998) found that there was a link between proximity to the nearest bus stop and number of weeks worked per year. For each additional 100 m away from a bus stop, the model predicted one (Portland) to four (Atlanta) less days work per year. The effect of proximity to a rail station was not as pronounced and the relationship did not apply to the non-white population in Portland. The limitations of this study, that is the ineffectiveness of rail and the non-applicability to the non-white population, is precisely what has transit critics doubting of the merits of transit in the fight against unemployment among the poor. This phenomenon has extensively been described in

the USA by Garret and Taylor who have described the orientation of public transit oscillating between the "strong demand for transit services by predominately low-income and minority inner-city residents on the one hand, and accommodating the political interests and desires of a more mobile, dispersed, and largely white, suburban-based electorate on the other" (Garret and Taylor 1999, Ong and Blumenberg, 1998). At the federal level, funding for capital projects are favored (mostly for heavy and light rail) over investment in operating expenses for bus services, despite the fact that overwhelmingly more trips are made by buses than rail (Garret and Taylor, 1999). The authors have argued that this phenomenon is the result of a simple political process: wealthier, suburban citizens paying higher taxes want to see their money back in programs addressing their needs (trains), and not necessarily those of poorer inner-city residents (buses).

Chapter 3 Methodology

The data used in this thesis is the Census 1996: Public Use Micro Data File, a 2.7% sample of the Canadian population for whom census information is released at the disaggregate level, (that is the sample is made of the census answers these respondents have provided at the moment of the census). Aside from ensuring the anonymity of the respondents, the confidentiality of the survey is warranted by certain variables being reported as not-available (for small geographic areas), or aggregated/round-off to avoid that excess detailing betrays the anonymity of the respondents. Nonetheless, the PUM file retains a certain level of disaggregation that makes it an invaluable tool to study certain social phenomena such as the one this study focuses on.

The PUM file contains information for all census metropolitan areas in Canada, but for the purpose of this paper, we have only selected CMA 462, corresponding to Montreal, our focus in this study being the single mothers in this region. This file contains a grand total of 91323 data points (corresponding to 91323 individuals), of which

- 3622 are single mothers (3.97%)
- 11278 have reported belonging to some visible minority (12.39%)
- 24765 (27.27%) are considered to be below the Statistics Canada low-income cut off point.

The model fitted to the 1996 data to obtain a prediction of the commuter mode choice stems from utility theories. These specify that if faced with more than one choice, a consumer (in our case, commuter) will pick the alternative that provides, within budget constraints, the maximum benefit. The choice is said to maximize the consumer's utility (Meyer and Miller, 2001). The utility theory is then written as a function of the choice-maker, attributes of the trip and an error term, such as:

$$y_i = \beta_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_n x_n + \varepsilon \qquad (1)$$

where,

- y_i is the utility derived from choosing one of the four alternatives (car driver, car passenger, transit or other modes)
- β_1 is an alternative-specific constant

- $[\beta_1 \ \beta_2 \ \dots \ \beta_n]$ is the vector of parameters values
- $[x_1 \ x_2 \ \dots \ x_n]$ is the set of observed data
- ε is the error term

If the error term is assumed to be *independent and identically distributed* (IID), following a distribution of known probability and density function, this utility function can be transformed into a multinomial mode choice model with alternative-specific β parameters and alternative specific constants.

To this purpose, the utility equation is rewritten as a function of the error tem, which forms the basis for a likelihood function. The goal is then through maximization of this likelihood function (hence the name maximum likelihood function) to estimate the set of β parameters that maximize, the probability of observing the choices made by the commuter (Kennedy, 1992).

Contrary to simple linear functions, β estimates of the multinomial logit function are not interpreted as corresponding β changes in the dependent variable for one unit change in the independent variable. Rather they are used to calculate the probability for a consumer (read commuter) to use a specific alternative. Let us assume that n alternatives are available to the commuter. The probability that the alternative 1 will be chosen can be written as:

$$P_1 = \frac{e^{X\beta_1}}{e^{X\beta_1} + e^{X\beta_2} + \dots + e^{X\beta_n}} \tag{2}$$

where X is the vector of independent variables, and β_1 is the estimated set of β parameters for alternative 1. Similarly, the probability that alternative n will be chosen is:

$$P_n = \frac{e^{X\beta_n}}{e^{X\beta_1} + e^{X\beta_2} + \dots + e^{X\beta_n}} \tag{3}$$

where X is the vector of independent variables, and β_n is the estimated set of β parameters for alternative n. For estimation purposes, the set of β parameters of one of the alternatives is arbitrarily set to 0 and this alternative is then considered to be the *base category* (Stata User Guide, 2005). If alternative 1 is considered to be the base category, the associated probability is then:

$$P_1 = \frac{1}{1 + e^{X\beta_2} + \dots + e^{X\beta_n}} \tag{4}$$

The probability of alternative n is:

$$P_n = \frac{e^{X\beta_n}}{1 + e^{X\beta_2} + \ldots + e^{X\beta_n}} \quad (5)$$

Although the multinomial logit model has become quite popular among researchers (in part because of the development of software packages that can easily compute a number of statistical parameters along with the values of the β's estimates), the formulation of the model is based on three fundamental assumptions about the stochastic (error) terms and attributes of the choices that can limit its use. These three assumptions are (Bhat, 2002):

1. The error terms are independent and identically distributed with a type I extreme value (or Gumbel) distribution, that is the unobserved attributes of each choice are independent across all choices and each unobserved attribute follows a similar (type I extreme or Gumbel) distribution. If the random parts of any two alternatives are correlated, the sum of the probabilities of these two alternatives will be overestimated while the probability of other choices will be underestimated. This property of the multinomial logit model is often known as the *independence from irrelevant alternatives* property.
2. Individuals respond homogeneously to attributes of the choices.
3. Unobserved attributes of the choices display similar variance-covariance structures for all individuals, that is the variance of the unobserved attributes of any given choice must be similar across all individuals.

Recent developments in discrete choice modeling have mainly focused in recent years on relaxing one or more of these assumptions and/or offering methods that decrease computational time. The proposed models fall into two classes: open-form and closed form models. In closed form models, the probability of selecting an alternative is computed through a number of fixed operations. These models include the nested logit, the generalized extreme value models, the universal logit models and the heteroskedastic model. In open form models however, the probability for mode choice i is found by estimating the value of a multi-dimensional integrand in the log-likelihood function of the logit model (Bhat, 2002). These models are known as *mixed logit models* because the probability is the integrand of the logit over an assumed density function of the β parameters (Train, 2003). Because no analytical solution exists for these multi-dimensional integrands, probabilities are approximated through simulation techniques such as the Monte-Carlo technique or the Halton sequence. Mixed logit models with appropriate mixing functions have proven to be

superior to multinomial logit functions but the time required to estimate the choices probabilities in these models is greater because of the use of simulation techniques. Given the size of our database, the number of parameters and choices, it appeared less computationally intensive to use a multinomial logit in this research.

Along with probabilities estimated in the multinomial mode choice, *relative risk ratios* are often used to describe alternative choices. For each β parameter in the utility function, corresponds a relative risk ratio calculated as the exponentiated coefficient of that β parameter. It can be interpreted as the relative risk of choosing alternative i over the base alternative for a unit change in the value of the corresponding independent variable. In the multinomial mode choice model developed in this dissertation, the base category is transit. Both probabilities and odds are used to describe the commuting mode choices.

The description of the commuted distance traveled by the individuals in the census is also handled through the use of another logit model: the ordered logit model used to treat data where the dependent variable is organized in ordered categories (eg.: small, large, very large). In the census, the commuting distance is organized in such ordered categories (distance less than 5 km, between 5 and 15 km...). In technical terms, this dependent variable is called the *observed variable* y. For modeling purposes, it is mirrored in the ordered logit model by a *latent variable* y* (Long, 1997). In the model where the latent variable y* is used, the observed variable category limits (5 km, 10km...) are replaced by *cut-points* or *thresholds* (τ) used to model the boundaries between these very categories. Hence, the probability that the observed variable is equal to outcome *i* is equal to the probability that the latent variable y* is between the two correspondent, software-estimated, thresholds such that:

$$\Pr(y = i) = \Pr(\tau_{i-1} \leq y^* \leq \tau_i) \tag{6}$$

where the equation defining the latent variable y* is given by:

$$y^* = \beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n + \varepsilon \tag{7}$$

The constant β_o and coefficients β_1 through β_n are also estimated by the software during the model estimation. ε is the error term.

After some rearranging, equations (6) and (7) can be combined so that the probability of outcome i would become:

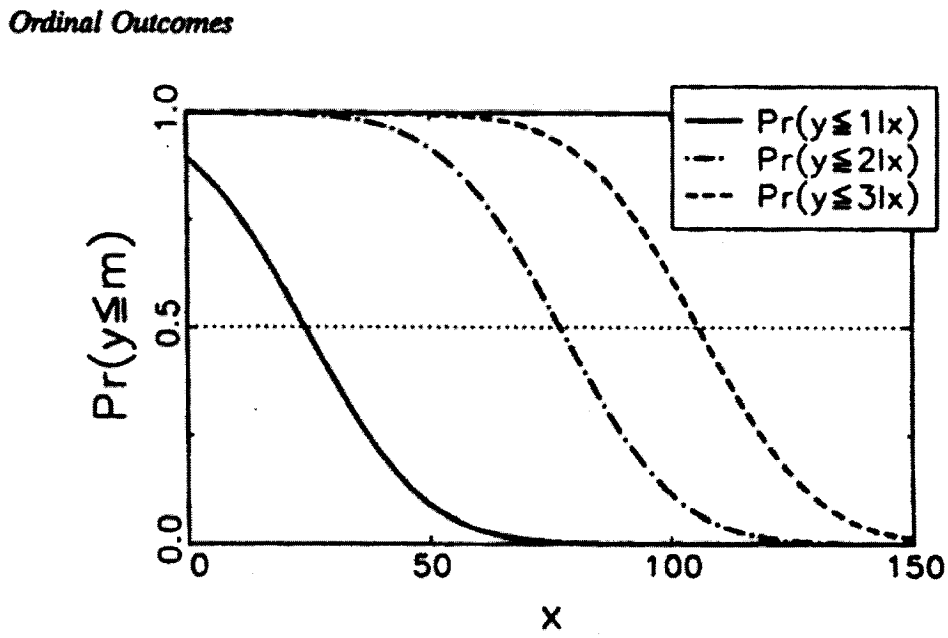
$$\Pr(y = i) = \Pr(\tau_{i-1} - \beta_0 + \beta_1 x_1 + ... + \beta_n x_n \leq \varepsilon \leq \tau_i - \beta_0 + \beta_1 x_1 + ... + \beta_n x_n) \quad (8)$$

The choice of the ordered logit (and hence the formulation of the corresponding equations) to model the commuting distance is directly linked to the assumption made on the form of the error term. If the error term is assumed to be logistically distributed, the ordered logit model results (Long, 1997). The cumulative density function (CDF) for the ordered logit model is then written as a function of this error term such that:

$$\Lambda(\varepsilon) = \frac{\exp(\varepsilon)}{1 + \exp(\varepsilon)} \quad (9)$$

Once the CDF is determined, the probability of outcome *i* happening is simply the probability of the error term being between the two values estimated in equation (8). This corresponds to the area under the CDF curve defined to the left by the lower value in equation 8, to the right by the upper value.

The use of the ordered logit model to estimate dependent variables of ordered categories is based on the *parallel regression assumption*, also known as *assumption of proportional odds* illustrated in Figure 29 below.



(Source: Long, 1997)

Fig. 1: The parallel regression assumption

This assumption states that the influence of independent variables is the same throughout outcomes. In other words, if say a model is defined with three ordered outcomes 1, 2 and 3, then the assumption of proportional odds states that the odds of outcome 3 vs. outcome 2 and 1 jointly considered should be the same as the odds of outcome 3 and 2 jointly considered vs. outcome 1 for any given variable x.

We recall following derivations described in the introduction, that the probability of outcome i happening is given as indicated in equation 8 by:

$$\Pr(y = i) = \Pr(\tau_{i-1} - \beta_0 + \beta_1 x_1 + ... + \beta_n x_n \leq \varepsilon \leq \tau_i - \beta_0 + \beta_1 x_1 + ... + \beta_n x_n)$$

If we suppose that an event is determined by three ordered outcomes only, and if the assumption of proportional odds is not violated, we can then rewrite the previous equation such that:

$$\Pr(y = 1) = \Pr(\tau_0 - \beta_0 + \beta_1 x_1 + ... + \beta_n x_n \leq \varepsilon \leq \tau_1 - \beta_0 + \beta_1 x_1 + ... + \beta_n x_n)$$

$$\Pr(y = 2) = \Pr(\tau_1 - \beta_0 + \beta_1 x_1 + ... + \beta_n x_n \leq \varepsilon \leq \tau_2 - \beta_0 + \beta_1 x_1 + ... + \beta_n x_n)$$

$$\Pr(y = 3) = \Pr(\tau_2 - \beta_0 + \beta_1 x_1 + ... + \beta_n x_n \leq \varepsilon \leq \tau_3 - \beta_0 + \beta_1 x_1 + ... + \beta_n x_n)$$

with a unique β vector valid for the three outcomes.

Before using ologit to model a dependent variable, tests must therefore be conducted to verify the validity of the hypothesis in the context of the data. In Stata®, the software used for estimation, the command to check for this assumption is *brant* named after the researcher who first proposed a Wald test to investigate the equality of all βs throughout outcomes and propose an overall test of the model's validity. The test estimates, for a dependent variable with n outcomes, n-1 binary logistic regressions with each its sets of estimated coefficients. In perfect conformity with the hypothesis, and in order to use the ordered logit model, any given variable must return identical coefficients for each binary logit model. But often, as is the case in the first model we tested, the hypothesis of

proportional odds is violated. In such situations, the use of the ordered logit model is illegitimate. To address this issue, a very neat program was written in Stata® code by Dr. Vincent Fu at the University of Utah (version 1.0), and later upgraded to version 2.0 by Dr. Richard Williams at University Notre Dame. The corresponding command gologit (generalized ologit) relaxes the assumption of proportional odds, and estimates different sets of coefficients for each of the outcomes, *if the assumption is violated for all variables.* If it is only violated for a few, it estimates coefficients for these variables and leaves the other ones unchanged (partial proportional odds).

Chapter 4 On the need for comprehensive transportation data

1. The Montreal OD survey

Detailed and reliable data are the central part of empirical research, especially in social sciences. In a field such as transportation, the importance of detailed, comprehensive data can hardly be overstated. Data (or more specifically, the lack of it) has been pointed as a significant obstacle in poverty studies. Often, its collection is jeopardized mainly for economic reasons: not owning a phone or a permanent address (Dowling and Coleman, 1995, Sen et al., 1995, as quoted by Clifton, 2003).

The study area in this thesis is the Montreal Census Metropolitan Area (CMA). Statistics Canada, the official statistcics agency in Canada defines a CMA as an *"area consisting of one or more adjacent municipalities situated around a major urban core"*. The urban core's population must have a population of at least 100,000 people and the urban fringes must be both economically and socially integrated to the core. In thê case of Montreal, the urban core in question is the Island of Montreal, and urban fringes include both the North and South shores. In 1996, the population of the Montreal CMA was approximately 3,326,510 people over an area of 4024.21 sq.km (Statistics Canada).

The main source for transportation data in Montreal is the Montreal OD survey, a disaggregated trip study conducted every five years in the Greater Montreal Region by the Quebec Ministry of Transportation and various collaborators at both the academic and governmental level. The most recent OD survey was carried out in the fall of 2003 but at the time of this thesis' editing , only the 1998 results were available at the disaggregate level. The database is comprised of 383176 valid trips made by 162594 people (65227 households). The trips recorded for each person are the ones made by any mode (on foot included) on the day before the surveyor made the call. The OD survey details very specific information about each trip made by the respondent the eve of the surveyor's call, namely the municipal sector of origin and destination, the departure time, its purpose and the mode(s). It also indicates whether the commute was a chain trip, and if applicable the mode utilized in the junction trip. Socio-demographic variables such as the age and the sex of the respondent are also included in the respondent's answer. Most importantly, car ownership in the household the

respondent belongs to is also reported. However, information on housing type, income, egress or waiting time is not provided.

2. Transportation data need to reflect the need of transportation disadvantaged groups

The choice of a dataset for transportation studies often involves compromises from the part of analysts who must choose between different data sources depending on their research objectives. The compromise I had to make for this thesis was the choice between, on the one hand, the Montreal OD survey and on the other hand, the Statistics Canada Census Public Use Micro Data file. Although the OD survey does permit analysis at the spatial level, the PUM file contains socio-demographic information such as family status or income that is not available in the OD survey.

The first comparison between the OD dataset and the PUM file tried to examine the respective representation of minority groups in those surveys. Single mothers were one of the few possible choices for comparison studies, because ethnicity or income is not indicated in the OD survey. An attempt was made at selecting single mother's households from the OD survey in order to analyze and describe transportation-related equity issues faced by the members of these households. To provide a similar basis of comparison between the census and the OD survey, I selected in the OD survey only the single mothers who were heads of households and lived with no other adult in the house. In the census, the corresponding group is coded as single mothers, heads of households comprised of only one census family[3]. In the OD, we found 1898 single mothers who corresponded to this criterion who made a total of 6779 trips. Therefore, these 1898 single mothers represent 1898/162594=1.17% of the population in the Montreal CMA. In the PUM File, we count 3267[4] single mothers who lived with their direct family only (no additional person). However, their proportion is three times greater in the PUM (3267/91323= 3.56%) than in the OD survey. Obviously,

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[3] In the census, the census family is defined as members of the same family related by close blood ties or marriage: spouses, common-law partners or single parents and their same blood or adopted children. On the other hand, an economic family comprises members living together who are related by ties other than marriage or close blood ties (nephews, cousins, in-laws...)

[4] This number is different from the 3622 single mothers previously stated because I had to exclude single mothers who did not live with their direct family *only*. The differences between these two numbers (355) represent the number of single mothers who lived with their children *and* other family or non-family members

expansion factors should adjust for these disparities. In the OD survey, the summation of all residents' expansion factors for the single mothers' database totals 42010. This is equivalent to saying that, in the OD survey, the 1898 single mothers actually represent 42010 single mothers. On the other hand, the unique expansion factor for the entire PUM file is 36, so the 3267 single mothers of that database actually stand for 3267*36=117612 single mothers. Even when expansion factors are accounted for, the proportion of single mothers in the OD survey is still only a bit more than a third of that in the PUM. This is a clear case of under-representation of single mothers in the Montreal OD survey.

Transportation disadvantaged groups also include the poor. Transportation officials have tried to include the income question in the 2003 Montreal OD survey as a "free-not-to-answer" item in the phone interview. Of course, issues related to social status, especially those revolving around income, never incite great enthusiasm from respondents. The dataset used for study in this thesis (the Public Use Micro Data file), does include personal income. However, Statistics Canada warns that the low-income measure it proposes is not an official poverty measure, and hence should not be used as such in poverty studies. In the absence of an official poverty measure, statistics on poverty for Montreal range from a low 10% to estimates nearing a third of the population. Identifying who the urban poor really are is essential to address issues of equity and disadvantage. In this regard, both the OD survey and the PUM file fail to provide resources to address the issue of poverty.

The other two groups particularly vulnerable in the population for mobility are the elderly and the physically disabled. The first group is usually defined as the population aged 65 and over. Because both the PUM file and the OD survey do provide information on the age of respondents, studies on the commuting patterns of this subgroup can rely on these datasets. Data for the physically disabled however, are scarcer. In Montreal, an analysis of their commuting patterns was conducted in 1997 by the team in charge of the OD survey. This analysis relied on a 14-day sample of trips taken by commuters in paratransit modes. These typically include adapted taxis and buses. The database, however, proved to be, by the analysts' account, not reliable for study due to systematic errors in the geo-coding exercise. The lack of data on the disabled commuters in Montreal and to some extent the poor leave a void that needs to be filled in the transportation research.

The Montreal OD survey is a great tool to study the travel patterns of Montrealers by gender, sex or age. It is virtually the only way of determining-however approximate the

measures- average commuting distances (the commuting distance in the PUM file is only given as a categorical variable between an upper and a lower limit). It is also of invaluable help in determining new poles of activities or new residential areas. In many transportation-related studies, the OD survey is the most appropriate working tool. Unfortunately, the OD survey does not report information pertaining to one's social capital: level of school attainment, profession, income...which are known to influence how (mode) and how far (commuting distance) a person is likely to travel. These details are reported in the Public Use Micro Data file as part of the Statistics Canada census work. This justifies to a great extent our choice of the PUM dataset for study in this thesis.

3. The study dataset

As explained above, when dataset choice for transportation studies is concerned, compromise is the name of the game, especially when disaggregate data is used. No one dataset, readily available for research purposes, contains at the same time detailed information on transportation variables (mode choice, commuting distance, availability of transit) *AND* socio-demographic variables such as income, household size and marital status. Whereas the OD survey contains detailed transportation information, it does not contain the socio-demographic variables mentioned above. On the other hand, the census PUM file does contain these variables and some transportation variables such as the work trip commuting mode and an approximation of the commuting distance (actual distances are not provided, but rather grouped in one of six categories: less than 5 km, between 5 and 10 km, 10-15,15-20,20-25, 25-30 and greater than 30km).

Chapter 5 Examining the Commuting Patterns of Female Lone Parents

1. The sample

Among the 3622 Montreal single mothers in the PUM file, only 1682 (46.43%) constitute the employed labor force (single mothers *currently* working). In the census, they were asked to report the distance of their work commute and all have done so (no missing data, see table below).

	Labor Force-Employed	Labor Force-Unemployed	Not in the labor force- Last worked in 1995-1996	Not in the labor force-Worked before 1995 or never worked
0 km (worked at home)	81	1	5	
Less than 5 km				
5-10 km				
10-15 km				
15-20 km				
20-25 km				1494
25-30 km				
30 and over km				
No fixed Workplace	46	7	6	
Worked outside Canada	1	2	1	
None of the Above	—	206	—	
Groups Subtotals	1682 =46.44%	321= 8.86%	124=3.42%	1494=41.25%
Grand Total	3622 single mothers in the Montreal CMA for the whole database			

Table 1: Commuting Distance and Employment Status among Single Mothers in Montreal

Note: 1. The shaded area represents the data points used in the regression model.

A few worked at home, some had no fixed workplace or worked outside Canada[5]. Consequently, these women have not reported a work commuting distance (81+46+1=128/1682=7.6% of the currently employed single mothers).

In the census questionnaire, individuals currently unemployed but who have worked at some time since January 1, 1995 were also asked to report the commuting distance relative to the job longest held since January 1, 1995. These single mothers account for 321+124=445=12.28% of the single mothers sample size, but only 217/445 ≈48.76% of them actually reported a commuting distance (the rest worked at home, had no fixed workplace or worked outside Canada).

In total, 1771 single mothers (48.9% of the single mothers' sample) have given information on their work trip distance. 41.2% of single mothers were unemployed and not part of the labour force and had no work commuting distance or mode choice to report.

The following section focuses on the analysis of the commuting patterns of these 1771 single mothers, as a group and as compared with other population segments. The comparison with the male lone parents will help us determine if the commuting differences are gender attributable. On the other hand, the contrast with married mothers will be enlightening in identifying if marital status has any influence on commuting patterns. Finally, we will compare single mothers to single women living alone to find out if the presence of children in the household has any impact on the commuting modes and distances of women.

2. Comparative Analysis of Commuting Patterns

a. Methodology

Although the exact work commute mode choice of respondents is reported in the census, their commuting distances are reported as aggregated variables (categorical variable), that is the length of commute is indicated as belonging to a window of distances (less than 5km, greater than 25 km...). To account for these disparities and present both variables analogously, the proportion of working individuals in each commute mode and each

[5] Single mothers working at home do not commute and hence cannot determine the mode choice they used (dependent variable not defined); on the other hand, those with no fixed workplace cannot report a unique commuting distance, which happens to be an independent variable in our l. They have therefore been removed from the sample.

commuting distance window is reported. Also, socio-demographic variables such as incomes or household size are indicated in later parts of the analysis with the use of the group mean and standard deviation.

This method of presentation calls for appropriate statistical techniques of comparisons. Z-test of means and proportions comparisons are used. These statistical techniques will allow us to determine if observed differences are not just due to random sampling variation. In order to compare the means, the following formula is used:

$$z = \frac{(\overline{x_1} - \overline{x_2}) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

Under the null hypothesis, the difference in population means is set to 0 and the z test determines if the difference in sample means is significant at a predetermined α level (usually 0.05).
Similarly, we use the z-test for proportions comparisons:

$$z = \frac{(p_1 - p_2)}{s_{p1-p2}},$$

where s_{p1-p2} is the standard error of the difference in proportions calculated as follows

$$s_{p1-p2} = \sqrt{\frac{p(1-p)}{n_1} + \frac{p(1-p)}{n_2}},$$

and where p is the weighted proportion of the two samples.

The mode choices and commuting distances discussed in sections b. c. and d. are as displayed in the following two graphs (figure 1 and 2). For ease of presentation, the modes car driver and car passenger have been abbreviated to "driver" and "pgr" respectively. Also, the mode "other" refers to bicycle, cab and walk. Finally, the fourth group (single living alone) only refers to single *women* living alone.

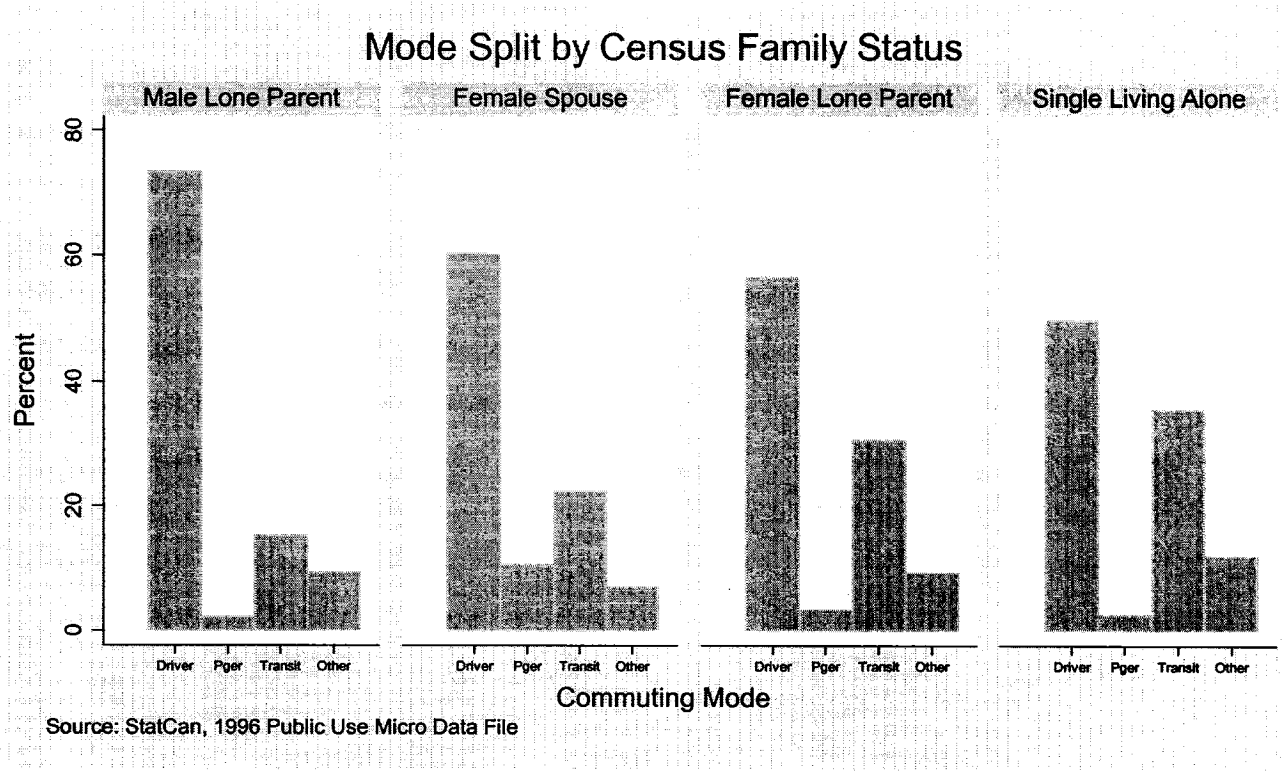


Fig. 2: Mode Choice for the Work Trip for Selected Population Segments

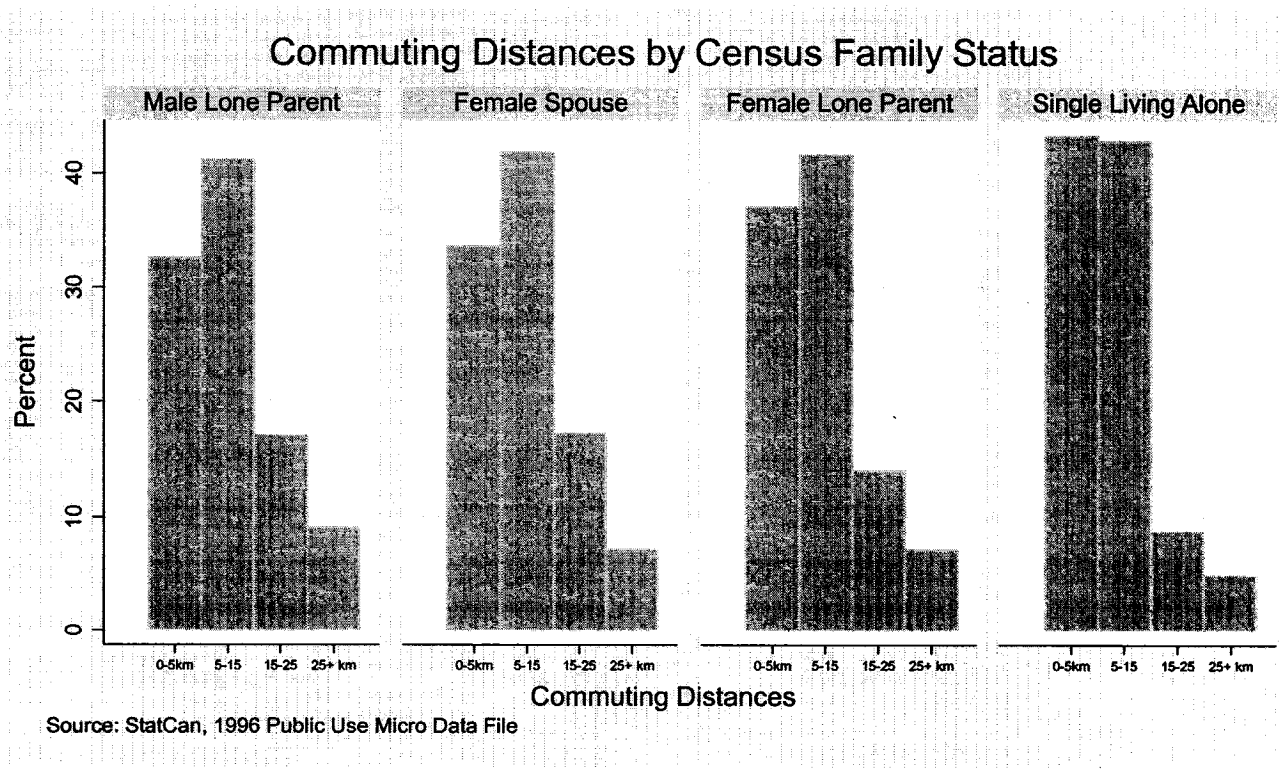


Fig. 3: Work Commuting Distances for Selected Population Segments

b. Male vs. Female Lone parents

In the PUM data file, we observe that 439 male lone parents have reported a commuting distance. An examination of the commuting patterns of lone parents reveals that the highest proportions of male and female single parents commute distances ranging between 5 and 15 km., and do so in equal proportions across both genders (41.23 % for the male lone parents, 41.67% for the female parents). The difference arises in very small and very large distances; in proportion, more single female parents are found in distances less than 5 km (37.1% vs. 32.57 % respectively, finding significant at $\alpha<0.1$) but more single male parents are found in distances greater than 15 km (26.19 % vs. 20.23%, significant at $\alpha<0.01$).

As far as the mode of transportation is concerned, similar proportions of male and female lone parents are car passengers (2.05% and 3.39% respectively) or use other modes to go to work (9.34% and 9.37%). However the data show a gender difference when drive alone and transit are concerned. Significantly more male lone parents drive alone than their female counterparts (about 20% more) while significantly more single mothers use transit than their male counterparts (about 20 %). This is probably the result of gender differences in earned incomes.

c. Female spouses vs. Single Mothers

Female Spouses who have reported a work commuting distance account for $8197/91323 \approx 9\%$ of the PUM file. As far as commuting distances are concerned, single mothers (SM) and female spouses have comparable patterns. The proportions found in the 5-15 and 25^{+} km are virtually equal for both categories: 41.84% of married mothers and 41.67% of single mothers commute distances between 5 and 15 km; similarly, 7.31% of married mothers and 7.23% of single mothers have work trip distances greater than 25 km. Hence, similar proportions of female spouses and single mothers commute very long and moderate distances. The difference in the commuting lengths of these two groups of women is to be found in the very short (less than 5km) and long (15-25 km) categories, and although these differences are not large, they are significant ($\alpha<0.01$): while a bit more than 3% of single mothers compared to female spouses commute distances of less than 5 km (37.1% SM

vs. 33.61 for MM), a bit more than 3% of female spouses compared to single mothers commute distances of 15 to 25 km (17.24% for MM vs. 14% for SM).

The mode choices of both groups, however, are less homogeneous. Compared to female spouses, single mothers rely less on the car to go to work, whether as car passengers or driver, and rely more on transit and other modes of commute (bicycle, walk, cab...). It is not surprising that a lesser proportion of single mothers (vs. married mothers) would be car passengers: car-pooling is often organized among members of the same family, especially husband and wife. In single-mother led households, the single mother is the only adult. Consequently, the probability of car-pooling is greatly reduced and numbers confirm this hypothesis: while 10.48% of female spouses car-pool to go to work, only 3.39% of single mothers do so. On the other hand, a higher proportion of car drivers among female spouses (60.2%) than single mothers (56.58%) is probably representative of lower incomes among single mothers. Single mothers who don't drive or are car passengers use transit and other modes of transportation to go to work. While only slightly more single mothers than female spouses use other modes of transportation (9.37% vs. 7.1%), a significantly higher proportion of them use transit. Almost a third of the working single mothers (30.66%) rely on public transportation to get to work, while only 22.2% of female spouses do.

d. Single women living alone vs. Single mothers

The 1996 PUM file contains 2590 single women who have reported living alone, and they account for 2.84% of the population. These women commute shorter distances to go to work and rely less on the car (whether as drivers or passengers) than single mothers. On the other hand they rely more (35.6% vs. 30.66%) on transit and other modes of commuting (walk, bike). While comparable proportions of single mothers and single women living alone travel moderate (5-10km) distances (41.67% of single mothers, 42.82% single women living alone), a higher share of single mothers commute distances greater than 10km to go to work (21.23 % vs. 13.9%). Also, single mothers rely more on the car, as both drivers (56.58% vs. 49.81%) and passengers (3.39% vs. 2.51%).

3. Detailed Analysis of Socio-Demographic Differences

In the previous section, I have established that when compared to male single parents, a significantly higher proportion of lone mothers use transit to go to work (about 20% more). I have also found that male single parents travel longer distances. Similarly, when compared to female spouses, a higher proportion of lone mothers use public transportation for their morning commute (about 10% more) but the commuting distances of single mothers and married mothers are comparable. Finally, I have observed that a higher proportion of single mothers are found to commute longer distances, rely more on the car to go to work but use less public transportation and other modes than single women living alone.

Therefore, there appears to be differences across genders (male and female single parents travel differently), but also commuting variations that could be attributable to marital status, although these are not as pronounced. Finally, there could be a link between household responsibilities and commuting patterns since women living alone and single mothers show different patterns in both their choice of commuting mode and commuting distances. But without controlling for other socio-demographic variables such as income, level of education and professional status, we can only describe these relationships as associative not causal. Before we account for these variables in our multinomial logit model in chapter 8, we will first try to determine if, compared to single mothers, male single parents, married mothers and women living alone have incomes significantly different from single mothers, and if these differences can explain the disparities we observed in the commuting patterns of these groups.

a. Income

The income statistics pertinent to the four groups we studied in the previous section are presented in figure 3 (next page). Also presented are the proportions, within each segment, of the people living above and below the poverty threshold (fig. 4). Of the four segments, female spouses make the lowest average income, followed by single mothers. These differences in total personal incomes however are not representative of disparities in wages (a z-test of differences between the mean earned wages of both groups shows these are not statistically different) but rather account for the fact that single mothers receive on average higher federal child tax benefits and other government transfer payments (the total

earnings that include government transfers and federal child benefits ***are*** statistically different at $\alpha<0.01$).

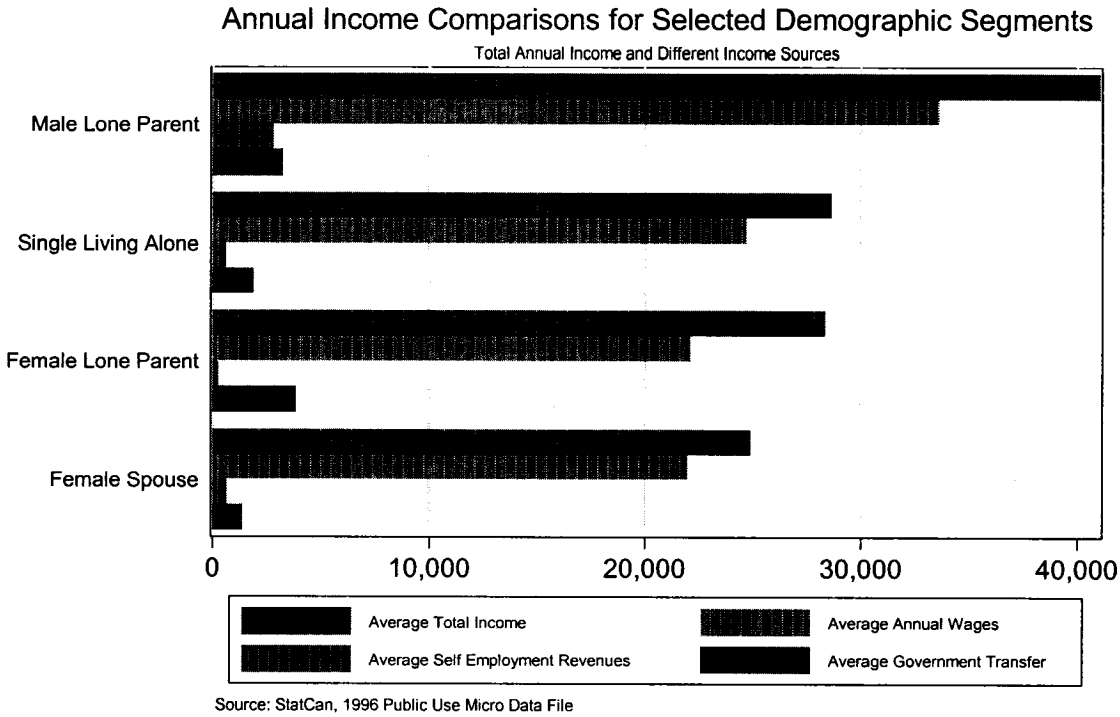


Fig. 4: Income Statistics for Selected Demographic Segments

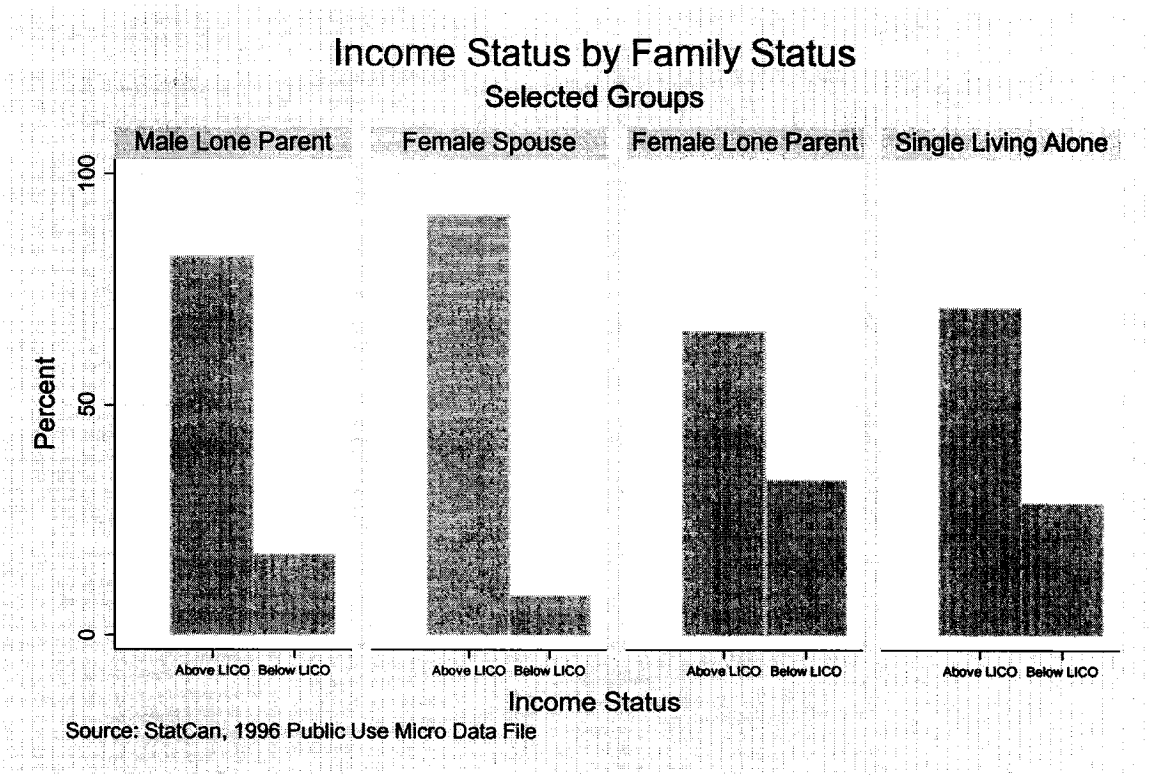


Fig. 5: Income Status for Selected Demographic Segments

We had hypothesized earlier that the fact that a higher proportion of female spouses than single mothers drove to work could be originating from single mothers' lower incomes. But we now find that single mothers actually earn higher average total yearly incomes than female spouses, the difference essentially originating in the form of subsidies from the government. This is an interesting finding because it indicates that it is the resource-pooling capacities of two earner households (of which female spouses are part) that partly enable a higher proportion of female spouses to drive to work, and not just their personal incomes. Along with personal income, it appears therefore that marital status also influences the mode choice of women in Montreal.

The income comparison between single mothers and single women living alone is also illuminating. We had observed that these two groups commuted to work quite differently, both in terms of commuting distances (single mothers travel longer distances), and mode choices (single mothers rely more on car and less on transit and other modes). However, single women living alone make on average almost $3,300 more than single

mothers in total yearly income, a difference significant at $\alpha < 0.01$. This observation leads us to hypothesize that socio-demographic attributes other than gender (household responsibilities, presence of children, level of education) also impact the work commuting mode choice of women.

Finally, when compared to single fathers, we observe that lone mothers make much less money on a yearly basis (close to $13,000 less), travel shorter distances and rely less on car. Consequently, twice as many single mothers than single fathers rely on transit for their work commute (30.66% vs. 15.26%). But are these income differences only due to higher levels of education among single fathers (as shown in the next section) or does gender discrimination also come into play? We have compiled in table 4 average remuneration for both single mothers and single fathers by level of education and occupation to examine this hypothesis. For simplification purposes, we only present the five most preferred occupations by single mothers. We observe that in virtually all categories, single fathers earn higher wages even when education levels are controlled for. For similar degrees and in similar professional categories, male single parents systematically earn more than lone mothers.

	Single Mothers				Single Fathers			
	No degree	High School or Trade	Bachelor	Graduate	No degree	High School or Trade	Bachelor	Graduate
Service: Clerical Positions and Clerical Supervisors (19.03%)	20926.64 (14075.81)	22355.14 (13157.3)	24029.89 (28253.26)	33032.83 (14818.94)	27057 (7967.95)	35819.06 (23517.88)	31482.67 (3058.58)	36000 (.)
Semi-Professional: Financial, Secreterial and Admin. Positions (12.42%)	21549.5 (10760.85)	23202.42 (14311.09)	21193.31 (18153.63)	___	___	29166.67 (15673.88)	54300 (.)	48314 (.)
Managers: Other than Senior management Positions (6.3%)	21089.57 (14039.32)	36405.56 (25984.02)	46591.14 (23907.3)	57204.44 (16774.57)	31125 (18019.33)	38621.17 (27804.54)	56473.95 (26562.24)	85281.5 (28135.01)
Manual Workers: Supervisors, machine operators and assemblers in manufacturing (5.76%)	11269.52 (10458.95)	12290.72 (11350.33)	34500 (.)	___	11122.83 (14556.92)	24454.94 (19088.28)	20891 (15710.5)	___
Service: Chefs and cooks, supervisors, and other occupations in food and beverage service (5.7%)	7050.04 (6646.313)	8555.571 (7933.375)	10000 (14142.14)	___	18583.33 (17884.12)	16775.25 (15750.37)	20271.5 (21536.35)	___

Table 2: Average remuneration by level of education and occupation-Single Mothers and Single Fathers only

In the "manager with a graduate degree category", the difference in earned incomes is as high as $28,000. Limitations in the number of individuals in each cell prevents us from determining if these differences are statistically different (although 872 -49.21%- of the

working single mothers occupy a managerial category, only 30.3% -133- of single fathers do), but the disparities are noteworthy.

In summary, we have observed that single mothers make, on a yearly basis, more than female spouses. However they rely less on both car drive and car passengers as commuting modes than them. We hypothesize that even if, on average, their personal earning is smaller than single mothers' revenues, the presence of a second income earner enables a greater share of female spouses to commute by car compared to single mothers. The opposite phenomenon is true for single women living alone. Although the average yearly income for this population segment is higher than the average annual revenue for single mothers, single women living alone commute shorter distances and more by transit than single mothers. This led us to hypothesize that the presence of children has an influence on commuting patterns. Finally, the comparison with single fathers gives partial credence to the theory of gender discrimination. For similar levels of education and in five of single mothers' occupations (revealed preference), single fathers systematically earn higher wages than their female counterparts. In the next section, we will determine if levels of education and professional statuses also influence travel patterns.

b. Level of Education and Professional Status

The previous section ended on the observation that male lone parent were more dependent on the car and commuted longer distances to work than their female counterparts. We hypothesized that this was likely due to higher earned incomes among male lone parents and we did indeed observe that this category makes, on average, over $13,000 more than working single mothers who commute. Do professional occupations and level of education also contribute to disparities in commuting patterns between male and female single parents on one hand, and among the different categories of women on the other hand? Before we reflect on this question, a brief overview of occupation classification in the Canadian Census is necessary.

The occupation categories of working individuals are defined in two ways in the 1996 Census and consequently reported through two different variables (SOC91P and OCC91P). The first variable follows the 1991 *Standard Occupational Classification (SOC)* and is the method used by Statistics Canada to code the data entered by respondents in their Census questionnaire. On the other hand, OCC91P is used by Human Resource and

Development Canada to classify jobs according to its own nomenclature known as the *National Occupation Classification (NOC).* These two indicators are essentially identical in structure. They both organize all jobs into ten groups of employment categories. At the lowest level, five hundred and fourteen (514) units for SOC91P and five hundred and twenty-two for OCC91P units are aggregated in one hundred and thirty nine (139) minor groups. However, while these groups are collapsed in 26 major groups in OCC91P, they are aggregated in 47 major groups in SOC91P. Furthermore, the way in which they are reported in also different; while OCC91P is geared towards providing information about one's hierarchical professional status (semi-skilled, senior manager...), SOC91P presents more information about the industry of the worker (transport and equipment, childcare, accommodation...)[6]. Preliminary analysis indicates that the influence of social status is greater than the influence of employment industry. Consequently, the OCC91P is primarily used in this dissertation.

To determine if dissonances in commuting patterns between male and female single parents on one hand, and single mothers and other women on the other hand could be also be associated with disparities in education and professional attainment, I have graphed in figure 5 levels of education for these groups.

6 This information is taken from the Census 1996 User Documentation and the Census 1996 Dictionary published by Statistics Canada.

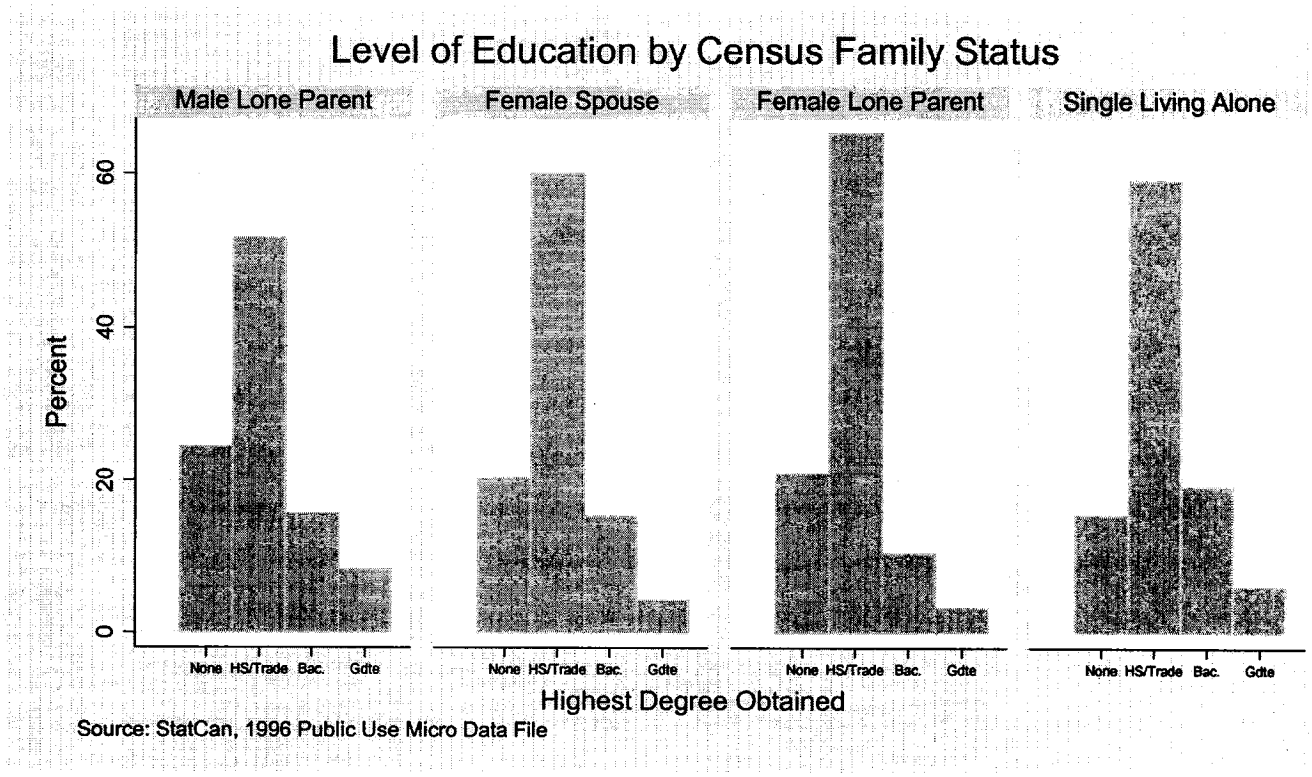


Fig. 6: Education Levels for Selected Demographic Segments

Figure 5 shows that there is a higher incidence of people without a degree among male lone parents than among single mothers (24.37% vs. 21.01%). However, the difference is not significant. Furthermore, there is also a higher share of single fathers with both bachelor and graduate degrees compared to single mothers (a little bit over 10% more, both categories included). Similarly a higher proportion of single fathers are employed as managers (almost 8% more) and professionals (3% more, although the difference is not statistically significant). Therefore, even though we found evidence to support the gender discrimination in earned wages, we can not exclude the possibility that higher levels of education and therefore higher incomes and better professional statuses among single fathers contribute to higher odds of auto drive compared to single mothers. Turning to the married vs. single mothers' comparison, we observe that these two groups share the most similarities. We find virtually equal proportions of these two groups in the no degree, graduate, semi-professionals and managers categories. However, almost 5% more married mothers have a bachelor's degree and 4% more are professionals when compared to single mothers. Both these statistics are significant at $\alpha < 0.01$. So it appears as though the higher incidence of car use among married mothers can be associated with both the structure of the household (presence of two earners) and somewhat higher levels of education. Finally, the table shows that single women living alone are clearly more educated than single mothers. Higher proportions of single women living alone have bachelor and graduate degrees. Higher proportions of single women living alone are also found in professional and managerial positions. We also recall that they make, on average, more money on an annual basis than single mothers. However, they use more transit, rely less on the car and travel shorter distances. This finding goes against intuitive assumptions we made as to the link between level of income and car ownership. We expected the lower car use among women living alone to be representative of lower education, but we find that among the three groups of women studied they are the most educated. Could higher education, better professional statuses be the way for women to shorten their work commute trips? We shall be exploring this hypothesis in the multinomial logit model of commuting distance.

c. Household Size & Responsibilities

In the literature, household responsibilities have often been pointed as the reason why women shorten their trips. However, we have observed that women who have no children (single women living alone), and therefore reduced household responsibilities traveled shorter distances than women who do have kids (single mothers, married spouses) which already contradicts the hypothesis. In this section, we will determine if the same applies for single mothers, female spouses and lone male parents.

In the census, some variables indicate the amount of household chores each individual accomplishes on a weekly basis by quantifying the number of weekly hours they spend doing unpaid housework (uphwkp), looking after the children (upkidp) or caring for seniors (upsrp). Also, although the census does not provide information on the number of children in each family, a variable defines the size of the census family (for definition, please see note on page). These statistics are presented in figure 6 below.

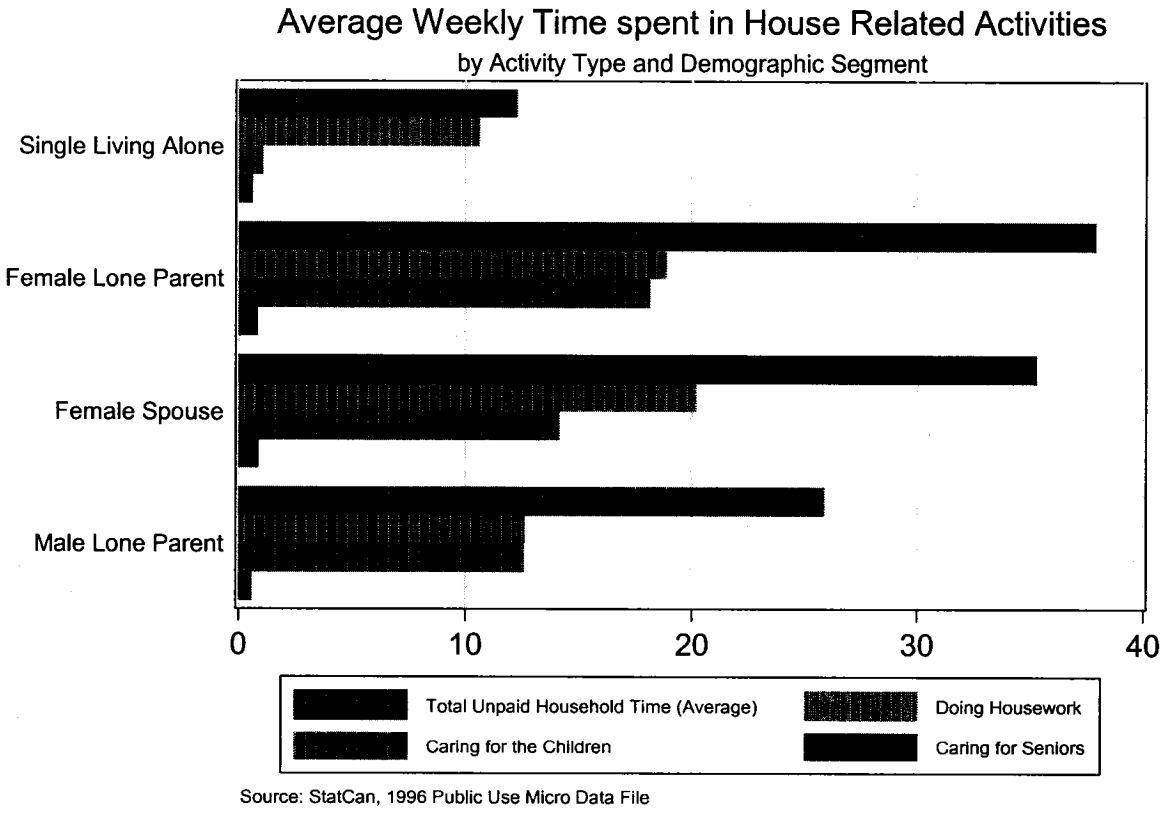


Fig. 7: Average Weekly Time spent in Household-Related Activities

	Single Mothers	Male Lone Parent	Female Spouses	Single Women Living Alone
Average Household Size	2.49	2.44	3.32	1
	(0.67)	(0.67)	(1.06)	(0)

Table 3: Average Household Size by Census Group

As expected, single mothers and female spouses spend the most time doing housework and caring for their children or the elderly. Compared to each other, single mothers spend significantly more time caring for children while female spouses spend significantly more time doing household work. The amount of time they spend caring for seniors are not significantly different. On an aggregate measure though, the total amount of time spent by single mothers working around the house or for members of their families is significantly higher than that of female spouses (5% level).

Compared to male lone parents, single mothers spend more time caring for children, older parents or doing housework, yet their household sizes are not significantly different as indicated in table 3 above, i.e. male lone parents and single mothers have on average, the same number of children. Finally, single women living alone spend the least time in household related activities.

Therefore, the statistics seem to provide partial support for the household responsibilities/commuting distance theory. Single fathers travel the longest, followed by female spouses and single mothers. On the other hand, single mothers spend the most time working around the house, followed by female spouses and lone male parents. The hypothesis, however, does not hold for single women living alone who spend the least time in household related duties and yet travel the shortest distances.

Synthesis: From the findings above, we gather that women will depend more on the car as a mode of transportation if they have to commute longer distances even if their incomes are low. This is the case for female spouses and single mothers. When they travel shorter distances, they rely more on transit and other modes of transportation. This is true for single women living alone. We have found no evidence of women shortening their work commuting distances in order to accommodate household responsibilities. On the contrary, we found that those with the most responsibilities at home (mothers and spouses) traveled longer than single childless women. Also, the most educated segment of women (single women living alone) earn significantly more money but travel shorter distances and hence can rely more on transit, and we hypothesize that it is precisely their higher education that enable them to shorten their work commuting trips by widening their choice and location of employment, although we have no evidence to support this hypothesis.

Single mothers are, on average, less educated than female spouses and single women living alone. This phenomenon translates into low earned wages for single mothers. The average earned wages of married spouses is almost identical to the average earned wages of single mothers, but their total personal incomes differ because single mothers receive substantial aid from the government in the form of government transfer payment and federal child support. Hence, single mothers make annually, on average, more money than married spouses, and this difference is statistically significant. Yet, through pooling resources with spouses, a higher percentage of female spouses are able to use personal motorized modes of transportations, as indicated by the higher proportion of female spouses commuting to work by car, as car drivers or car passengers.

Finally, we found that male lone parents are more educated, and hence earn more money than their female counterparts. This contributes to a much higher proportion of them driving to work. But inequities in earned wages when occupations and education levels are controlled for also exacerbate the already existing differences. Although single fathers use the car more, they also travel longer distances to work than single mothers. They also work less around the house and spend less time caring for families than single mothers although their household sizes are virtually identical. Hence, there appears to be an association

between the amount of time spent doing housework and the work commuting distance but the direction of causality between these two phenomena can not be determined for certain.

An array of social phenomena contribute to the transportation disadvantage single mothers face. Lower levels of education, and consequently lower incomes; the absence of a second income earner to share resources or divide household responsibilities with, all seem to affect their commuting patterns and possibly their well being. They have to compromise between taking care of household responsibilities - statistically speaking, they do the most housework of all the four groups studied- and hence working close to home, and traveling long distances to go to work because they are not as educated as say, single women living alone.

To validate the analysis, surveying single mothers to determine if their commuting distances are the result of choice or constraints would be an interesting exercise. Whichever of these two options it is, the multinomial logit model we develop later in this thesis will help us establish and quantify how their socio-demographic characteristics come into play to influence their commuting patterns.

Chapter 6 The Interaction between Low Incomes and Transportation Choices

1. Measuring Poverty

In Canada, although a number of statistics try to provide some sense of poverty measure, none of these indicators serve as an official indicator of poverty. The most widely used is the Statistics Canada Low-Income Cut-Off point. However, the agency warns: "*The setting of poverty lines necessarily involves a value judgement as to the level of minimum income below which an individual or family would generally be regarded as "poor". No such judgement has been attempted in constructing the low income cut-offs*". Rather, Statistics Canada advises that its LICO measure should be taken as an indication of which population segment makes the less income on an annual basis, and not as an absolute measure to identify in a given population the poor from the non-poor.

a. The Census Low-Income Cut-Off Point

First introduced in 1968, the LICO measure was based on a 1959 analysis of consumer spending conducted by Statistics Canada which determined that, on average, families spend about half of their income on primary needs such as shelter, food or clothing (Ross et al.). Consequently, the agency established an arbitrary measure of the onset of poverty and estimated that families spending more than 70% of their income on these primary needs were considered to be below the poverty line (Statistics Canada).

The calculation of the LICO measure is based on the Survey of Household Spending (1992), formerly known as the Family Expenditure Survey (FAMEX). The method consists of asking and plotting for each respondent (a family) the percentage of income spent on food, clothing and shelter vs. their total annual income. A regression line is fitted to the data and an average percentage of income spent on basic necessities is calculated (Statistics Canada, 1999). The procedure is repeated for different consumers varying the size of the urban area of residence and the family size. Thirty five measures are produced and low income families are identified as those whose incomes would suggest relatively higher spending of their resources, in percentage, on primary needs (20% higher than the average).

In 1992, the share of household income dedicated to clothing food and shelter was found to be on average, 34.7%. Therefore the LICO point was set to be at 54.7% (Human Resources and Development Canada, 2000).

The LICO measure is indexed to follow the changes in consumer expenditures patterns. The 1996 indicator, which will be used in this dissertation to determine levels of poverty, is a set of thirty five annual incomes determined on the basis of urbanization area and family size (see table below).

Family Size	Degree of Urbanization				
	500 000 or more	100 000 to 499 999	30 000 to 99 999	Small Urban Regions (1 000 to 29 999)	Rural (farm and non-farm)
1 person	$16 874	$14 473	$14 372	$13 373	$11 661
2 persons	$21 092	$18 091	$17 965	$16 716	$14 576
3 persons	$26 232	$22 500	$22 343	$20 790	$18 129
4 persons	$31 753	$27 235	$27 046	$25 167	$21 944
5 persons	$35 494	$30 445	$30 233	$28 132	$24 530
6 persons	$39 236	$33 654	$33 420	$31 096	$27 116
7 + persons	$42 978	$36 864	$36 607	$34 061	$29 702

Source: Statistics Canada

Table 4: Statistics Canada's Low-Income Cut-Off (LICO) Point for the 1996 Census

In the 1996 Canadian census used in this analysis, I have created a binary indicator to determine income status. Individuals living above LICO are coded as 0 whereas individuals living below are coded as 1.

b. Other Poverty measures

Aside from LICO, Statistics Canada has also developed other poverty measures to cater to different research needs. One such measure is the Low-Income Measure derived to facilitate income comparisons at the country level (Statistics Canada). Whereas LICO accounts for the family size without distinguishing between adults and youngsters, the Low-Income Measure (LIM) weights each family individual differently, according to their age and their economic responsibility in the household. This adjusted family size is the basis for an adjusted family income which is used to index families in the lowest quartile for that adjusted income category (Statistics Canada). This measure is not reported in the census. Income Adequacy Categories on the other hand, were determined in 1996-97 for the National Population Health Survey and provide a qualitative categorization (low-income, upper-middle) of families based on its size and the total household income. Finally, the Market Based Measure (MBM) of poverty was developed in collaboration with Human Resources Canada, in part because of growing concerns that the issue of poverty was not properly addressed due to the lack of an official statistic to measure it, and also because politicians felt that the LICO indexes, estimated overly generous by critics, overestimated the number of poor in Canada (Mitchell et al, 2003.). The MBM of poverty defines for the year in which they are calculated, the cost of a basket of goods and services for a reference family of four[7] including food, clothing, shelter, transportation and an allowance for other items. In 2000, the Market Based Measure of poverty for the reference family in Montreal was estimated at $ 22,441.

Critics of poverty measures used in Canada have voiced a number of concerns about the use of LICO in poverty research. Hence, they have argued that the low-income cut-off points should not be used to assess poverty because they were set too high to really capture the individuals that are genuinely living below the poverty threshold. Secondly, LICO is a measure developed for the whole of Canada, without accounting for provincial differences in housing or food costs (Sarlo, 1992). Chris Sarlo, at the Fraser Institute, has come up with the *basic needs poverty line* that develops a province by province index to determine a family-

[7] One male and one female parent, aged 25-49 and two children, a boy aged 13 and a girl aged 9 (Statistics Canada).

size adjusted annual income needed to cater for primary needs. These take into account the actual provincial cost of a wide array of necessities from food to shelter and from public transportation to insurance and furniture. The author's analysis finds that Quebec is one of the least expensive Canadian provinces to live in. In 1997, the estimated basic needs poverty line for a family of four was $16,721, well below the Canadian average of $18,856. In 2001, it was adjusted to account for inflation and estimated to be $17,436, while the Canadian average for a family of four rose close to $20,000 at $19,662. Sarlo further extended the concept to provide measures by major CMA's. Hence, it was estimated that the poverty line for a family of four was $17,028 in 1997 and $17,756 in 2001. Any of these numbers are far from the estimated threshold of $31,753 (LICO for a family of four in an urban area).

The method adopted by the Fraser institute is similar to the approach proposed by the US National Research Council and is based on the use of weight factors known as equivalency scales. First, the needs in dollars for a family of four are determined. Then a weight to adjust for the size and composition of the family are applied. The recommended formula for use by the NRC is:

$$ES= (A+0.7C)^{F},$$

Where ES, is the equivalent weight

A, the number of adults in the household

C, the number of children

And F, a factor adjusting for the economy of scales (0.65-0.75)

The factor of 0.7 is to take into account the fact that children generally consume less than adults (70% is the recommended fraction) , and the factor F takes into account the fact that as households increase, costs on a proportion scale, decrease (NRC). In the case of Sarlo's study, the weight of 0.65 for the variable F is used to calculate the equivalent scale.

A critique of LICO in Sarlo's study is the incongruity between on the one hand households qualified as low-income families according to the LICO measure and on the other hand living in houses estimated at very high values. And the data analysis of our micro data file only confirms the existence of this paradox: in 1996, the PUM file for Montreal indicated that roughly a quarter of the individuals found to be living below LICO owned their houses, and that nearly half of these home owners estimated their houses at $100,000

and more. More surprisingly, over a quarter of them estimated theirs at $150,000 and more. These are clearly contradicting figures that outline the need for cautious use of the data.

In this context of several poverty measures, differing definitions and levels of poverty, differences in statistics depending on the use of before or after-tax-income, contradictory life styles of the poor and under-reported incomes by individuals working illegally or not reporting their full incomes, identifying the poor from the rest of the population from merely observing the data is a more subtle game than one can imagine. Also, one needs to account that poverty can be a sporadic event in the life of an individual or a family and does not necessarily reflect a life-long condition. If a family or person's total income is limited any given year for because of the loss of a job or poor investments, they would be considered poor that year, even if savings, networks of friends and family enable them to maintain their standard of living. Currently, no estimate can capture the many nuances of poverty: absolute measures such as the ones developed at Fraser Institute are to the author's opinion the "better" measures of poverty in Canada even if they are often critiqued to be too stringent in denying them the need for a certain level of "social comfort" as opposed to just primary needs. However, in the absence of an official measure of poverty, the measure proposed by the national statistical agency will be the one used to conduct our study, at least in the exploratory data analysis. The use of the measure proposed by the Fraser Insitute will be investigated in the modelling part of this thesis.

2. Identifying Low-Income Families in the 1996 PUM file

The Public Use Micro data File contains information on 91323 individuals for the Montreal CMA. In this dataset, 27.11% of all individuals (24,765) were estimated to be below the low-income cut off-point (see table below).

Census Family Status	Low-Income Individuals By Census Family Status (%)	Proportion of Low-Income in each Category (%)
Male Spouse	11	17.14
Male Common-Law Partner	3.05	16.52
Male Lone Parent	0.83	29.47
Female Spouse	10.85	16.9
Female Common-Law Partner	3.25	17.31
Female Lone Parent	7.66	52.4
Never Married Child in a Married Couple	14.19	18.96
Never Married Child in a Common-Law Couple	3.01	20.23
Never Married Child living with a Single Father	1.22	30.1
Never Married Child living with a Single Mother	12.61	55.98
Non-Family Person living with relatives	3.12	27.9
Non-Family Person living with non-relatives	7.88	57.89
Non-Family Person living alone	21.35	49.73
Total	100%	

Table 5: Prevalence of Poverty and Proportion of Poor by Census Family Status

Over one fifth (21.35%) of all poor are single individuals living alone, and this represents the single highest proportion of all the poor individuals in Montreal. Of this share, 60.57% are women. Conversely, the proportion of poor among all the individuals of this category is a staggering 49.73% as indicated in the second column. That is, a high proportion of the single individuals who are living alone are poor and they account for a great share of the poor population in Montreal.

These two phenomena do not always happen simultaneously. Hence, the second highest share of poor is the category representing never-married children in married couple

households (14.19%). However, less than 20% of this category is poor. This entity regroups all never-married individuals, regardless of age, who are still living with their married parents. The age distribution of the proportion of this category which is under the LICO-point shows that 90% of them are less than 21. Both male and female children of this category are equally affected by poverty.

Aside from single people living alone, the population segments where poverty is especially prevalent (over 50%) are single individuals living with non-relatives, the single mothers and children living with single mothers, but all three groups together account for less than a third of the poor population (28.15%). Because single mothers have already been discussed extensively in the previous chapter, they will not be analyzed here. Rather, we will focus in a first part on singles (living with relatives, non-relatives or alone), then on children still living with at least one of their parents and finally individuals living in some kind of marital arrangement and single fathers.

a. Single individuals

As indicated in table 8 below:

- 2767 people have reported living with a relative other than a parent or a spouse. They account for 3.04% of the PUM. A bit less than a third (27.9%) of them live below the poverty threshold (Low-Income Cut Off Point).
- 3370 individuals in the PUM dataset have reported living with non relatives and this segment represents 3.71% of the data. More than half (57.89%) of this population segment has been determined to be below the low-income cut-off point.
- Finally, 5288 of the 10634 who have reported living alone do not make a sufficient yearly income to cater for their basic needs.

Single individuals living alone or with non-relatives only are considered in the census to be unattached individuals, which means that they are not part of any economic family.

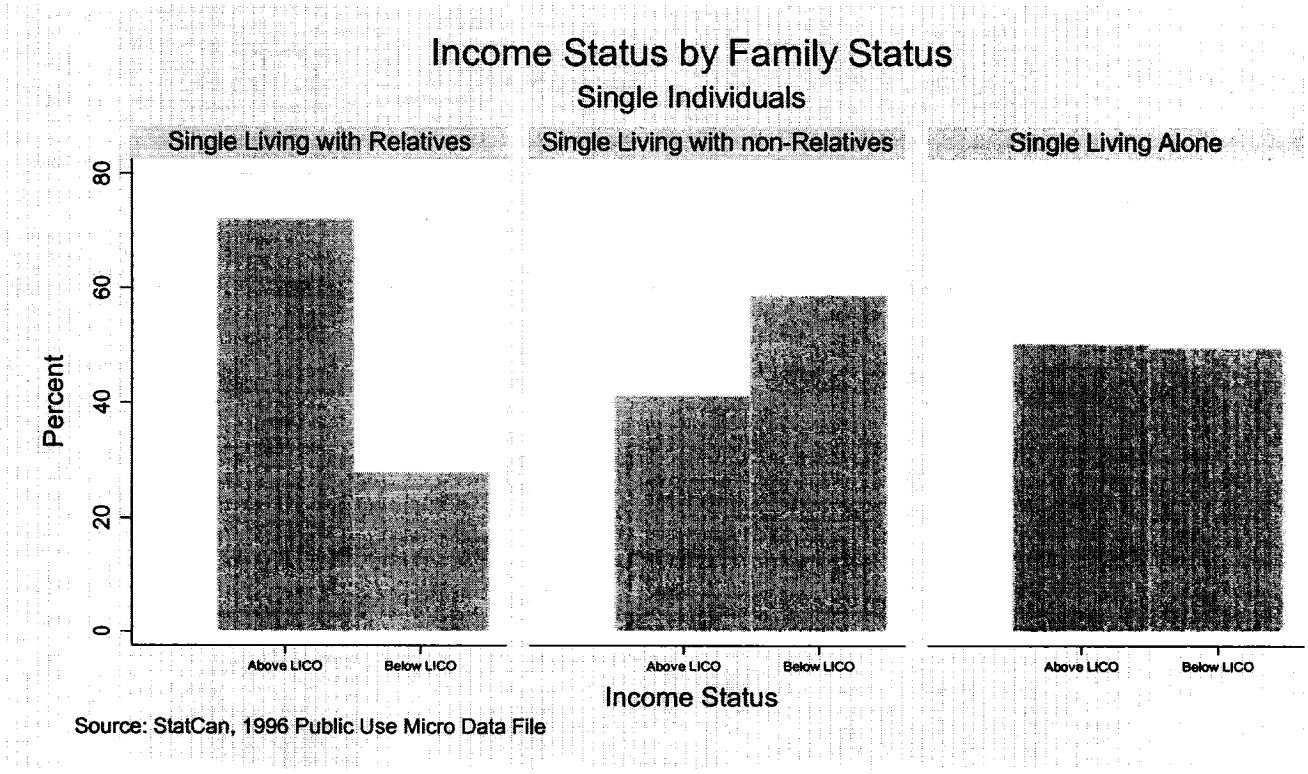


Fig. 8: Income Status by Census Family Status-Single Individuals

Their level of welfare or poverty is solely dependent upon the income they make, even if they live with roommates.

This is why the income status of individuals who are less than 15 and live with non-relatives only (48) is not reported, even if they are raised by the people they live with. On the other hand, 200 of the 2767 people who have reported living with a relative other than a parent or a marital partner are less than 15, but because they are related by blood with at least one member of the household they live in, they carry the income status of that relative.

All three census groups considered, the prevalence of poverty is anywhere between 27 and 57%, which are very significant rates of poverty. Not surprisingly, part of this poverty can be explained by very high rates of unemployment as detailed in table 6 below: 53.15% of the single living with non relatives and 73.5% of the single living alone are not working. Although a portion of the non-working individuals are looking for new employment opportunities, the highest majority are not considered to be part of the labour force because they last worked two years before the census or never even worked. The severity of this phenomenon is especially acute among singles living alone where well over half of the poor have not worked in the two years previous to the census.

772/2767 **single living with a relative** below the LICO measure	168 are in the Labor Force and Employed	160 with a commuting distance 52 without a commuting distance
	102 are in the Labor Force but Unemployed	35 with a commuting distance 67 without a commuting distance
	50 are not in the Labor Force and last worked in 1995-1996	43 with a commuting distance 7 without a commuting distance
	339 are not in the Labor Force because they worked before 1995 or never worked	
	113 are less than 15 and are not considered to be part of the labor force	
1951/3370 **single living with non relatives** are below the LICO measure	914 are in the Labor Force and Employed	843 with a commuting distance 71 without a commuting distance
	294 are in the Labor Force but Unemployed	123 with a commuting distance 171 without a commuting distance
	131 are not in the Labor Force and last worked in 1995-1996	112 with a commuting distance 19 without a commuting distance
	612 are not in the Labor Force because they worked before 1995 or never worked	

5288 /10634	1401 are in the Labor Force and Employed (1 2)	1277 with a commuting distance
single		124 without a commuting distance
living alone	608 are in the Labor Force but	202 with a commuting distance
are below the	Unemployed (3 10)	363 without a commuting distance
LICO	207 are not in the Labor Force and last worked in	171 with a commuting distance
measure	1995-1996 (11 12)	13 without a commuting distance
	3072 are not in the Labor Force because they worked before 1995 or never worked	

Table 6: Labour Force Activity and Availability of Transportation Variables among Singles

The issue of unemployment among the poor is particularly relevant to the research on the transportation disadvantaged population because people who do not work do not report a commuting distance, and this prevents researchers from analyzing their commuting patterns and determining their transportation needs. As an illustration of this problem, we have determined that of all three census groups to which singles belong, 8011[8] individuals are below the LICO indicator but because a great deal of them do not work (and hence have not reported a commuting distance), the dataset is automatically reduced to 3853 data points. Missing transportation data from people who currently work or have worked at some point since 1995, further reduces the dataset to 2966 (the difference is made up by people who do not have a fixed workplace or worked outside Canada). This means that the commuting patterns of over 60% of the poor and single individuals will not be analyzed because they are unemployed and could not report any transportation variable or did work, but not at a fixed location.

b. Children living with at least one parent

28,782 individuals are coded in the census as living with at least one of their parents (father and/or mother). Of those, over 25% (7,681) live below the poverty threshold. The distribution by census family and income status is detailed in figure 8 below.

[8] 772 Single living with relatives +1951 Single living with non-relatives + 5288 Single living alone

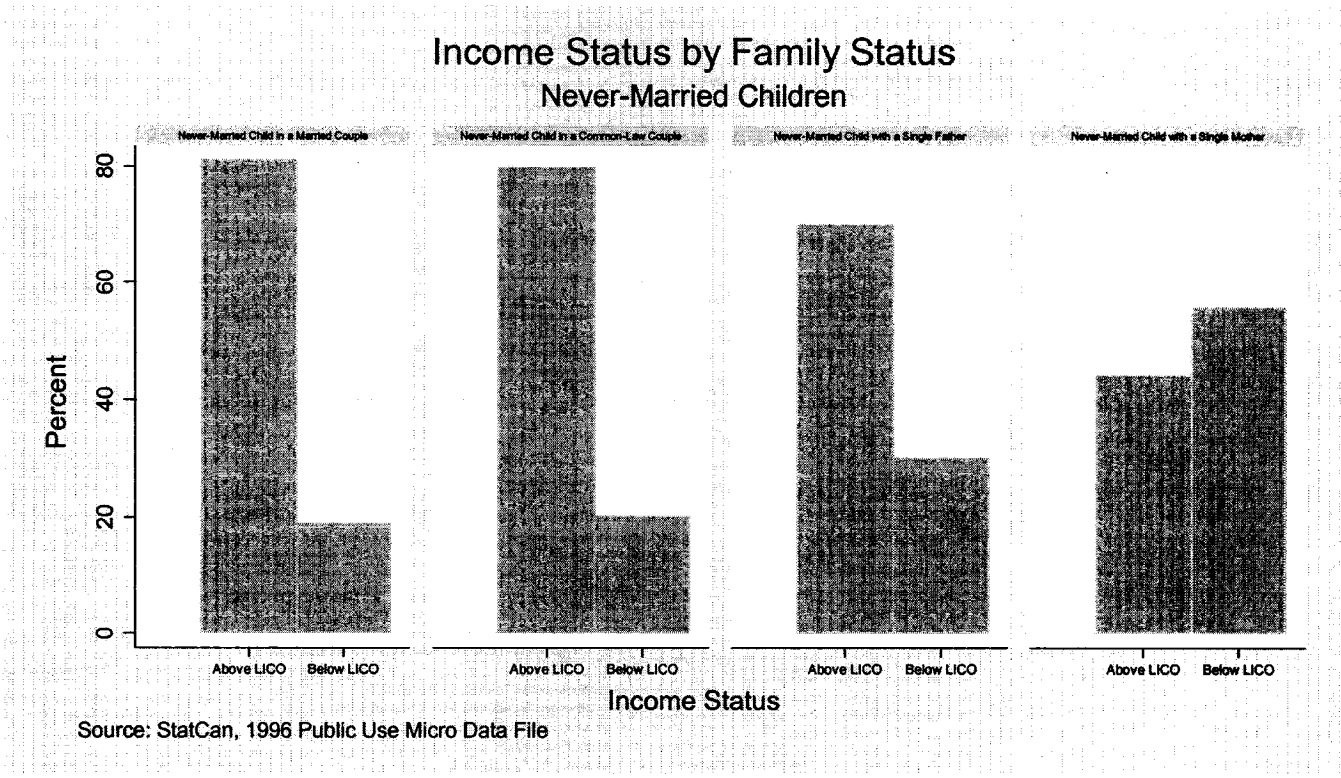


Fig. 9: Income Status by Census Family Status-Never-Married Children

This figure illustrates that, as expected, children living with single mothers are the most disadvantaged (almost 56% of them live below the poverty threshold). Of all children, they are the only group where there are more individuals living below LICO than above. Because the census definition of a child living with a parent is irrespective of age, the age distribution of these children is quite widespread and we observe that 5,225 of the 28782 "children" are aged 21 and over, well over 15% of the sample. And age is an important

factor to consider with this segment of this population because it will determine the employment status, which will in turn influence commuting patterns.

And hence, we observe from table 7 below that the poor population in this segment that commutes is quite reduced compared to the original dataset of 28,782 children living with their parents. In total, we have gathered commuting information on only 789 of them, the rest being above the poverty line, underage to work or simply unemployed. Detailed information on the employment and census statuses of poor (under LICO) children living with their parents is also presented in table 7. The 789 individuals on which we have gathered transportation variables are obtained through summing the category subtotals in the shaded cells.

3,513 Never Married Children in a Married Couple live below LICO	287 are in the Labor Force and Employed	25 without a commuting distance
	120 are in the Labor Force but Unemployed	73 without a commuting distance
	91 are not in the Labor Force and last worked in 1995-1996	3 without a commuting distance
	623 are not in the Labor Force because they worked before 1995 or never worked	
	2392 are less than 15 and are not considered to be part of the labor force	
745 Never Married Children in a Common-Law Couple live below LICO	20 are in the Labor Force and Employed	1 without a commuting distance
	15 are in the Labor Force but Unemployed	12 without a commuting distance
	5 are not in the Labor Force and last worked in 1995-1996	1 without a commuting distance
	48 are not in the Labor Force because they worked before 1995 or never worked	
	657 are less than 15 and are not considered to be part of the labor force	
301 Never Married Children living with a Single Father live below LICO	35 are in the Labor Force and Employed (1 2)	3 without a commuting distance
	24 are in the Labor Force but Unemployed (3 10)	21 without a commuting distance
	10 are not in the Labor Force and last worked in 1995-1996 (11 12)	1 without a commuting distance
	69 are not in the Labor Force because they worked before 1995 or never worked	
	163 are less than 15 and are not considered to be part of the labor force	
	240 are in the Labor Force and Employed (1 2)	

3,122		19 without a commuting distance
Never Married	121 are in the Labor Force but Unemployed (3 10)	[redacted]
Children living		89 without a commuting distance
with a Single	78 are not in the Labor Force and last worked in	[redacted]
Mother live below	1995-1996 (11 12)	9 without a commuting distance
LICO	487 are not in the Labor Force because they worked before 1995 or never worked	
	2196 are less than 15 and are not considered to be part of the labor force	

Table 7: Labour Force Activity and Availability of Transportation Variables among Children living with at least one Parent

c. Spouses, Common-Law Partners and Single Fathers

Incidences of poverty are present in all demographic segments but its prevalence is less pronounced among spouses, common-law partners and single fathers than among the other two groups discussed in the previous paragraphs. In the same way we did in the previous paragraphs, we present in figure 9 the proportion of individuals within these groups who live below LICO.

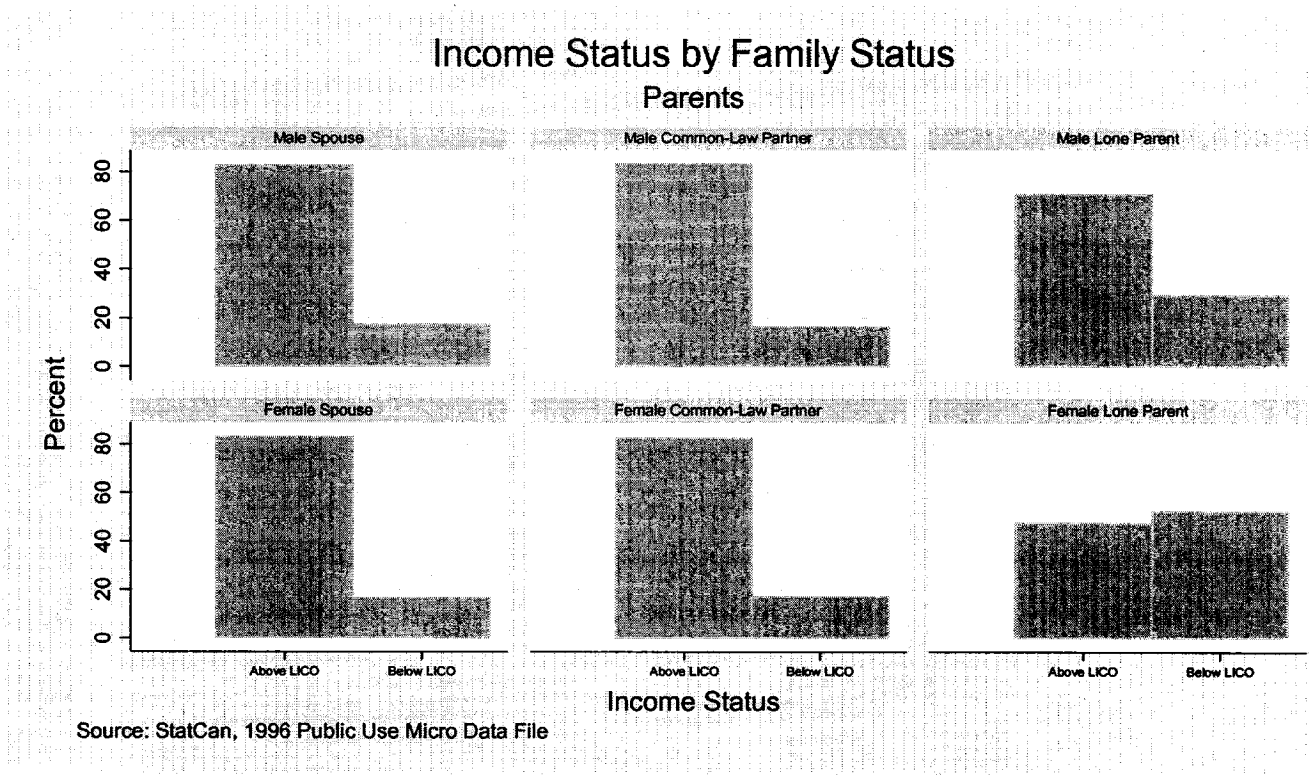


Fig. 10: Income Status by Census Family Status-Parents

Single mothers are the most affected by poverty, whereas the proportion of poor among common-law partners and spouses are significantly lower and virtually identical. This is a potential indication that marital status plays a role in the incidence of poverty among families and individuals. Along with marital status, unemployment is also to blame for the causes of poverty, which incidentally is more common among single fathers than among spouses and common-law partners (table 8). Table 8 below also details the availability of transportation variables for these demographic segments. Once again, the statistics illustrate quite well why the issues of poverty and unemployment are particularly relevant to transportation studies: in total, 7175 spouses, common-law partners and single fathers have reported incomes below LICO. However, work commuting variables are reported only for 2950 of them, less than half of the original study pool.

5409/31779 Spouses (both male and female) below the LICO measure	1,808 are in the Labor Force and Employed	[redacted] 197 without a commuting distance
	659 are in the Labor Force but Unemployed	[redacted] 454 without a commuting distance
	270 are not in the Labor Force and last worked in 1995-1996	227 with a commuting distance 43 without a commuting distance
	2,670 are not in the Labor Force because they worked before 1995 or never worked	
1560/9219 Common-Law partners (both male and female) are below the LICO measure	730 are in the Labor Force and Employed	[redacted] 80 without a commuting distance
	262 are in the Labor Force but Unemployed	[redacted] 173 without a commuting distance
	93 are not in the Labor Force and last worked in 1995-1996	[redacted] 9 without a commuting distance
	474 are not in the Labor Force because they worked before 1995 or never worked	
206/699 Single Fathers are below the LICO measure	76 are in the Labor Force and Employed (1 2)	[redacted] 10 without a commuting distance
	48 are in the Labor Force but Unemployed (3 10)	[redacted] 33 without a commuting distance
	9 are not in the Labor Force and last worked in 1995-1996 (11 12)	[redacted] 6 without a commuting distance
	73 are not in the Labor Force because they worked before 1995 or never worked	

Table 8: Labour Force Activity and Availability of Transportation Variables among Spouses, Common-Law partners and Single Fathers

Table 8 is a summary of all the information we have presented above and some more. In this table, we show the proportion of both above and below LICO individuals by census family status. We have also provided information on their employment rates. When the whole Public Use Micro Data File is considered, over 22,000 people were found to be under the poverty threshold but transportation-related information on less than a third of them is available for study. Several causes are at the origin of this paucity of information. First, over a quarter of the poor population is under the age of 15. Because this segment of the population is too young to work, and because the only mobility information the survey includes relates to work commutes, there is no mobility information for individuals under

the age of 15. This is represented in column 2 (children) by high rates of unreported employment statuses (60% of the "children" do not have a reported employment status). Secondly, those who can work have limited rates of participation in the labour force (65% of the poor population who could potentially work- 15 and over- is unemployed). Hence Table 9 unambiguously shows that low participation rates in the labour force are associated with increased rates of poverty. Among the three main censuses groups identified, we observe that rates of employment are systematically twice as high in the above LICO population than in the below LICO population. This constitutes a double edged sword for the poor population. First, low participation in the labour force is concomitant with high rates of poverty. Secondly, these low employment rates limit the abilities of researchers to study the commuting patterns of the poor because information of their transportation habits is so limited. Although we can only analyze how the poor who commute do so, we also inquire why such a substantial proportion of the poor do not work.

	Single other than Single parents		**Children**		**Spouses, Common-Law, Single Fathers**	
	Below LICO	Above LICO	Below LICO	Above LICO	Below LICO	Above LICO
Total Proportion in the PUM	16771/91323= 2.51%		28782/91323= 31.52%		41697/91323= 45.66%	
Proportion by income status	8011/16723=47.9%	8712/16723=52.1%	7681/28782= 26.69%	21101/28782= 73.31%	7175/41697=17.2%	34522/41697=82.8%
Employed Labour Force	2483= 31.4%	5590= 64.81%	582= 25.60%	4916= 53.60%	2614= 36.43%	23725=68.72%
Unemployed Labour Force	1004= 12.53%	382=4.28%	280=3.6%	814=3.86%	969=13.5%	1343=3.89%
Not in the Labour Force	4411= 55.06%	2653= 30.45%	1411= 18.37%	3442= 16.31%	3591=50.05%	9454=27.39%
Employment Status not Reported	113= 1.41%	87= 1%	5408= 70.41%	11929= 56.53%	1<1%	0
Proportion for whom transportation-related information is available	2757/8011= 34.42%	5582/8712= 64.07%	763/7681= 9.93%	5764/21101= 27.32%	2653/7175= 36.98%	23046/34522 =66.76%
Size (n) of Sample Used for further analyses	2757	5582	763	5764	2653	23046

Table 9: Summary Table for Section 2

3. Socio-demographics and commuting patterns of the poor

On the low-income individuals who work and have reported a work commute and a commuting mode, we have tabulated relevant information in figures 10 to 13 below. The same information is also reported for the non-poor population for comparison purposes.

As was the case with working single mothers, we observe that poor individuals are systematically less educated than their individuals living above LICO. In each of the major census families we have presented, the majority of poor individuals hold no more than a high school or a trade degree. On the other hand, non-poor people are more represented in higher education categories and fewer of them have no degree at all. This is an important, yet expected, finding because it points to the importance of education in the fight against poverty. Predictably, higher education among the people above LICO capitalizes in higher statuses jobs; while at least three quarters of the low-income individuals are manual workers or service personnel, higher education among people living above LICO enable them to occupy higher status, better paying jobs. These better paying jobs in turn translate in higher use of motorized modes of transportation for the work morning commutes. While people living above LICO largely rely on the car to go to work, and primarily as car drivers, poor people rely mostly on transit and other secondary modes. Only poor spouses, poor common-law partners and poor single fathers rely more on the car, despite their financial precariousness (when compared to other segments in the poor population). This is possibly an indication of the role of marital status and family size in the commuting patterns of household members. We also observe that the commuting patterns of the poor are characterized by short commutes: independently of their census status, at least 80% of the poor commute distances smaller than 15 km. On the contrary, individuals who make incomes above LICO commute longer distances, a clear corollary of higher motorization rate in this population segment.

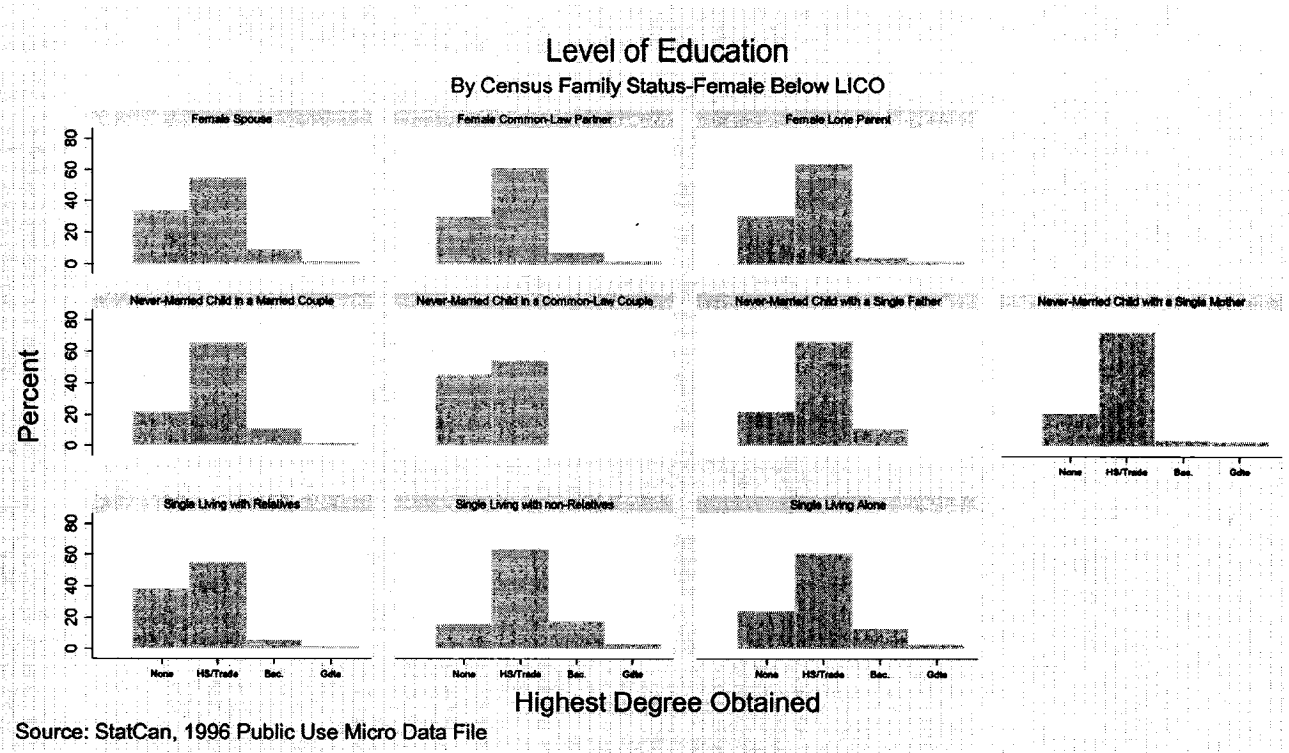


Fig. 11: Level of Education by Census Family Status- Women below LICO

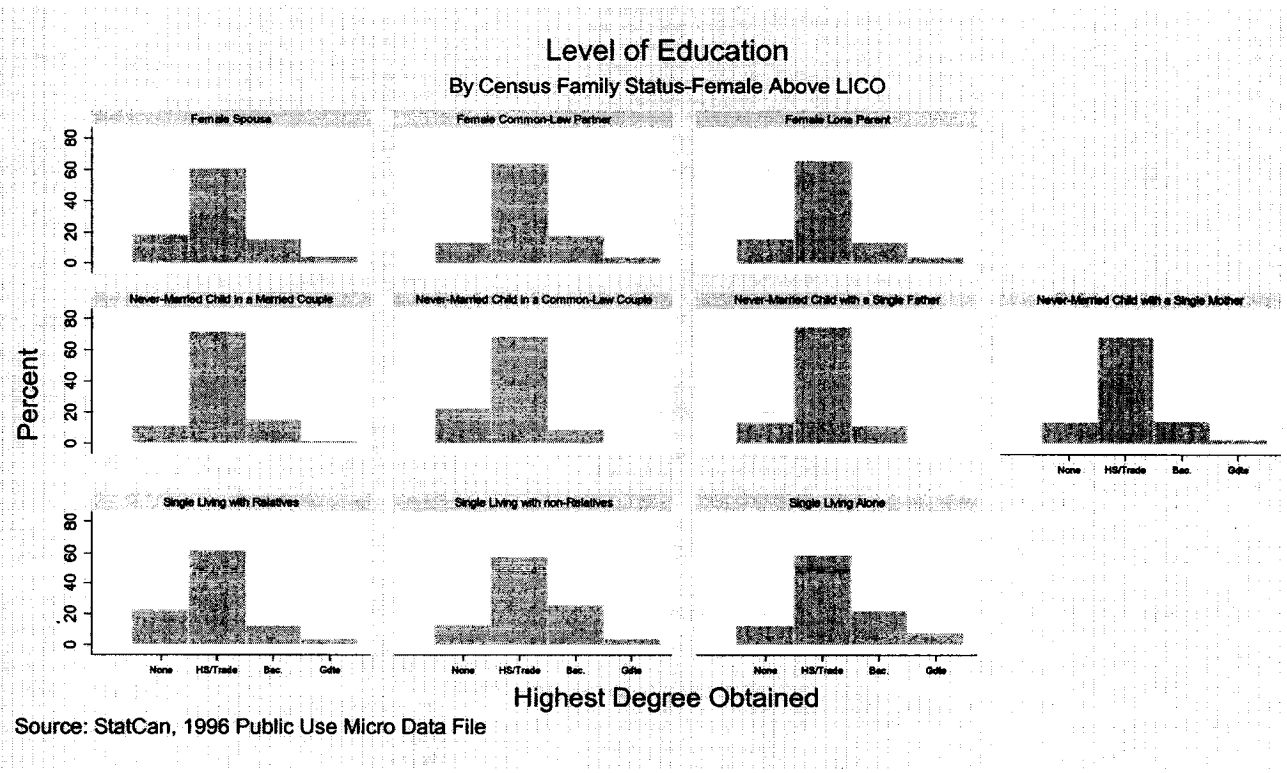


Fig. 12: Level of Education by Census Family Status- Women above LICO

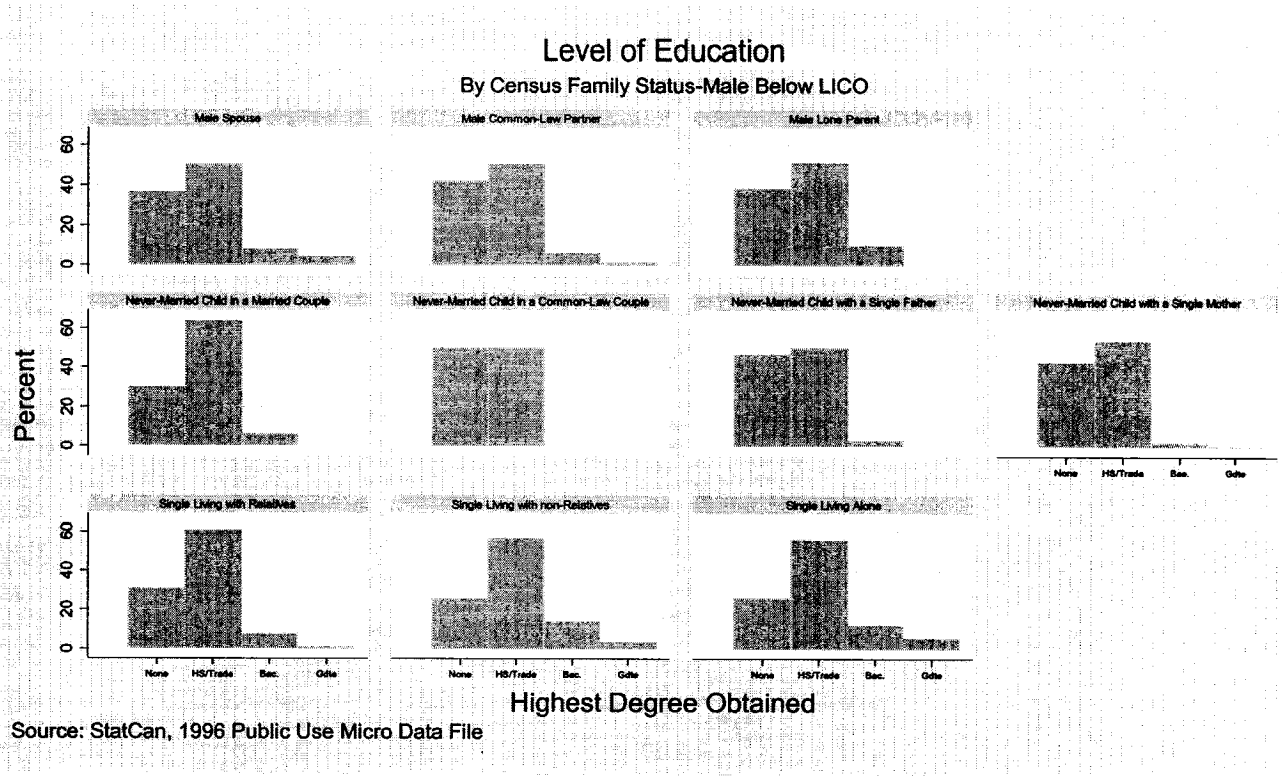


Fig. 13: Level of Education by Census Family Status- Men below LICO

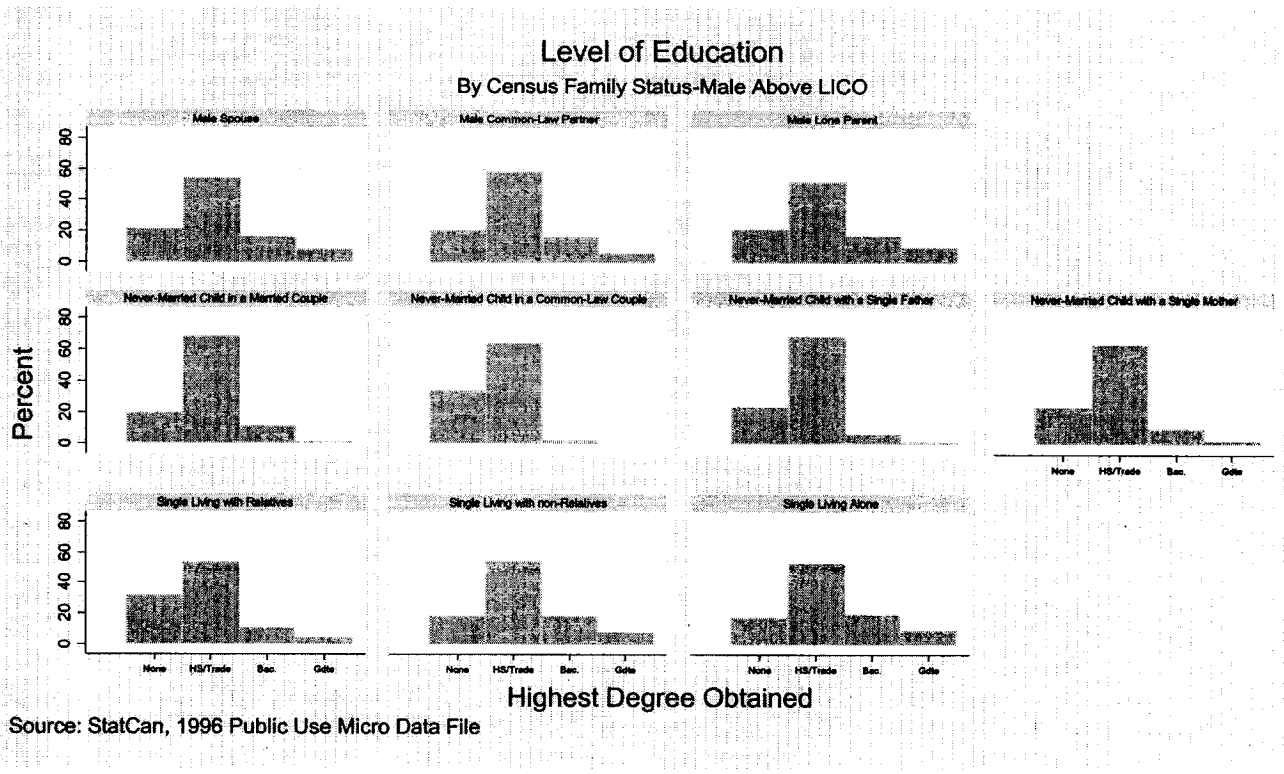


Fig. 14: Level of Education by Census Family Status- Men above LICO

One of the inferences of the spatial mismatch hypothesis is that suburbanization of jobs translate in longer commutes for the poor population. The observations drawn from the analysis of the previous four graphs above suggest however that this implication of the spatial mismatch hypothesis is not verified in our dataset. The graphs show that low-income individuals, who are less motorized and therefore rely more on transit also favor jobs in close proximity to their residential location. While the SMH suggests that the suburbanization of jobs has lengthened the commutes of the low-income working class, our data analysis suggests that low-income individuals do not have long commutes and actually commute shorter distances than individuals earning higher wages. To investigate further this hypothesis, we have tabulated in table 10 below commuting distances by professional status for both the poor and non-poor population.

			Manual Workers	Service Personnel	Semi-Professionals	Professionals	Managers
Above LICO	Sample Size		7464	[illegible]	[illegible]	[illegible]	[illegible]
	Commuting	Less than 5km	36.37%	31.29%	26.34%	28.89%	27.92%
	Distance	5-15	39.66%	41.36%	43.77%	41.82%	39.24%
	(%)	15-25	15.43%	17.83%	20%	18.98%	19.94%
		25+ km	8.53%	9.52%	9.89%	10.31%	12.9%
Below LICO	Sample Size		2457	[illegible]	[illegible]	[illegible]	[illegible]
	Commuting	Less than 5km	43.35%	44.58%	38.4%	42.63%	42.99%
	Distance	5-15	41.03%	38.63%	44.7%	37.59%	36.89%
	(%)	15-25	9.24%	10.16%	11.46%	11.18%	9.76%
		25+ km	6.39%	6.62%	5.44%	8.6%	10.37%

Table 10: Commuting Distances by Professional Status- above and below LICO individuals

Table 10 above clearly verifies the hypothesis formulated above. Within an income group (above or below LICO), individuals in higher professional statuses will commute longer distances than individuals in low-skill jobs. This phenomenon is especially acute among workers above LICO, where managers and professionals commute significantly higher distances than manuals workers or service personnel. Also, within a same professional group (semi-professionals, service personnel), the workers above LICO systematically

commute longer distances. Commuting distances, it appears, are primarily influenced by personal economic constraints. Poor people, who incidentally are also less educated, commute short distances partly because they can not afford to commute long distances. Contrary to the spatial mismatch hypothesis, they do not commute longer distances than white collars. The observations we have made suggest that the spatial mismatch hypothesis is not applicable to Montreal.

Chapter 7 The Influence of Ethnicity on Commuting Patterns

1. An overview[9]

The issue of racial differences and its implications in social behaviours have received extensive reviews from researchers, especially in the United States. Because information on individuals' ethnic origins is available in the census, we can analyze whether race is a contributing factor in observed differences in commuting patterns in Montreal.

In 1996, 3.2 million individuals living in Canada identified themselves as visible minorities, a quarter of which immigrated after 1991. In that year, they accounted for 11% of the entire Canadian population. Montreal was home to 13% of the Canadian visible minorities and in the whole of Quebec, 6.2% were minorities. Compared to the majority group, minority individuals are younger and more educated: while in 1996, 19% of the visible minorities held a university degree, only 13% of the non-minority group did. Also, close to 70% spoke at least French. Yet, minorities are less likely to be employed, and over one in three lived below the poverty threshold. Poverty among minorities is especially prevalent among the Black, the Arabs and the Latinos.

A study conducted on the commuting patterns of the poor in Toronto (Haider et al., 2005) indicates that immigrants are more likely than Canadian born to use transit. Interestingly though, these patterns were found to become less different the more immigrants lived in Canada, even when socio-demographics are controlled for. A report by Statistics Canada confirms that these patterns are found throughout Canadian cities (Heisz and Schellenberg, 2004).

The 1996 census for the Montreal CMA contains over 11,000 records of people who have indicated belonging to at least one visible minority. Over three quarters of them indicated being black or being some other minority. The other 25% was equally distributed among Chinese immigrants and South-Asians. Socio-demographics are reported in figures 14

[9] The statistics presented in this section are taken from *Visible Minorities in Canada*, a 2001 Statistics Canada publication

and 15 below for Chinese immigrants, South-Asian immigrants and the Caucasian population.

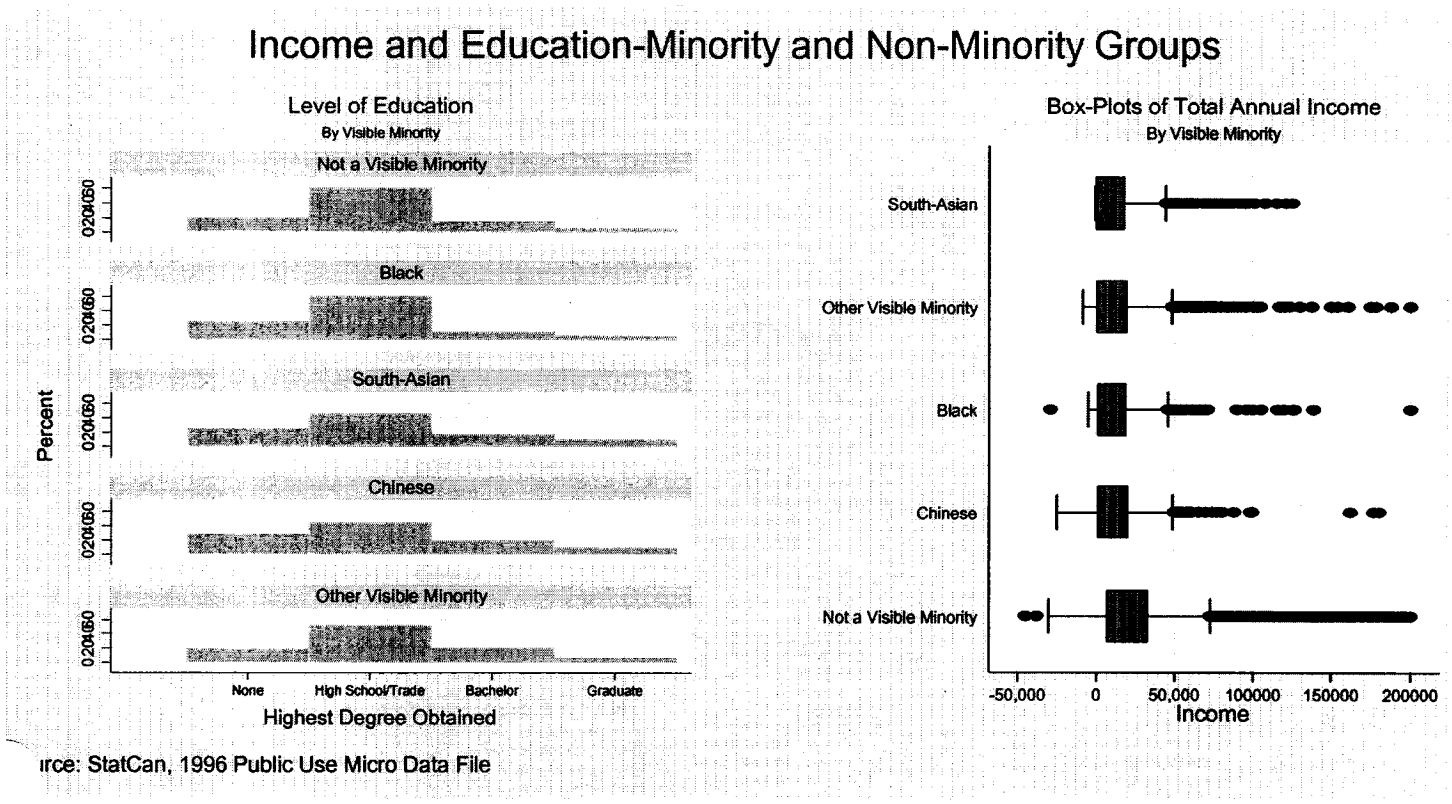


Fig. 15: Income Distribution and Level of Education by Visible Minority

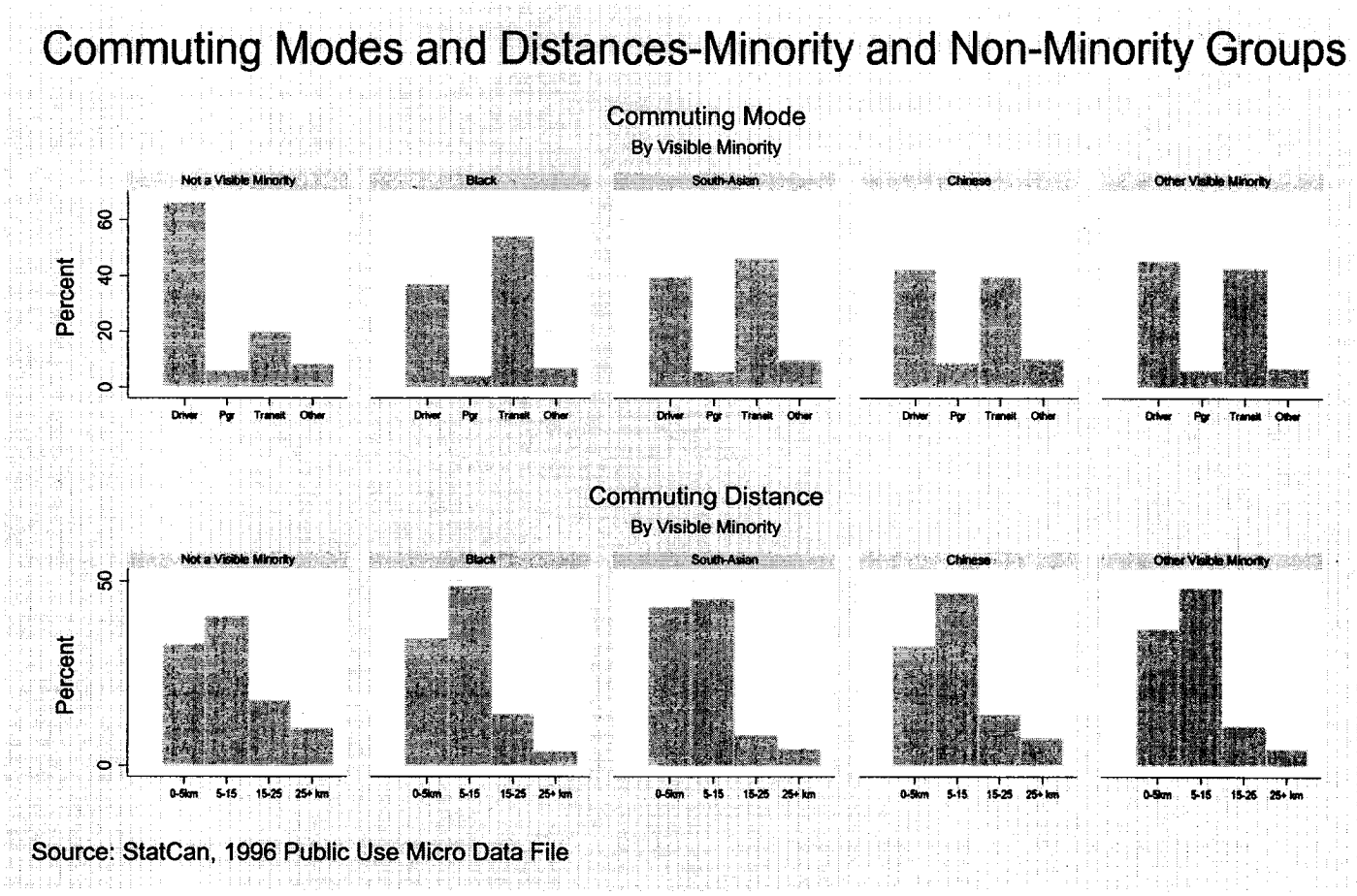


Fig. 16: Commuting Modes and Distances by Visible Minority

	Not a Visible Minority	Other Visible Minority	Black	Chinese	South Asian
	38,001=	**1,903=**	**1,316=**	**574=**	**511=**
	89.83%	**4.5%**	**3.11%**	**1.36%**	**1.21%**
Individuals below LICO within the ethnic group	**13.70%**	**34.40%**	**38.22%**	**35.95%**	**37.06%**
Average Yearly Income (1996 $, std deviations in brackets)	**30163.15 (25343.12)**	**21959.48 (22113.81)**	**19509.95 (18191.3)**	**19695.99 (19067.99)**	**20681.76 (20568.68)**

Table 11: Socio Demographics variables Comparison- Working individuals 15 and over (Majority and minority groups and Working Minorities

Table 11 shows higher incidences of poverty among minorities than among the white population: In each of the minority groups, the proportion of poor is at least 20% higher than it is in the non-minority group. This very significant difference is all the more striking as it is not really imputable to lower levels of education among minorities: although higher proportions of minorities[10] have no degree compared to the White population, higher proportions of minorities also hold university degrees compared to the White population. There is roughly 8% more bachelor and graduate degrees holders among the Chinese, South-Asian and other visible minorities than there are among the White. The Black group is the only minority whose proportion of university degree holders is smaller than the corresponding percentage in the White population. Yet, these higher proportions of university educated individuals among minorities have not enabled them to hold higher-status, better paying jobs; and although the proportion of highly educated workers is smaller among White individuals (after the Black), it is in this very group that we find the greatest proportion of professionals and managers (32.67%).

[10] Except other minorities whose proportion of individuals with no degree is virtually equal to the corresponding proportion in the white population

This phenomenon is partly responsible for the very different commuting patterns we then observe across racial groups. Working white individuals rely significantly more on the car than any other mode of transportation, and they do so in proportions that are significantly higher than any other group: our analysis found that in 1996, 66% of working white individuals drove to work, whereas the next major car driving group (individuals belonging to other minorities) did so in a considerably smaller proportion (45%). The difference in car use is even as high as 30% when we compare the white and the black population (66 vs. 36%). Interestingly enough, the ethnic group of an individual seems to influence the mode choice more than its level of education as indicated in table 12 below:

	No Diploma	High School	Bachelor	Grad
Black	26.39%	37.66%	50.7%	54.1%
South-Asian	39.69%	35.29%	44.2%	45.28%
Chinese	40%	38.46%	50.91%	46.15%
Other Vis. Min.	41.48%	43.86%	49.51%	59.57%
Not a Vis. Min	62.39%	67.51%	69.28%	67.54%

Table 12: Proportion of Car Drivers in minority and non-minority groups by level of education

In this table, we observe again that the White population uses the car more than any other group. Most interestingly, we see that the level of education of the White group has very little influence on its car use rate: high school graduates and graduates drive to work with virtually identical rates. Analysis of the table further reveals that the White population with no degree drove to work in proportions that are much higher than rates for visible minorities, *even when they are more educated.*

As we had previously shown, the use of the car as a mode choice enables workers to commute longer distances to work, and this is again verified with the comparison of commuting distances among ethnic groups: Whites rely more on the car than the other groups, are also more likely than other groups to drive distances greater than 15 km: 27% of them did so in 1996, whereas the corresponding proportions for Chinese (21.08%), Black (17.25%), other minorities (14.97%) and South-Asian(12.14%) are all smaller.

The crucial issue here is therefore not to merely observe the different commuting patterns across ethnic groups but also isolate and comprehend the very phenomena that exacerbate these differences. While not all individuals of all minority groups have gone for higher education, it stands to reason that those who have would be able to hold better jobs, drive to work in higher proportions than we have observed, and be able to commute, if they wish, longer distances. However, the connection -we have observed through the comparison of ethnic groups- is not systematic, and therefore calls for further investigation. So why are minorities not as motorized as Whites? Why are their mean incomes significantly lower? The most plausible explanation is that while statistics indicate higher levels of university educated individuals among minorities, the census provides no indication on the country where these degrees were granted, and this has fundamental implications on the employability of an individual because not all foreign degrees are recognized in Canada. Some professions are so exclusive that holders of non-Canadian degrees are not allowed to exercise their professions.

This issue and other will further be addressed in the following two chapters dedicated to the very purpose of understanding how socio-demographics, including ethnicity, come into play to influence the way individuals commute, both in terms of mode and in terms of commuting distance. Chapter 8 is a presentation of a multinomial commuting mode choice model developed to account for and quantify the influence of all the variables we have analyzed: education, income, race. In chapter 9, we present an ordered logit model of commuting distance.

Chapter 8 Mode Split Model

1. Independent and Control Variables

In the light of the findings from the previous chapters, we argue in this section that a number of socio-demographic variables (some independent, other control) influence the commuting mode choice of individuals. These variables capture:

- Attributes of the trip: commuting distance.
- Economic attributes of the commuter: income, income status (below or above the poverty line), professional status (an indicator variable coded 1 for managers and professionals, 0 otherwise), employment status (full-time, part-time workers).
- Household characteristics: household size, marital status, weekly time spent in household-related activities.
- Dwelling attributes: tenure (rental or ownership), housing type (1 for condominium, 0 otherwise), rent/mortgage to family income ratio, number of rooms.
- Social attributes of the individual: sex, age, identification to a visible minority group, education, period of immigration if applicable.

Car ownership is a function of household income. Consequently, high-income households are more likely to rely on the car than any other mode, and more likely than low-income households to drive.

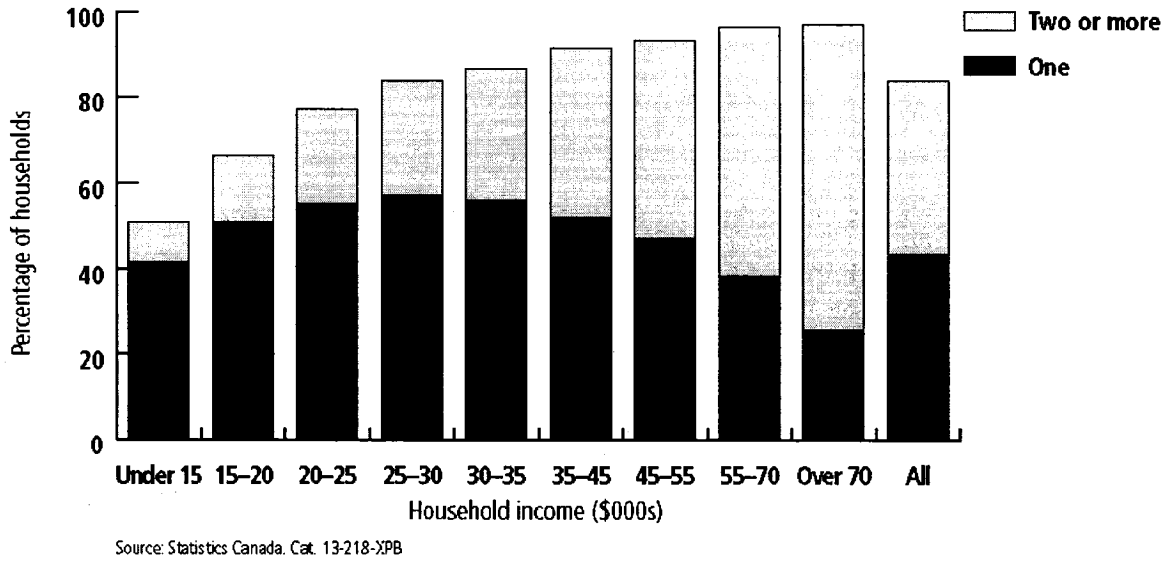


Fig. 17: Household Car Ownership by Income Category, 1996

The Statistics Canada figure above describes this reality for Canadian households in 1996. The graph depicts a couple of interesting phenomena. First, the general trend of the mean percentage of households owning one or more than one car is positively correlated with higher incomes, confirming the intuitive assumption described earlier. The figure also shows that among higher income households, the probability of owning more than one car is higher than in households with lower incomes (this may be also be due to the fact that higher income households are more likely to live in the suburbs and hence rely more on their car).

We also hypothesize there is a certain prestige about driving a car and that this prestige, defined by one's professional category is especially prevalent among managers and professionals. This hypothesis is not new. In the collective conscience, the car is a status symbol. It embodies the idea of social status. Sheller has argued that "*high-income earners and professional elites [...] equate car worth with personal worth*". Similarly, quoting Marsh, Cassel notes (1989) "*The driver of the rusty beetle, and the one in a gleaming turbo-charged Porsche both make equally powerful statements about themselves. They define themselves to be particular kinds of people and so define themselves socially*". Consequently, even when income is controlled for, managers and

professionals (considered in the census as the professionals) are believed to be more likely to drive to work precisely because of their status (the indicator variable is coded 1 for managers and professionals, 0 otherwise).

Finally, income status (being above or below the poverty line) is entered in the model as a dummy variable with the implication that people living below the poverty line are more likely to rely on less expensive modes of transportation such as transit and walk. On the other hand, individuals above the poverty line are more likely to rely on the car.

The third group of variables included in the model captures the influence of household structures on commuting patterns. This hypothesis is supported by studies that have identified a link between household structure and the income status of the family (see Rosenbloom, 1996)[11] . So far, findings from the analysis section have revealed that higher rates of transit use were found among single women living alone. This leads us to hypothesize that lesser household responsibilities will increase the probability of using transit. This theory is intuitively correct: trips made by women in general, and single mothers in particular, are often in the form of trip chaining; women rarely make single trips, but rather commute before and after work for household-serving purposes: pick up the children, do some groceries, run errands...In the case of dual-earners households, we can hypothesize that some of those household-serving purposes are also shared by the father, but in single parent households, all the work is borne by the single mother. Naturally, family related trips like the ones described above are directly influenced by the size of the family; the greater the number of children, the more complex the trip-chaining. Studies however (see for example Hensher and Reyes, 2000), have shown that trip chaining was incompatible with transit, or any other mode than car drive for that matter. A bigger family size will increase the complexity of trip chaining, which in turn will reduce the probability of using transit as a mode choice. The rationale for the use of the household size as an independent variable becomes then self-evident. More specifically, we posit that smaller households and fewer hours spent working in and around the house will increase the probability of using transit. We will be using three variables to "operationalize" this construct: the first variable will be the census family household size, whereas the second will be the structure of the household

[11] Trends in Women's travel patterns

(married or single person). The third variable is the sum of weekly hours spent doing housework and caring for family.

Next, the link between urban form and transportation is acknowledged in the model. The bases of this hypothesis are twofold. The first reason is the direct implication of utility theories. These show that (in the case of transportation), individuals will commute longer distances if they "consume" more residential space (a house as opposed to a rented apartment) in an effort to maximize their utility. These long commutes naturally translate in higher car use. Therefore a first dummy variable, tenure (indicating whether the commuter owns or rents the dwelling where they reside) should help indicate the likelihood of car use. However, tenure only can be misleading. While condominium owners are home owners, they could potentially rely more on transit than owners in the suburb if their properties are located in the central city and/or close to transit facilities. The second variable therefore, housing type, indicates if the dwelling is a condominium or not.

In the same breath, we present one last variable related to housing. This constructed variable is calculated as the ratio of housing costs to total yearly household income. Housing costs are indicated by respondents as the sum of utilities and rent for those who rent, and utilities and mortgage for homeowners. In both cases, the housing costs are truncated at $1,100/month. Ratios of housing costs to total census family income are then reorganized in three categories: ratios of less then 33%, ratios between 33 and 66% and ratios greater than 66%. The common figure of 30% or less is usually mentioned in the literature as the acceptable level of housing expenditures. Ratios greater than 30% are an indication that the family may be spending a disproportionate amount of their total amount in housing costs, and therefore may not dispose of sufficient resources for other necessities such as transportation. We then posit that families where this calculated ratio is high may depend more on commuting modes such as transit or walk and less on the car.

Last but not least, the model will include a number of variables to test and control for individual socio-demographics: these are sex and visible minority indicator, education, age (proxy for experience), employment status (full time or part time), immigration status and period of immigration.

The hypothesis of gender influence on commuting behavior is not new[12] . In this very study, we have observed in chapter 4 that single mothers and single fathers, although with comparable household structures, commuted very differently, both mode-wise, and distance-wise and gender was hypothesized, both directly and indirectly (through gender discrimination in wages), to be at the origin of these variations. To test this proposition, sex will therefore be entered in the model as a dichotomous variable. Along with gender, a visible minority indicator will also be included. This is a corollary of the paradoxical differences observed in commuting mode choice between the White population and minority groups (see chapter 7 for a reminder). Age (a proxy for work experience) and education, both control variables, are entered in the model because of their known influence on income. Their presence in the model will allow us to avoid spurious conclusions by capturing only the true influence of income. Education is captured through highest level of education (highest degree obtained). Age, however, is entered as a polytomous variable (0 for individuals less than 25, 1 for 25-30 year olds, 2 for 30-35, 3 for 35-45 and 4 for 45 and older). In the absence of a variable capturing experience, age can stand for a reasonable proxy. The rationale for using this proxy is to try and account for the fact that older individuals (ie. with many years of experience) may have had the opportunity to accumulate wealth through the years and hence afford a car, even if their average annual income is not very high. If so, it is of importance to account for this phenomenon. Next, because the employment status of a person has a direct influence on the income level of an individual (full-time workers will earn more than part-time workers, *ceteris paribus*), this variable is entered as a control variable.

2. Model Results

Building any mathematical model requires a careful selection of variables that unequivocally influence the dependent variable. In the previous section, we have presented both control and independent variables that are thought to have a significant impact on the mode choice of commuters in Montreal. However, the influence of each variable or set of variables can not truly be measured if all variables or sets of variables are entered at the same

[12] For a review, see Law (1999) and McDonald (1999)

time to build the model. Rather variables or sets of variables must be entered progressively to identify their individual influence and test if their presence is justified in the final model. This technique based on likelihood ratio tests, consists then in quantifying the increased likelihood from a base to an improved model, and gauging through a chi-square test if this increased likelihood is statistically high enough to justify the use of the added variables. In the literature, this quite common problem of choosing to add or not variables that can only but improve the fit of the model is often referred as the battle of fit with parsimony.

The control variables in the model are education, age (entered as a proxy variable for experience) and a visible minority indicator. Along with these, an interaction between education and the visible minority indictor is also entered because we observed higher rates of university educated individuals among certain minorities, and because these higher rates that should have translated in higher rates of car use for these minorities, did not. Hence education appears to have different influence levels across minorities, and the interaction variable is entered in the model precisely to capture these varying influences. Model 1 presents the result of this first model containing only the control variables. Model 2 contains all variables contained in model 1, plus the commuting distance variable entered as an indicator variable with four categories. In model, 3, we have replicated the variables choice of model 2 and added 2 new variables: income status (below or above the LICO measure) and the natural logarithm of income. The process goes on and is fully reported in table below.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Education	✓	✓	✓	✓	✓	✓	✓
Visible Minority Indicator	✓	✓	✓	✓	✓	✓	✓
Education *Visible Minority	✓	✓	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓	✓	✓
Commuting Distance		✓	✓	✓	✓	✓	✓
Income Status			✓	✓	✓	✓	✓
Natural Logarithm of Income			✓	✓	✓	✓	✓
Employment Status				✓	✓	✓	✓
Professional Status				✓	✓	✓	✓
Period of Immigration					✓	✓	✓
Tenure and Housing Type						✓	✓
Housing Cost to Family Income Ratio						✓	✓
Number of Rooms						✓	✓
ex							✓
Marital Status							✓
Household Size							✓
Unpaid Weekly Time Spent in Household or Family related Activities							✓
Sample Size n	**40440**	**40440**	**40440**	**40440**	**40440**	**40440**	**40440**
Degrees of Freedom	**39**	**48**	**54**	**60**	**66**	**81**	**93**
McFadden r^2	**3.19%**	**9.32%**	**11.42%**	**11.53%**	**11.71%**	**13.61%**	**15.57%**
LR χ^2	**2520.51**	**7374.79**	**9030.38**	**9121.27**	**9258.96**	**10768.56**	**12314.70**
$\Delta\chi^2$							

Table 13: Multinomial Logit Model-Variable Selection Process

As indicated above, model 1 contains only the control variables, while model 7 integrates all control and independent variables. The intermediate models 2 to 6 incorporate independent variables incrementally. Likelihood ratio tests can only be made on samples of

identical sizes (same observations used for all models). However the gradual introduction of variables can cause fluctuating sample sizes if information on the newly entered variables is missing. Therefore the technique requires estimating *first* the most complex model (here, model 7), indexing the observations used in this model and estimating the prior models using only the indexed observations. Our models, as indicated in table 13 contain each the same 40440 observations. Both likelihood ratios and increases in likelihood ratios are indicated in table 14.

Likelihood ratio tests completed on the successive models indicate that the use of all variables is justified as indicated in table 14 below.

. lrtest M1 M2	LR chi2(9) = 4854.28
likelihood-ratio test	Prob > chi2 = 0.0000
(Assumption: M1 nested in M2)	
. lrtest M2 M3	LR chi2(6) = 1655.59
likelihood-ratio test	Prob > chi2 = 0.0000
(Assumption: M2 nested in M3)	
. lrtest M3 M4	LR chi2(6) = 90.89
likelihood-ratio test	Prob > chi2 = 0.0000
(Assumption: M3 nested in M4)	
. lrtest M4 M5	LR chi2(6) = 137.69
likelihood-ratio test	Prob > chi2 = 0.0000
(Assumption: M4 nested in M5)	
. lrtest M5 M6	LR chi2(15) = 1509.60
likelihood-ratio test	Prob > chi2 = 0.0000
(Assumption: M5 nested in M6)	
. lrtest M6 M7	LR chi2(12) = 1546.14
likelihood-ratio test	Prob > chi2 = 0.0000
(Assumption: M6 nested in M7)	

Table 14: Likelihood Ratio Tests on Nested Models- Input and Output

Consequently, we choose the best model to be the most complex and elaborate, model 7, which results we present in table 15 below. Because the multinomial logit model determines n-1 set of coefficients for the n different modes (one mode is the comparison mode), we have tabulated coefficients for the three modes determined: car driver, car passenger and other (walk, bicycle...). Transit is the base mode. The coefficients reported

are odds ratios, comparing for each alternative the probability of that outcome to the probability of the base category (transit).

	Car Driver	Car Passenger	Other
Education (base= No Diploma)			
High School	0.981	0.606***	0.859**
Bachelor	0.81***	0.451***	0.835**
Graduate	0.559***	0.307***	0.995
Visible Minority Indicator (base= Not a minority)			
Minority	0.483***	0.295***	0.51***
Education *V.M.I(base=no diploma, not a visible minority)			
High School*Minority	1.058	2.399***	0.973
Bachelor*Minority	1.441***	2.586***	1.233
Graduate*Minority	1.769***	4.333***	1.536
Age (base=less than 30 year)			
30-34	1.207***	0.805***	0.977
35-39	1.203***	0.757***	1.04
40-44	1.208***	0.652***	1.028
45-49	1.148***	0.666***	1.12
50-60	1.11**	0.627***	1.09
60 and over	0.942	0.587***	1.168
Commuting Distance (base= 5 or less kms)			
5-15 kms	0.823***	0.755***	0.07***
15-25 kms	1.38***	1.147*	0.062***
25 or more kms	2.769***	2.726***	0.565***
Income Status (base= above LICO)			
Below LICO	0.744***	0.831**	0.952
Natural Logarithm of Income	1.363***	0.934***	0.893***
Employment Status (base=part-time worker)			
Full-Time Worker	1.154***	1.246***	0.942
Professional Status (base=not a professional, nor a manager)			
Manager or Professional	1.167***	0.963	1.107*
Period of Immigration (base= not an immigrant)			
Before 1986	0.632***	0.806***	0.71***
1986-1996	0.493***	0.78**	0.492***
Tenure and Housing Type (base= Rental)			
Owns a House-Condo	1.38***	1.258*	0.836
Owns a House-Not a Condo	1.963***	1.63***	1.106*
Housing Cost to Family Income Ratio (base= 0-32%)			
33-65%	1.101*	0.772**	0.986
66% and over	1.857***	0.796	1.068
Number of Rooms	1.075***	1.12***	0.983
Sex (base=Male)			
Female	0.473***	1.365***	0.562***
Marital Status (base= Married)			
Single	0.576***	0.467***	0.837***
Household Size	0.998	1.036	0.951*
Weekly Time Spent in Household-related Activities	1.002***	1.001	1.002**
Sample Size n		**40440**	
Degrees of Freedom		**93**	
McFadden r^2		**15.57%**	
LR χ^2		**12314.70**	

Data Source: StatCan Public Use Micro Data File, Montreal CMA, 1996

Note: * Significant at 10% level
** Significant at 5% level
*** Significant at 1% level

Table 15: Multinomial Logit Mode Choice Model Results

The first proposition we set out to test with the MNL model was the hypothesis of different influence levels of education for minorities vs. non-minority groups. To this purpose, we had introduced in the model an interaction variable between education and the visible minority indicator. The underlying assumption was that similar levels of education capitalized differently for the Whites and the minorities. The data fails to support this hypothesis: the graduate*minorities interaction term, as well as the bachelor*minorities did return a significant values and the magnitude of the coefficient (greater than 1) still invalidates the hypothesis stated above (the model shows that the odds that educated minorities will drive a car vs. use transit are 44 to 76% higher compared to the same odds for White commuters with no diploma).

Age, entered to proxy work experience, returned very significant results in the car driver and car passenger category, partly confirming our theory: between 30 and 45 year of age, the odds of driving a car vs. using transit are 20% higher than comparable odds among the less-than-30 age group, which is in accordance to the theory that people drive more as they acquire more work experience and hence, higher wages. Odds greater than 1 in all age categories after 30 is also an indication that car driving is the preferred mode choice of commuters aged 30 and over: in any age group, the odds of driving vs. using transit, all greater than 1 indicate that, independently of their age, people over 30 are more likely to drive than use transit compared to people under 30. The odds then start decreasing after 45, but still remains greater than 1. This last result also confirms the hypothesis that people change commuting patterns as they become older, relying less on car driving and more on other modes for health or safety reasons.

The first and probably most important independent variable in the model is the commuting distance variable. Coefficients related to this variable are all found to be significant at the 1% level, indicating the clear link between commuting distance and mode choice. The model indicates that the odds of driving vs. using transit are 18% smaller for commuters living within 5 and 15km of their job than for commuters living within 5 kms of their employment place. This is a slightly unusual result as it would be expected that longer commutes would increase the odds of driving vs. using transit. Beyond the 15km threshold however, the odds of driving vs. using transit are 1.4 to 2.8 times higher than for commutes under 5km., following increases in the commuting distance variable. The odds of being car passengers vs. using transit are also higher for longer commutes than for commutes under 5 km.

Next in line, two income variables are presented: these are the natural logarithm of income and the income status variable. As expected, both returned very significant results. More specifically, the result from the income status variable indicates that the odds of driving a car vs. using transit are 25% smaller for people living below the low-income point than people living above it. However, it is expected that the true influence of the LICO is underestimated because the model also includes annual income (in log-form). Although variance inflation factors indicate the absence of correlation between these two variables, estimation of the MNL model without the ln(income) variable indicates that the coefficient for the LICO variable is smaller than the value estimated with both variables in the model.

As expected, the odds of driving vs. using transit are 15 to 16% higher for full-time workers compared to part-time employees and for managers vs. non-managers.

Another interesting variable is the period of immigration indicator. This variable highlights a number of notable points: first, it indicates as observed in the E.D.A. section that the odds of driving vs. using transit are smaller for immigrants than for non-immigrants (all odds ratios smaller than 1). Secondly, this variable indicates that, compared to non-immigrants, the odds of driving vs. using transit are higher for immigrants who immigrated before 1986 than those who immigrated after. This is an illustration of integration processes: immigrants who have stayed the longest start adopting patterns of the non-immigrant population.

The model also investigates the land-use/transportation interaction. Two variables related to housing are introduced in the model: the first one has categorized the 40440

individuals in our model as renters, owners of condominiums or owners of other types of housing. Quite naturally, it was found that owners were more likely to drive vs. use transit than renters. More specifically though, owners of houses were found to be the most likely to drive vs. use transit, more likely than renters or owners of condominiums. In essence, this finding suggests that tenure but also housing type are statistically associated with the commuting mode choice: while owners of condos are only 1.4 times more likely to drive vs. use transit compared to renters, owners of houses are almost 2 times more likely to do so. This phenomenon is also tied to high residential density, which has been evidenced in the literature to increase the rate of transit use. Condos are usually built in residential areas of medium to high density, which is probably the reason why residents of these areas seem to rely slightly less on the car than residents living in other housing types, as indicated in the model. The MNL model also suggests a link between the housing to income ratio and commuting mode, although the results are counter-intuitive and invalidate the hypothesis we had proposed. While we had posited that people who spend high shares of their yearly incomes on their rent may be more prone to rely on transit, the model suggests quite the opposite: we hence find that, controlling for socio-demographics, the more people spend on housing costs, the more likely they are to choose car driving vs. transit (when compared to the base group of people spending 33% or less of their yearly income on rent).

Last, we present the results of constructs introduced to test the influence of family related variables: marital status, family size and weekly time spent in household related activities. But first, we present the results of the sex variable where we found strong evidence (significant at the 1% level) of gender influence on commuting patterns: hence, the model suggests that the odds for females driving to work vs. using transit are about half those of males. On the other hand, the model estimates that the odds of being a car passenger vs. using transit are roughly 35% higher for women than they are for men.

In the descriptive analysis section, we had discussed in great length about the difference in commuting patterns of single mothers and other population segments (single fathers, married women...). The model establishes that the household structure we had then hypothesized as the *raison d'être* of these differences is indeed statistically related to the choice of commuter mode. In the sample, singles use transit at a rate that is almost twice as important as married individuals (30.75% vs. 15.83%). As a corollary of this phenomenon, they use personal motorized modes of transportation (drive and passenger) less than

couples, a fact which makes their odds of using motorized modes vs. using transit always smaller than the corresponding odds for couples. After women and immigrants, we observe that transit is also favoured by the singles, probably because of the relatively low cost of using this mode and the absence of household-related constraints. Finally, the model predicts that neither the size of the family, nor the amount of time spent caring for its members affect mode choices.

3. Probability Plots

We recall here that calculations of probabilities are estimated as follows:

For the base mode (transit), the probability of choice is given by:

$$P(transit) = \frac{1}{1 + e^{X\beta_{c,d}} + e^{X\beta_{c,p}} + e^{X\beta_o}}$$

For the other modes:

$$P(car\_driver) = \frac{e^{X\beta_{c,d}}}{1 + e^{X\beta_{c,d}} + e^{X\beta_{c,p}} + e^{X\beta_o}}$$

$$P(car\_passenger) = \frac{e^{X\beta_{c,p}}}{1 + e^{X\beta_{c,d}} + e^{X\beta_{c,p}} + e^{X\beta_o}}$$

$$P(other) = \frac{e^{X\beta_o}}{1 + e^{X\beta_{c,d}} + e^{X\beta_{c,p}} + e^{X\beta_o}},$$

where X is the vector of independent variables,

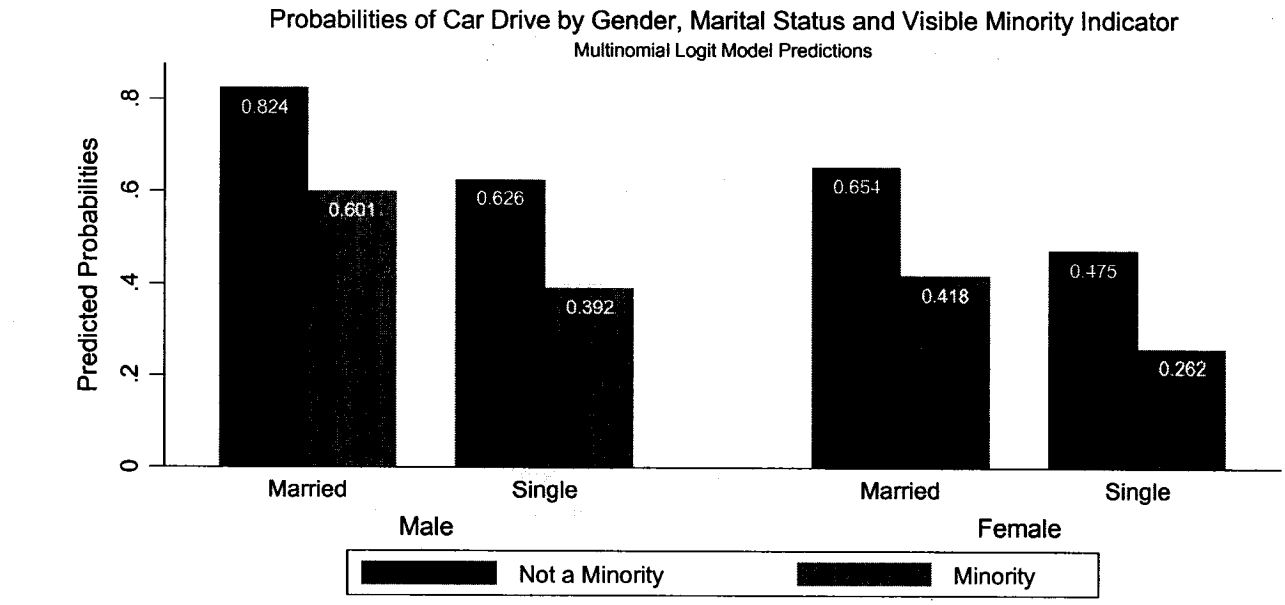
$\beta_{c,d}$ is the vector of estimated parameters for the car driver category,

$\beta_{c,p}$ is the vector of estimated parameters for the car passenger category and

$\beta_{c,p}$ is the vector of estimated parameters for all other modes

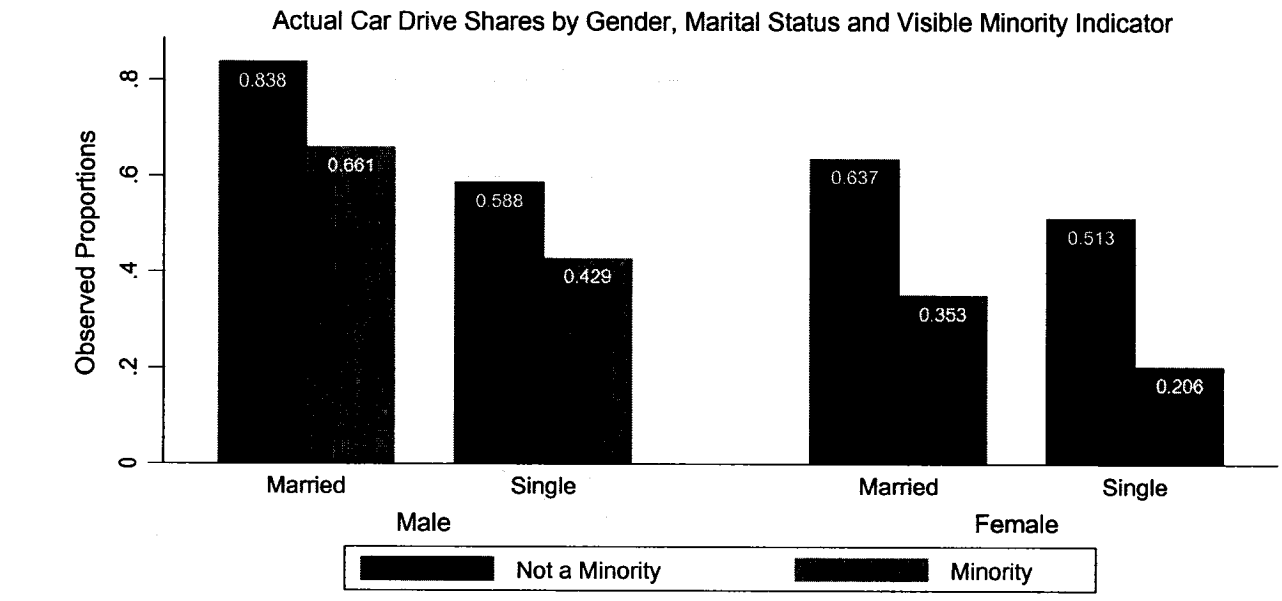
Following these equations, we are able to estimate the probability of use of the four modes proposed (car drive, car passenger, transit and other modes) by different ethnic or/and gender-defined populations segments. For each of the following graphs, we have plotted the probability of use of a mode for the groups defined, *holding other variables at their means.* For comparison purposes, we also graph the result of tabulations from the data.

The first four graphs investigate the effects of being a minority, the next four the effects of poverty while the final four, the effects of household size.



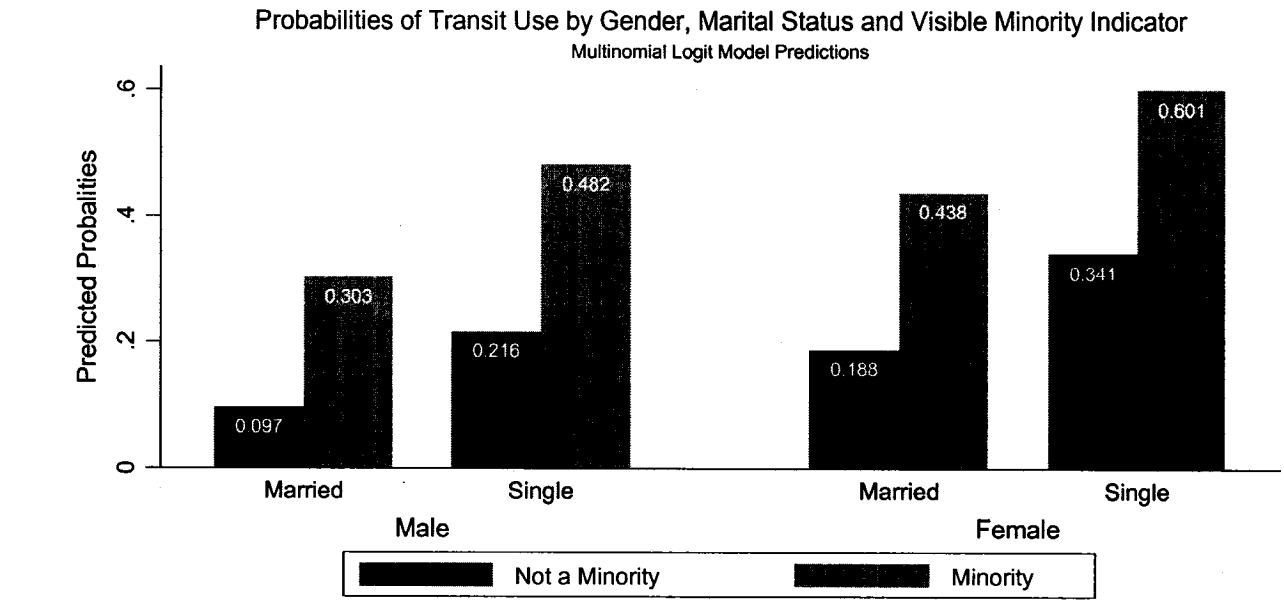
Source: StatCan, 1996 Census Public Use Micro Data File

Fig. 18: Probabilities of Car Drive by Gender, Marital Status and Visible Minority Indicator



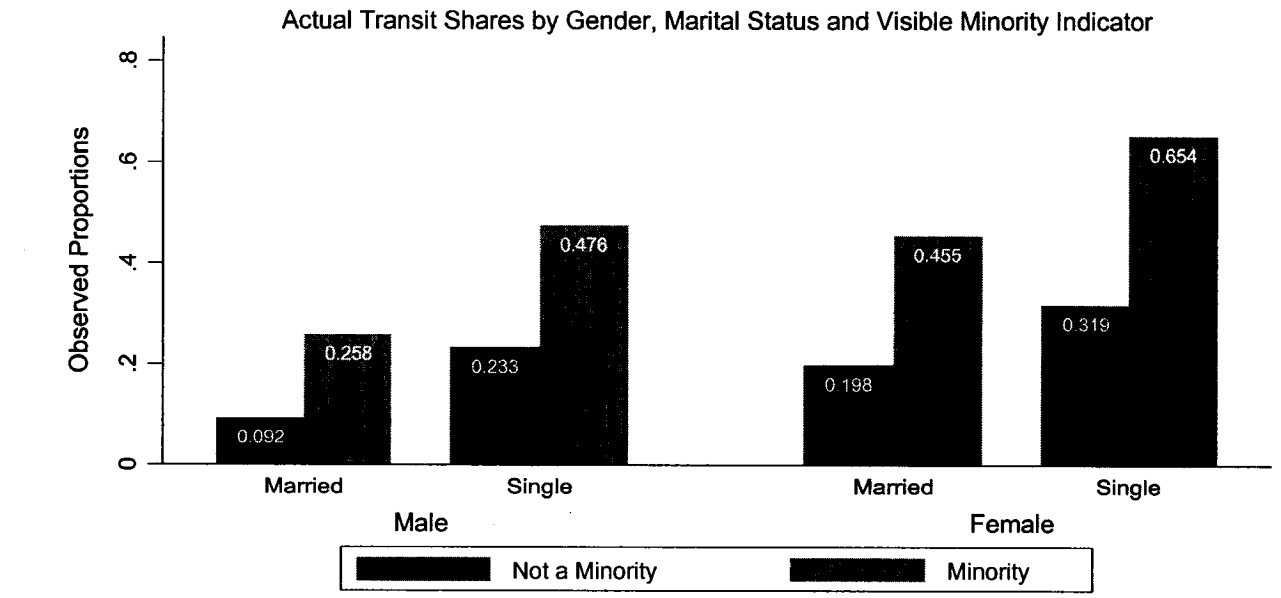
Source: StatCan, 1996 Census Public Use Micro Data File

Fig. 19: Actual Car Drive Shares by Gender, Marital Status and Visible Minority Indicator



Source: StatCan, 1996 Census Micro-Data File

Fig. 20: Probabilities of Transit Use by Gender, Marital Status and Visible Minority Indicator

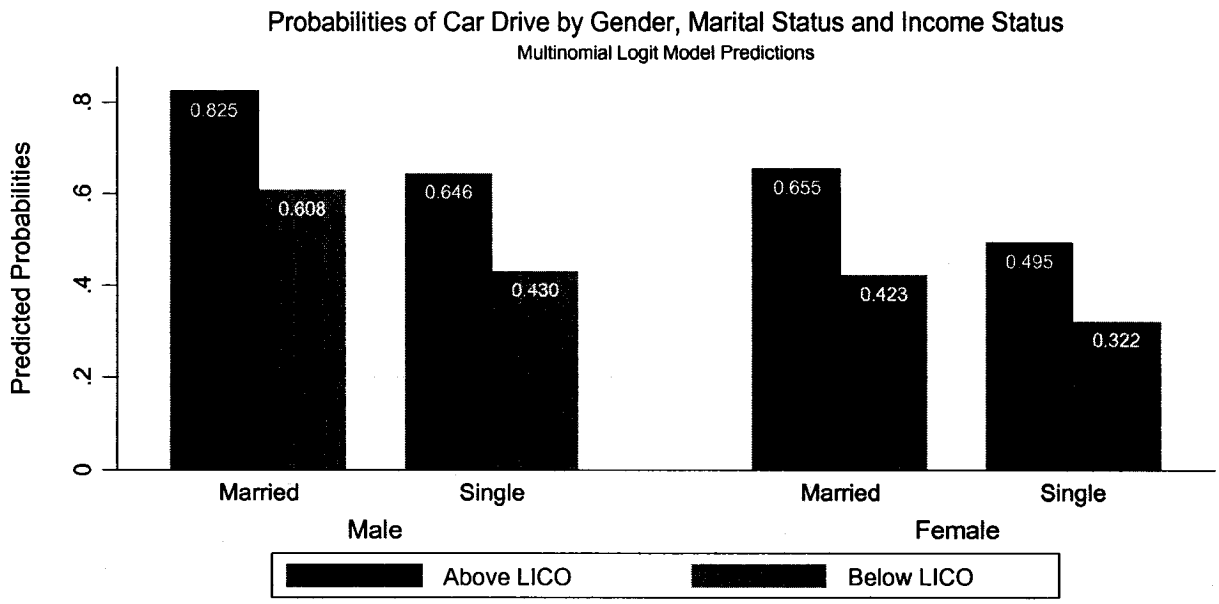


Source: StatCan, 1996 Census Public Use Micro Data File

Fig. 21: Actual Transit Shares by Gender, Marital Status and Visible Minority Indicator

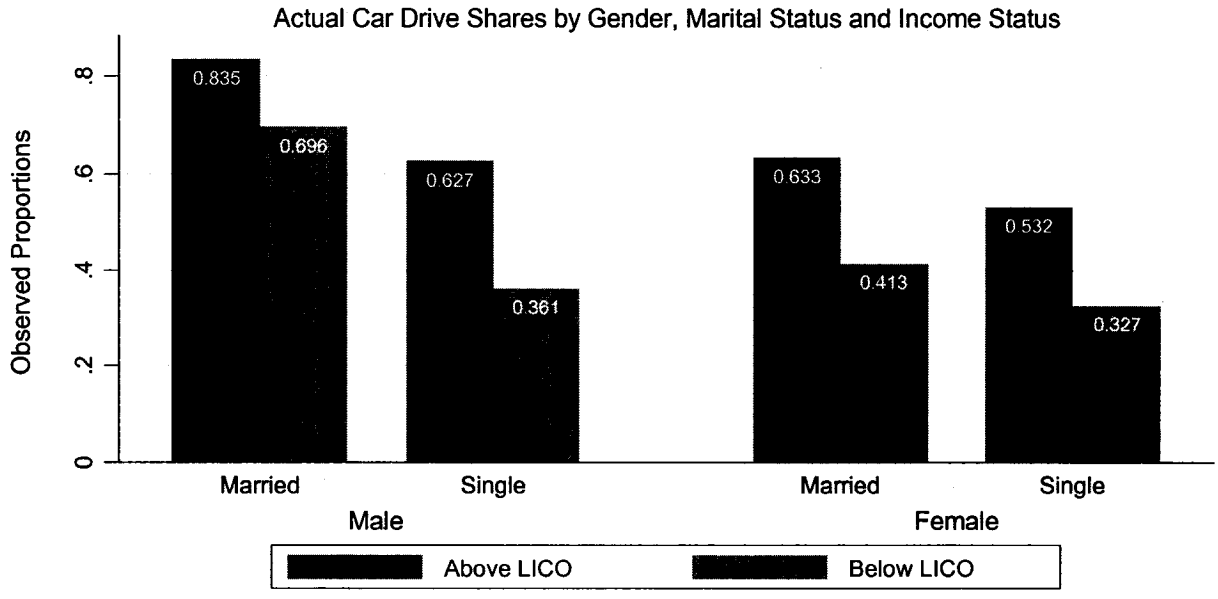
The first four graphs depict the predicted shares of car drive and transit use by gender, marital status and minority indicator. They are contrasted with graphs produced from tabulations in the data. Absolute errors in predictions (%predicted- %dataset, comparison to the dataset of estimation) range for the car driver category between -6% and 5.6%, and for the transit category between -5.3% and 4.5%. Generally, the largest absolute values of errors are observed from estimations in the minority group. The differences between predicted rates and observed values are fairly small and as a whole, the model fit is judged to be reasonably good (see table of model fit at the end of this chapter).

Predicted probabilities indicate that, controlling for marital status and gender, differences in car use rates between minority groups and non-minority groups were on average equal to 22%. However, controlling for other socio-demographic variables, minorities only have probabilities of driving that are 5 (married males) to 10% (single females) smaller than the probabilities for the corresponding non-minority groups. Of course, this would seem to suggest the influence of ethnicity on commuting patterns, but a word of caution is in order. In the absence of geographic data such as density or transit access, we could spuriously conclude that the pattern observed in graphs 18 to 21 are solely due to ethnicity. Not necessarily so. Minority groups often choose to live in central cities, where density is high, and transit frequent. On the other hand, Whites who can afford housing costs in the suburbs will choose to live there. Controlling for density is therefore required before one can conclude with certainty that there exists a link between ethnicity and the rates of car drive in the population. The use of density as an explanatory variable was not possible in the model presented herein because the data were not available.



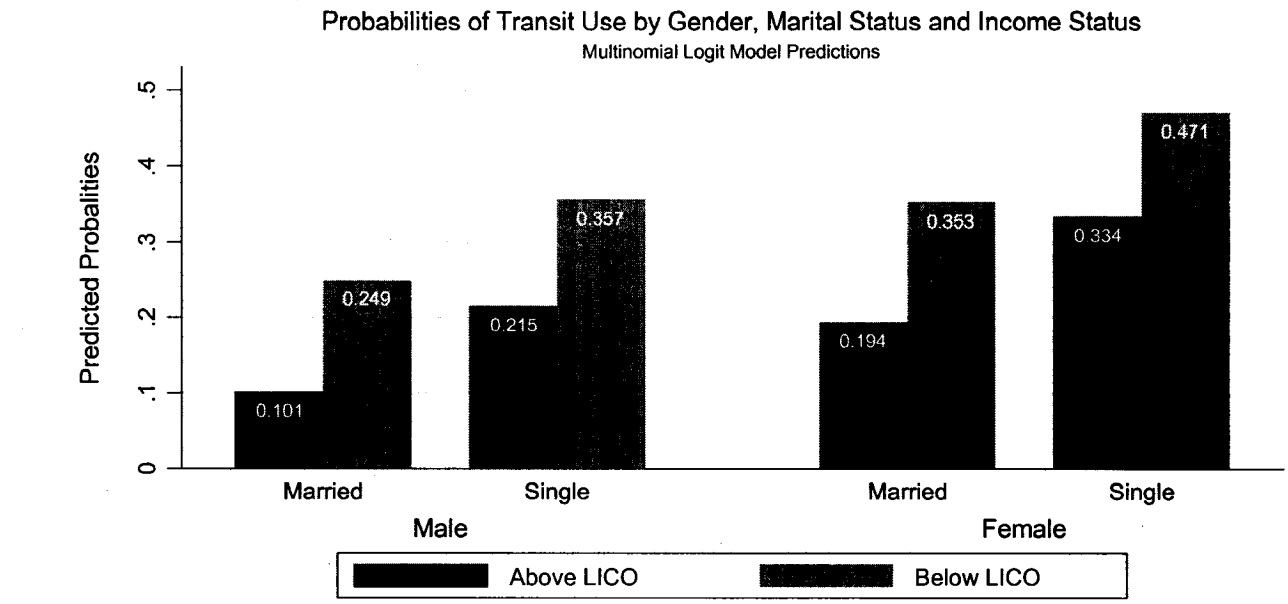
Source: StatCan, 1996 Census Public Use Micro Data File

Fig. 22: Probabilities of Car Drive by Gender, Marital Status and Income Status



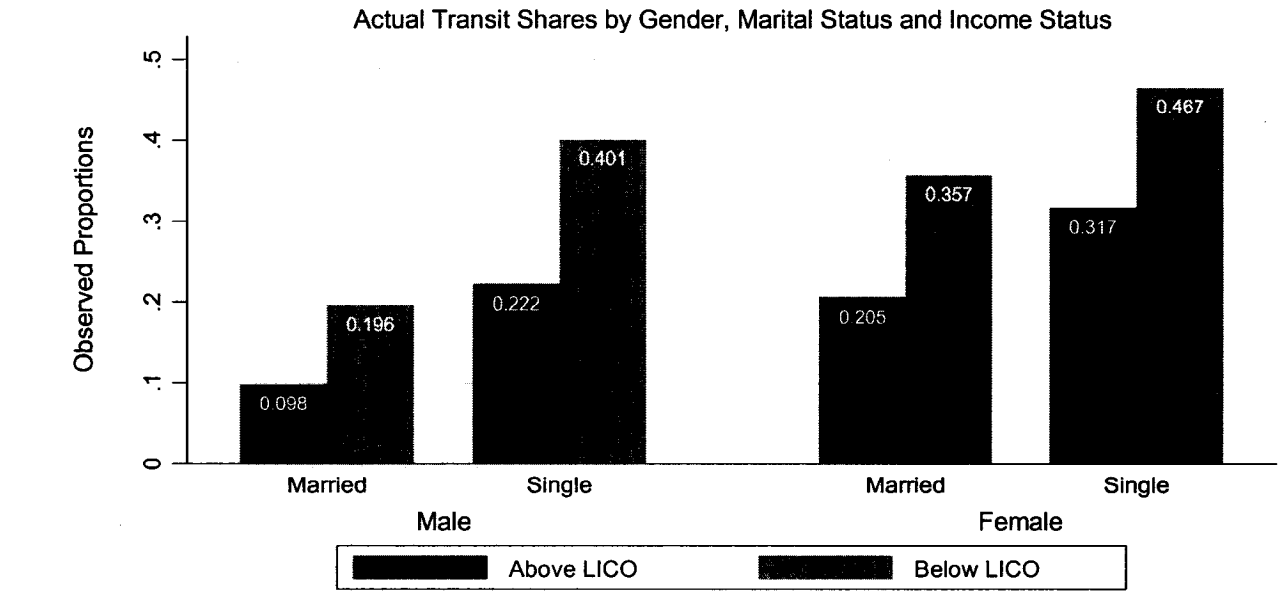
Source: StatCan, 1996 Census Public Use Micro Data File

Fig. 23: Actual Car Drive Shares by Gender, Marital Status and Income Status



Source: StatCan, 1996 Census Micro-Data File

Fig. 24: Probabilities of Transit Use by Gender, Marital Status and Income Status



Source: StatCan, 1996 Census Public Use Micro Data File

Fig. 25: Actual Transit Shares by Gender, Marital Status and Income Status

Figures 21 to 24 investigate the influence of income status. The model predicts, following patterns in the data, that married males living above LICO are the most likely to commute to work by car drive, while single females living below LICO, the least likely. As a corollary, the exact opposite phenomenon is observed in transit use. The model has a tendency to over-estimate differences in car rates among married individuals, and under-estimate those differences among singles. The model is better at predicting rates for females (especially females below LICO) than predicting rates from males. For individuals of same gender and same marital status, the predicted difference in car drive rates for individuals above and below LICO average about 20%. The same is observed in the data.

An interesting and recurrent debate in the literature is the inappropriateness of the LICO measure as an indicator of poverty. Researchers have argued that the measure is set too high and fails to capture the real proportion of poor individuals in a given population. To test the validity of this hypothesis the LICO measure was replaced in the model by the indicator suggested by the Fraser Institute. Because of limitations in the data, this measure was only estimated on a subset of the original dataset. The model is then run with this measure and the new mode splits are recorded. Predicted vs. actual shares of car drives for the two models are then tabulated separately. Following McFadden (1978), it was then possible to calculate for each of the models a success index gauging the prediction accuracy. This index is calculated as the ratio of the percent predicted correctly over the percent obtained by chance only. This ratio was calculated only for the car mode, and only for individuals living on the first model below LICO, on the second model, below the BNPL suggested by the Fraser Institute. The success index was found to be 1.19 for the LICO model and 1.29 for the BNPL model. In other words, the model is able to predict better using the measure proposed by the Fraser Institute than using LICO, which gives credence to the argument invoked by LICO detractors. However, the LICO model performs relatively well also, and because it is the only measure available for the entire dataset, it will be used for the rest of this analysis.

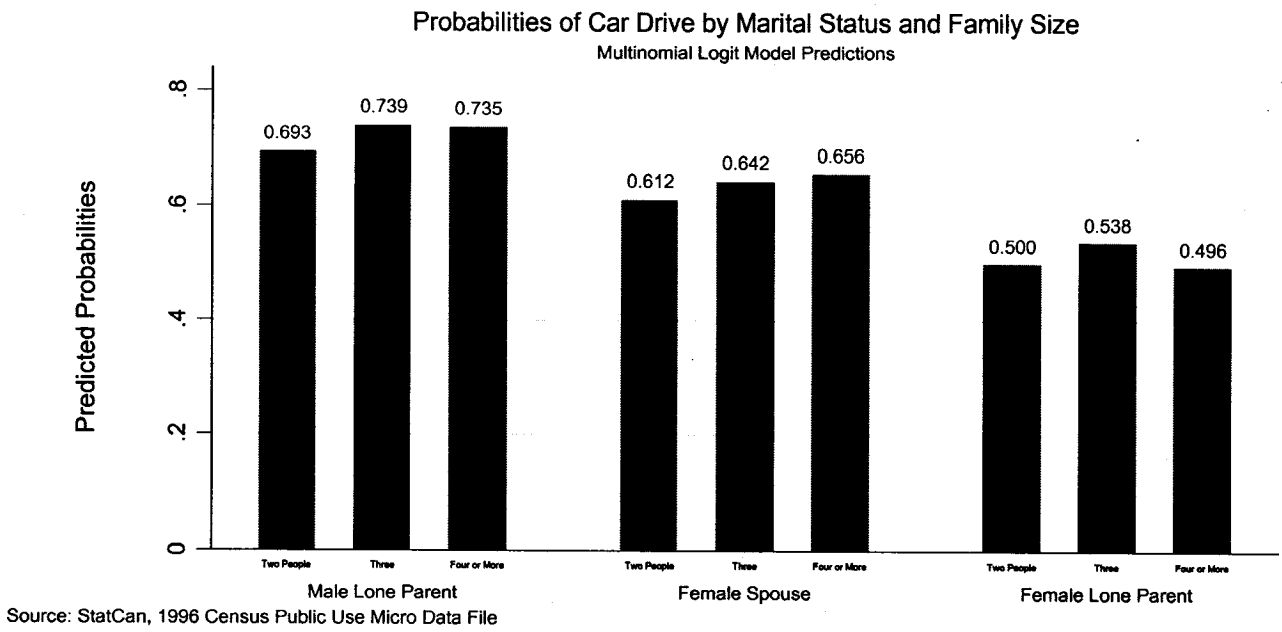


Fig. 26: Probabilities of Car Drive by Marital Status and Family Size

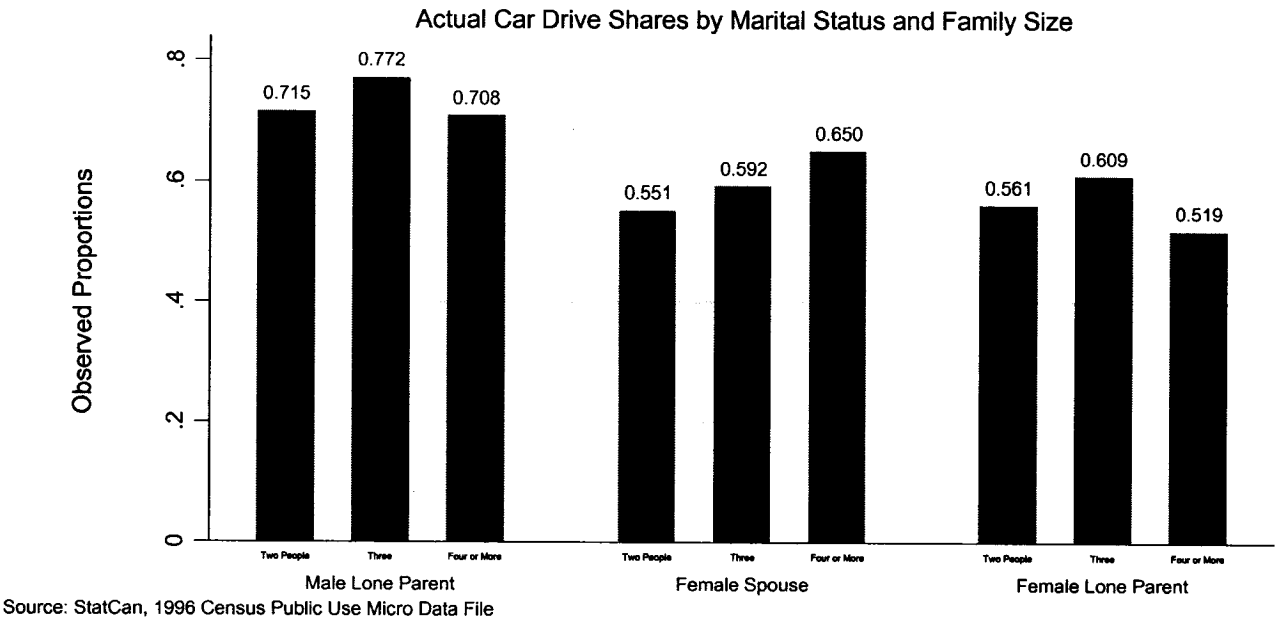


Fig. 27: Actual Car Drive Shares by Marital Status and Family Size

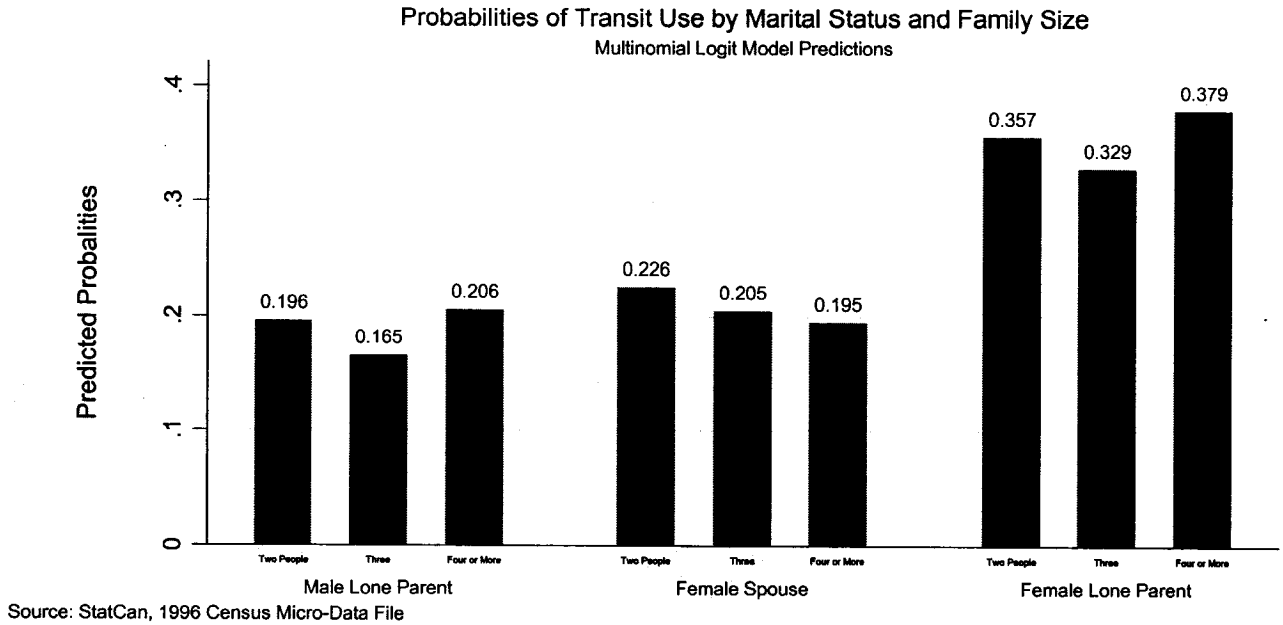


Fig. 28: Probabilities of Transit Use by Marital Status and Family Size

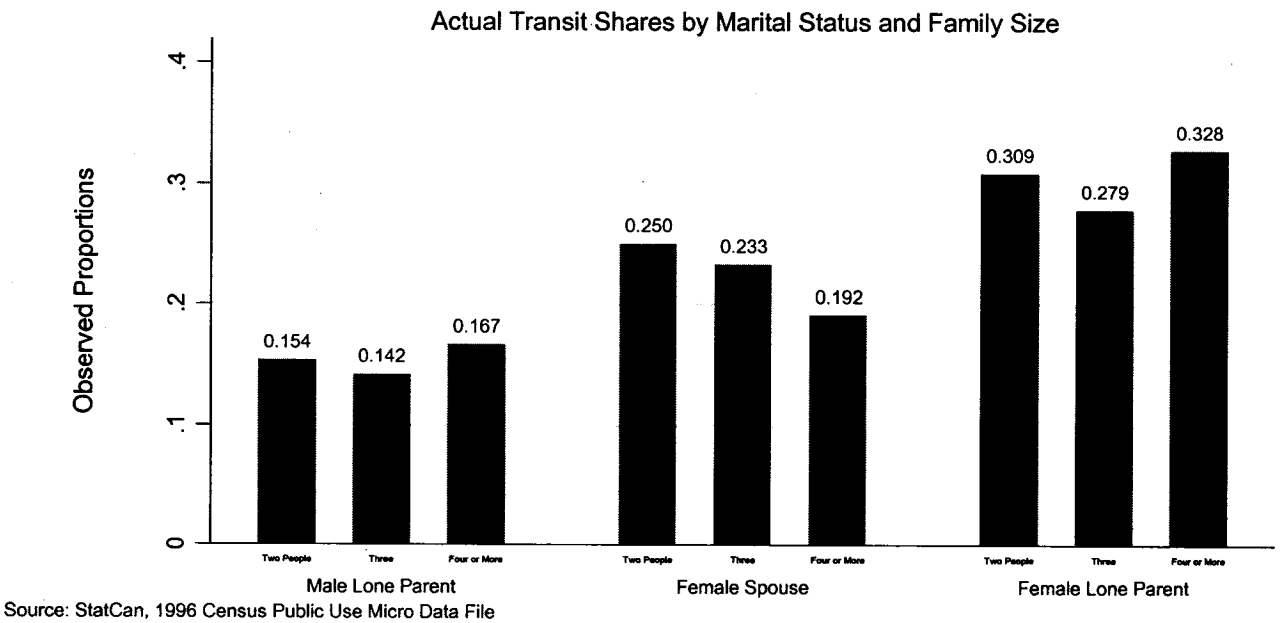


Fig. 29: Actual Transit Shares by Marital Status and Family Size

Figures 25 to 28 display predicted vs. observed car and transit splits for single mothers, single fathers and female spouses. These shares are presented for three different family sizes. The model predicts correctly that within the selected sub-sample, male lone parents are the most likely to drive to work, single mothers the least likely. A tendency of the model for these groups is to overestimate car drive shares for female spouses and underestimate them for single parents, especially single mothers. Errors in estimates are the largest for single mothers, and reach a maximum of 7% in absolute value for single mothers of two children. Interesting patterns observed in the data and replicated very well in the model, are the negatives effects on car drive shares of increasing family size for single parents. In both the data and the model, it is found that independent of their genders, single parents with more than 3 children have reduced probabilities of driving a car to work when compared to their counterparts with less than 3 children. This is especially true for single mothers of three or more children. Further analysis of the data reveals that this pattern exists because larger family sizes among single mothers are also associated with higher poverty rates.

Finally, and as a conclusion for both this section and the chapter, we present the prediction success table as a measure of overall goodness-of-fit of the model as suggested by McFadden (1978). Summations over each row represents the number of people who actually chose that mode, while summations over a column, the number of people who were predicted to do so. Each of the highlighted cells represents people who were predicted *and* chose a particular mode. Hence, the number 18599.3 represents the number of people who were predicted to drive to work and indeed chose that mode. However, 1404.999 (adjacent cell) represents the number of people who drove to work but were predicted by the model to be car passengers. The % correct row indicates the proportion of commuters the model was able to predict correctly within each mode. For example, the model was able to predict correctly that 71.14% of drivers would choose that mode to commute. The high percentage of correctly predicted cases in the car driver category results from the fact that this mode is overall the most commonly used in the population. Finally, the success index estimates the quality of estimates using the model vs. by chance only. An index of 1 would indicate that an analysis based on the model or chance (actual shares observed) would produce similar

results. The success index indicates that the model predicts best proportions of other modes (walk, bike).

Chose mode...	...But were predicted to use mode... Car Drive	Car Passenger	Transit	Other	*Row Total*	*Actual Share*
Car Drive	[illegible]	1404.999	4604.529	1535.169	*26144*	*=26144/40440 =64.65%*
Car Passenger	1408.347	[illegible]	544.853	188.957	*2342*	*=2342/40440 =5.79%*
Transit	4584.787	547.1691	[illegible]	799.329	*8793*	*=8793/40440 =21.74%*
Other	1551.563	189.989	781.902	[illegible]	*3161*	*=3161/40440 =7.82%*
Column Total	*26144*	*2342*	*8793*	*3161*	*40440*	

[illegible]

Total Percent Correct = (18599.3+199.843+2861.715+637.546)
= 55.14 %

Table 16: Multinomial Logit Model-Overall Goodness-of-Fit Table

Chapter 9 Commuting Distance Model

In this last chapter dedicated to analysis and results, is presented a model of commuting distance. The sample remains the same as the one used for the estimation of the multinomial logit model in the previous chapter and we refer the reader to chapter 1 of this thesis for the theory behind ordered logit models, used here to capture the commuting distance of workers.

1. Independent and Control Variables

We recall here that the commuting distance in the census is a categorical variable, re-organized for ease of computation into 4 major categories: distances of less than 5 km, between 5 and 15, 15 and 25 km and finally, distances greater than 25 km. In the ordered logit model, these 4 categories represent conjointly the dependent variable. They are mirrored (without indication of distance) as ordinal outcomes of the dependent variable: small, medium, large and very large distances respectively. Because the relationship between commuting distance and mode choice is of interactive nature (with mode choice influencing how far we travel, and distance dictating our mode choice), mode choice is entered in the ordered logit model, this time as an independent variable. Personal modes of transportation are hypothesized to facilitate longer commutes. However, the odds of commuting long distances are hypothesized to be smaller for females, singles and older commuters. It is also hypothesized that household responsibilities and larger families will decrease the odds of commuting long distances. I also hypothesize that belonging to a visible minority and low levels of school attainment decrease the odds of commuting long distances, following findings from our exploratory data analysis. Often, this combination is observed among younger immigrants, although not necessarily the case. We therefore test this conjecture with the period of immigration variable. Poor people, as well as people who spend high shares of total income on rent/mortgage and other housing expensed are hypothesized to limit their commuting distance in order to reduce transportation costs but full-time status is believed to be enough of an incentive to justify longer work trips. We also hypothesize in the model that people are ready to trade more space for longer commutes, and we test this assumption by the introduction in the model of both the tenure, entered as a categorical variable, and the number of rooms variable (continuous variable). Finally, while only occupational prestige

was entered in the mode choice model, this time we enter industry type as well as the independent variable in the commuting distance model. Because of land use regulations, certain industries such as agriculture or other primary industries impose longer commutes than industries such as services. In the census, all industry types are grouped in 16 sectors, including transportation and storage, trade, finances, government services and health services. For our model purpose however, these 16 sectors have been grouped into 8 major industry segments.

2. Model Results.

Model estimation and results are presented in table 22 below. Different coefficients were estimated for variables that violated the proportional odds assumption. Coefficients for variables that did not violate this hypothesis are identical through all three ordinal outcomes (the above 25 km category is base and omitted in the estimation). This model is known as the partial proportional odds model.

	5 km and more (1) vs. less than 5 km(0)	15-25 km (1) vs. 0-15 km (0)	25 km and more (1) vs. 25 km and less (0)
Education (base= No Diploma)			
High School	0.078***	0.078***	0.078***
Bachelor	0.054	-0.084**	-0.098*
Graduate	-0.189***	-0.143**	0.155*
Visible Minority Indicator (base= Not a minority)			
Minority	0.174***	-0.036	-0.173**
Age (base=less than 30 year)			
30-34	0.096***	0.096***	0.096***
35-39	-0.004	-0.004	-0.004
40-44	-0.132***	-0.132***	-0.132***
45-49	-0.192***	-0.192***	-0.192***
50-60	-0.394***	-0.394***	-0.394***
60 and over	-0.454***	-0.454***	-0.454***
Commuting Mode (base=Auto Drive)			
Car Passenger	-0.119**	-0.088*	0.075
Transit	0.01	-0.64***	-0.983***
Other	-2.343***	-1.476***	-0.658***
Income Status (base= above poverty line)			
Below LICO	-0.029	-0.029	-0.029
Natural Logarithm of Income	0.105***	0.047***	0.013
Employment Status (base=part-time worker)			
Full-Time Worker	0.345***	0.242***	0.139***
Professional Status (base=not a professional, nor a manager)			
Manager or Professional	0.031	0.102***	0.14***
Industry Type (base=agriculture)			
Other Primary Industries	0.608**	0.608**	0.608**
Manufacturing	-0.003	-0.468***	-0.758***
Construction	-0.146	-0.397**	-0.754***
Transportation and Storage	0.385**	-0.225	-0.672***
Communication and Other utilities	0.315*	-0.322**	-0.665***
Trade	-0.38**	-0.699***	-1.009***
Services	-0.261	-0.631***	-0.869***
Period of Immigration (base= not an immigrant)			
Before 1986	-0.191***	-0.476***	-0.529***
1986-1996	-0.374***	-0.374***	-0.374***
Tenure and Housing Type (base= Rental)			
Owns a House-Condo	0.153***	0.153***	0.153***
Owns a House-Not a Condo	0.557***	0.815***	0.6***
Housing Cost to Family Income Ratio (base= 0-32%)			
33-65%	-0.031	-0.031	-0.031
66% and over	0.232***	0.232***	0.232***
Number of Rooms	0.014**	0.014**	0.014**
Sex (base=Male)			
Female	-0.194***	-0.246***	-0.372***
Marital Status (base= Married)			
Single	-0.223***	-0.252***	-0.119***
Household Size	-0.036***	-0.036***	-0.036***
Weekly Time Spent in Household-related Activities	0.001***	0.001***	0.001***
Constant	-0.262	-1.162***	-1.622***
Sample Size n		40440	
Degrees of Freedom		73	
Wald chi2		7046.12	
McFadden r^2		8.13%	

Source: StatCan Public Use Micro Data File, Montreal CMA, 1996

* Significant at 10% level
** Significant at 5% level
*** Significant at 1% level

Table 17: Partial Proportional Odds Model-Commuting Distance Model Results

A negative coefficient for an independent variable in a commuting distance category indicates that higher values of this independent variable increases the chance to be in this commuting distance category or *lower,* while a positive coefficient indicates that higher values of the independent variable increases the chance of commuting longer distances than the current commuting distance range (Williams, 2005).

The model predicts that high school graduates are more likely to travel longer distances than people without a diploma. On the other hand, individuals with a bachelor degree are less likely to travel longer distances than those with no diploma, and especially less likely to travel very long distances. Results also show that individuals with graduate degrees are more likely than those with no diploma to travel distances greater than 25 km. The model also predicts that, controlling for other socio-demographics, graduates are also less likely than those with no diplomas to travel distances greater than 5 km. The implications of these findings are that, in general, higher education enables workers to reduce commuting distances.

Visible minorities are, in general, less likely than the Caucasian group to travel very long distances (-0.035, -0.173), but also less likely to commute for very short distances (0.173). What this implies is that, all else being equal, minorities tend to be less at the extremes of commuting distances than the Caucasian population.

The implications made by the coefficients of the age variable are that the more people age, the less likely they are to commute long distances (compared to the base group of people aged 30 or less). Controlling for other variables, the model suggests that people tend to change their commuting patterns after 40. This is the age group where coefficients for the age variable become negative (and significant), and increasingly more so as the age group gets closer to 60 and more. This is an indication that people will tend to adjust their commuting patterns with age, traveling less as they get older. A possible explanation for this

phenomenon is that individuals will tend to optimize their work and home location after the age of 40.

The commuting mode variable returned intuitive and correct results. The model indicates that people using any other mode than car drive are less likely than car drivers to travel long distances. In order of (in)convenience for long commutes, other modes (walk, bike) are less convenient than transit, which is less convenient than being a car passenger, as shown by the magnitude of the coefficients. An interesting point is that coefficients for transit become more and more negative, while those for other modes become less and less negative; this is an attempt by the model to replicate the fact that, in the data, the proportion of commuters 25km+ was higher among those who used other modes than those who used transit. Employment and income variables also returned valid results. People with higher incomes and with full-time jobs can afford to commute longer distances than their counterparts. The income status variable returned insignificant coefficients.

The model shows that individuals do commute differently depending on their activity sector, mainly because of land use planning, and while not all the differences due to this phenomenon could be captured due to the lack of geo-coded information, some part of the variance could successfully be accounted for, thanks to the introduction of the industry variable. First, the model captures quite well that the base category of agriculture is, after the category of other primary industries, the sector in which there is a higher proportion of people traveling the longest commutes: in 1996, 20.83% of the people working in the agricultural field did commute distances longer than 25 km, second only after workers in other primary industries, where a third of the workforce was found in this commuting category. Consequently, only the "other primary industries" did return significant positive results, while other sectors returned coefficients incrementally negative, an indication that in sectors other than primary industries, people were less likely to travel longer distances, and especially less likely to travel very long distances compared to workers in agriculture or fisheries. On the immigration front, the model predicts correctly that, controlling for other variables, immigrants travel shorter distances than the non-immigrant population (all coefficients negative).

As predicted, the transportation and land use interaction is very present as illustrated in the model. First, home ownership is more likely than rental to be associated with longer commutes (coefficients all positive), but most specifically house owners are more likely than

condo owners to travel longer distances than renters (coefficients for home owners higher than those for condominium owners). Also, bigger houses are associated with longer commutes, although the relationship is not quite as strong as originally predicted. Finally for these variables, the model shows that people who spend 66 or more percent of their household income are more likely to travel longer distances than those who spend 32% or less.

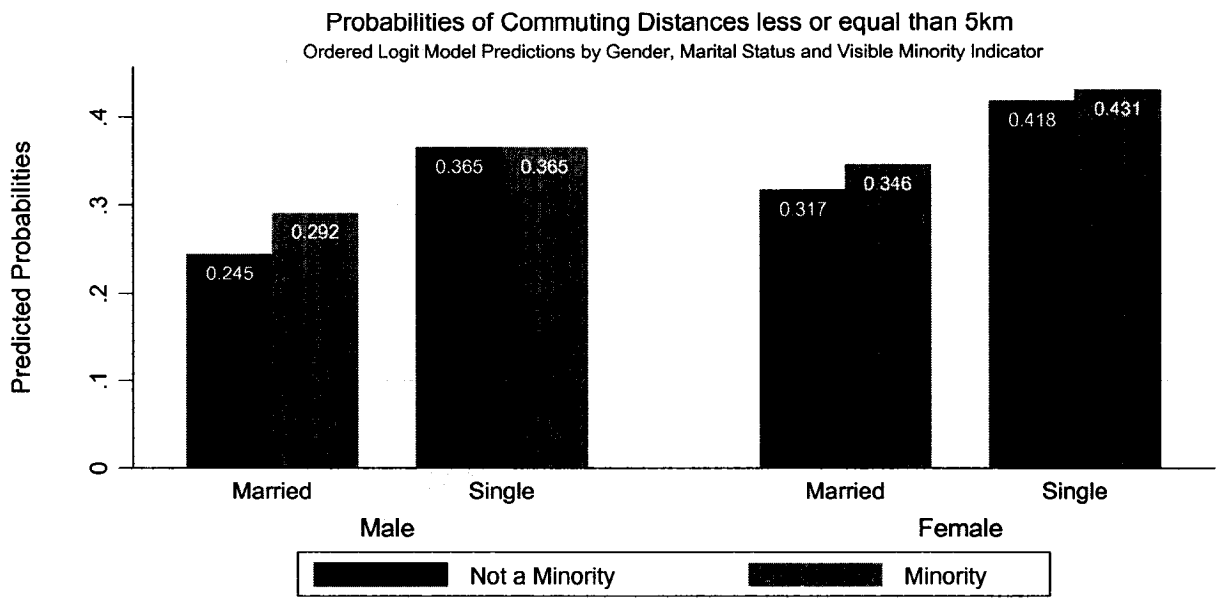
Also, the model shows that women are less likely than men to commute long distances, and especially less likely to commute very long distances (the coefficients for this variable are negative and become increasingly so). The result is very significant (1% level), and concord with both our intuitions and data results. Similarly, singles are found to be less likely to commute longer distances than married people. We hence prove the influence of gender, of marital status on the commuting patterns of the working population.

The last variables of household size and hours spent in household activities returned both ambiguous and unconvincing results. For one, the magnitudes of the household variable coefficients are too small, albeit very significant. But the two sets of coefficients taken together also point to an hypothesis and its counter-argument simultaneously: while bigger households are predicted in the model to slightly deter people from commuting long distances, increased time spent caring for this household is predicted to leave the odds unchanged. These inconsistent results are left in the model to control for the influence of these variables, but will not be further analyzed.

In the last part of this thesis' results, we propose to plot as we did for the commuting mode choice model, the probabilities and observed distributions of commuting distances for selected socio-demographic groups.

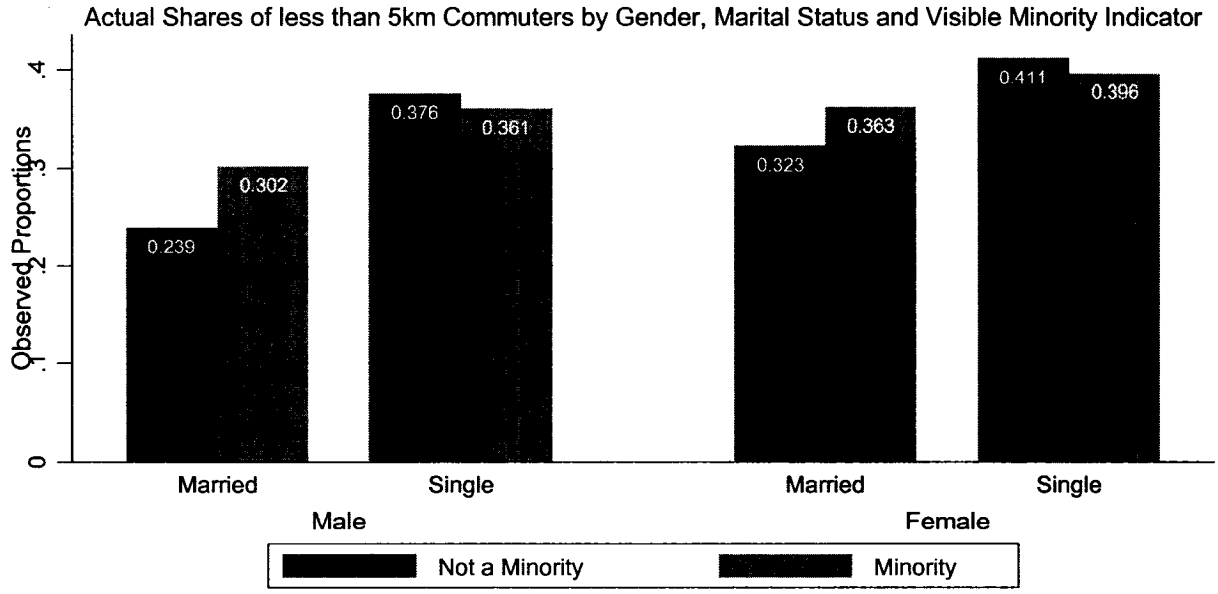
3. Probability Plots

Plots of predicted probabilities are proposed for the same groups as the ones in the previous chapter. For simplicity reasons, only short (less than 5km) and very long (over 25km) commutes are presented. Probabilities and actual shares in both these two commute categories are plotted. The fist four set of graphs present the data by gender, marital status and ethnic group. The next four group observations and predications by gender, marital and income status. Finally, the last four graphs examine the influence of marital status and family size for single mothers, single fathers and female spouses only.



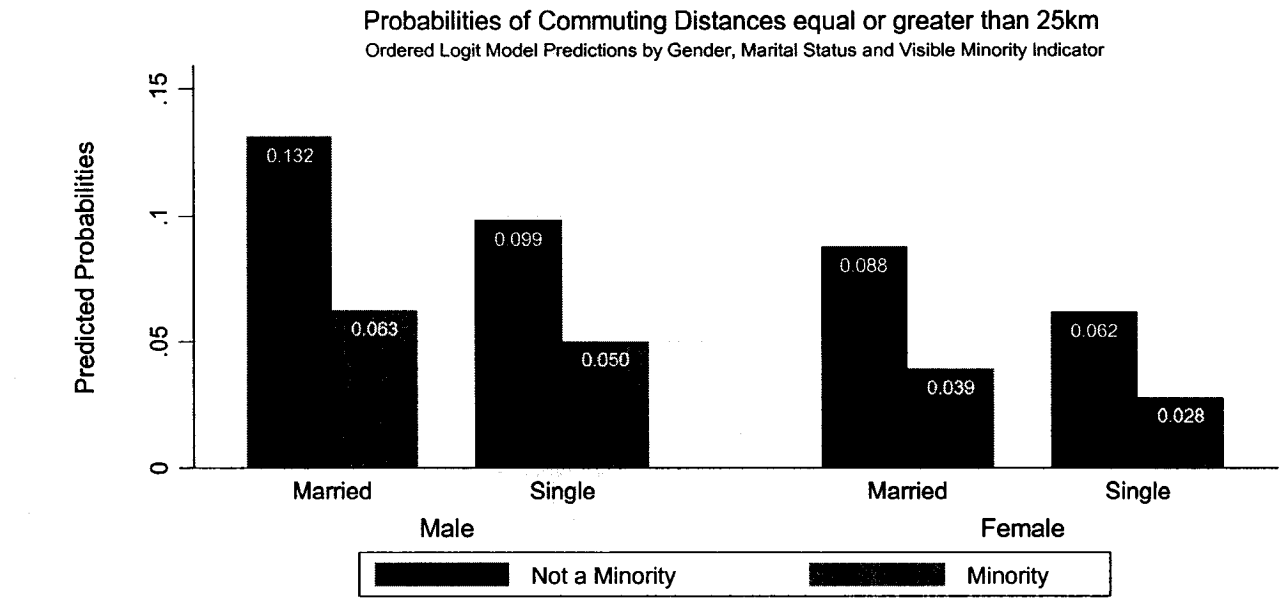
Source: StatCan, 1996 Census Public Use Micro Data File

Fig. 30: Probabilities of Commuting Distances 5km or less by Gender, Marital Status and Visible Minority Indicator



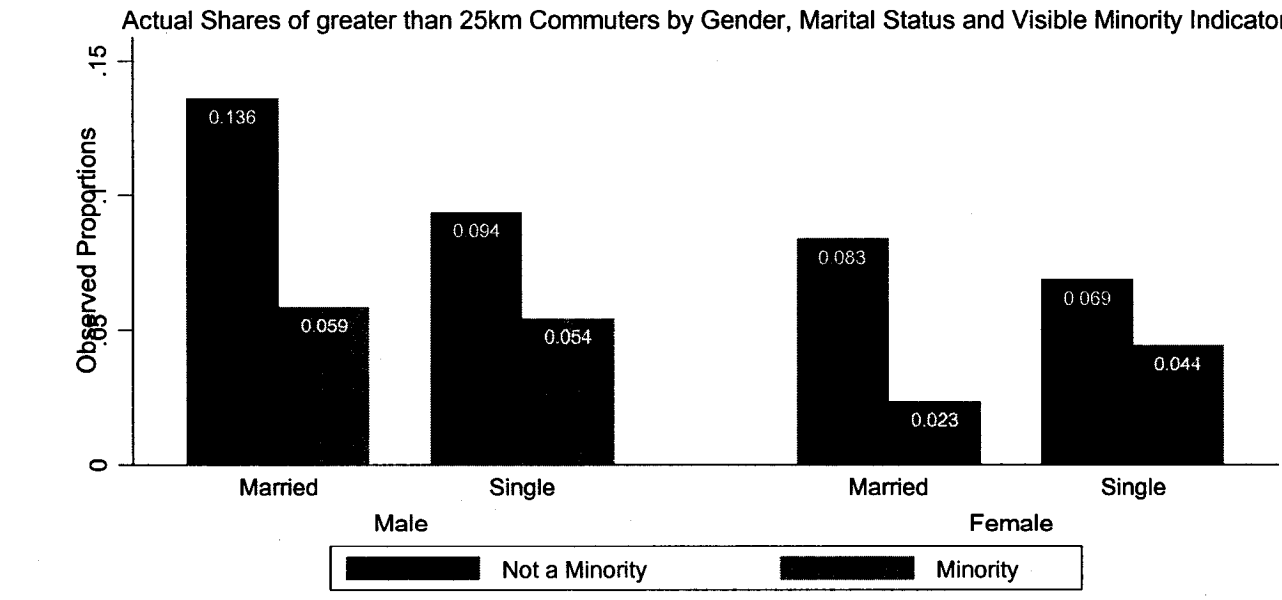
Source: StatCan, 1996 Census Public Use Micro Data File

Fig. 31: Actual Shares of less than 5km Commuters by Gender, Marital Status and Visible Minority Indicator



Source: StatCan, 1996 Census Public Use Micro-Data File

Fig. 32: Probabilities of Commuting Distances Equal or Greater than 25km by Gender, Marital Status and Visible Minority Indicator

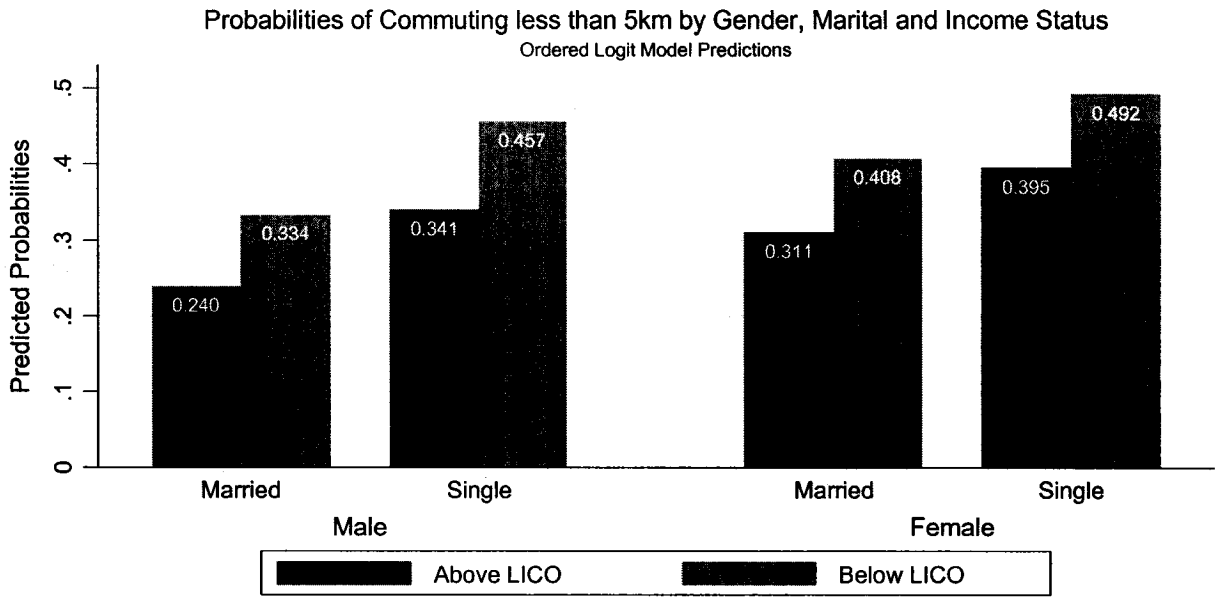


Source: StatCan, 1996 Census Public Use Micro Data File

Fig. 33: Actual Shares of Greater than 25km by Gender, Marital Status and Visible Minority Indicator

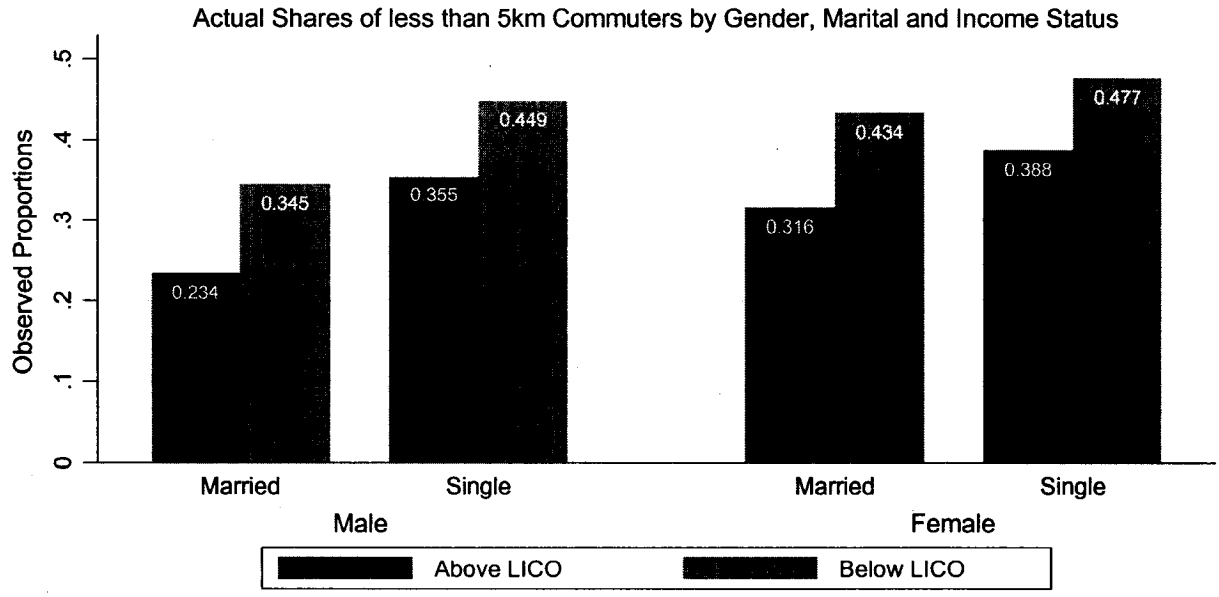
Figures 30 to 33 display probabilities and observed shares of commutes by gender, marital status and ethnicity. The statistics are provided for distances less than 5km and greater than 25 km only. The model results are relatively close to the data values. Predictions for distances smaller than 5km are better than predictions for distances greater than 25km. Incidentally, the model's success index by commuting distance is found to be the largest in these two extreme categories (small and very large, 1.29 and 1.33, respectively). In other words, errors could be larger for commuting distances between 5 and 25 km, where the model performs less well.

Generally, singles and minorities are found to commute smaller distances than married individuals and individuals who do not belong to any minority group, but figure 30 and 31 depict an interesting phenomenon. First, both the model and the data, show that the differences between minority and non-minority groups are smaller for singles than for married individuals. In other words, independently of their ethnic group, singles of the same gender will tend to display similar patterns in small distances choices. However, once they get married, a slightly higher proportion of non-minority groups start commuting longer distances. This suggests that marital status may have more influence in altering the commuting patterns of non-minority than those of minorities. The other tendency is that for very long distances, marital status, ethnicity and gender will influence the probability of commuting long distances: married males of non-minority groups are the most likely to commute distances greater than 25km while women who have identified to a visible minority group are the least likely to be found in that commuting category.



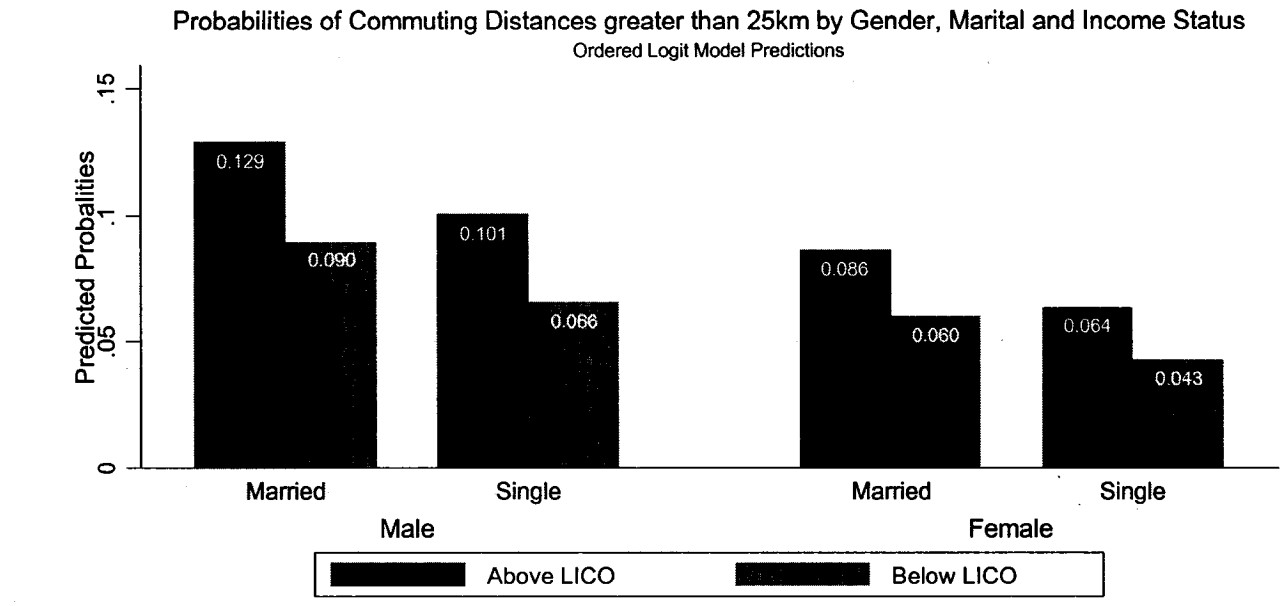
Source: StatCan, 1996 Census Public Use Micro Data File

Fig. 34: Probabilities of Commuting less than 5km by Gender, Marital and Income Status



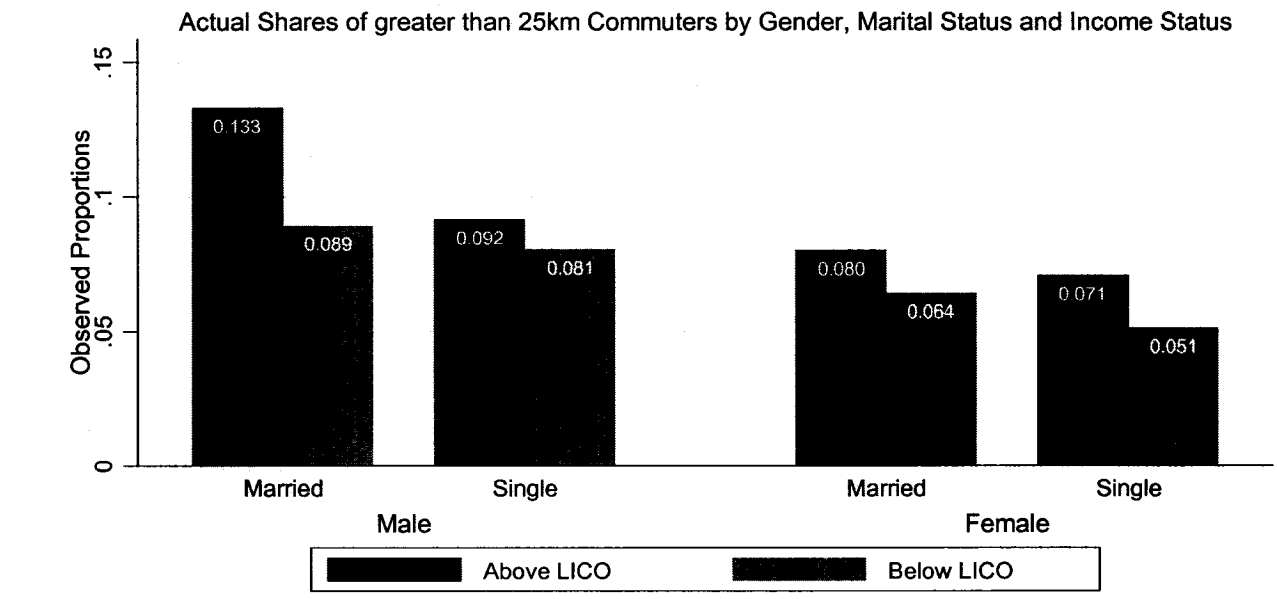
Source: StatCan, 1996 Census Public Use Micro Data File

Fig. 35: Actual shares of less than 5km Commuters by Gender, Marital and Income Status



Source: StatCan, 1996 Census Public USe Micro-Data File

Fig. 36: Probabilities of Commuting Distances greater than 25km by Gender, Marital and Income Status



Source: StatCan, 1996 Census Public Use Micro Data File

Fig. 37: Actual Shares of greater than 25km Commuters by Gender, Marital and Income Status

Figures 34 to 37 display probabilities and observed shares of commutes by gender, marital and income status. Errors for these predictions are small, and once again better for the short distances than the longer commutes (of 25km and over). LICO, referred to in the legend of these graphs is the low-income cut-off point defined by Statistics Canada. The most interesting pattern in these graphs, observed in both the model and the data is that independent of their income statuses, married women have higher probabilities of travelling distances greater than 5km than single males of similar income status. In other words, marital status appears to be more important than gender for small commutes.

Generally, differences between individuals of same gender and marital status but who differ on their income status are found to be about 10% in both the model and in the data for the commutes of less than 5km. In other words, when gender and marital status are controlled for, individuals below LICO have 10% more chance than individuals above LICO to choose distances equal or less than 5km. For commutes greater than 25km, these differences are around 3%, that is the rates, predicted and observed, indicate that, controlling for gender and marital status, commuters above LICO are about 3% more likely to commute distances greater than 25km compared to commuters below LICO.

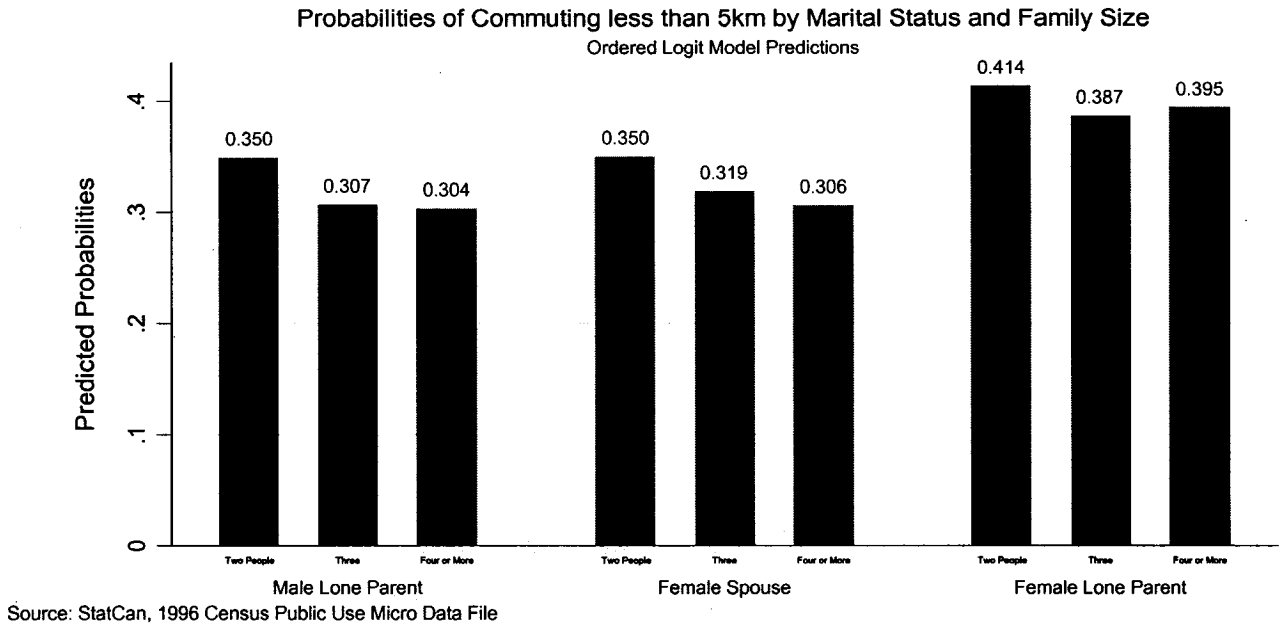


Fig. 38: Probabilities of Commuting Distances less than 5km by Marital Status and Family Size

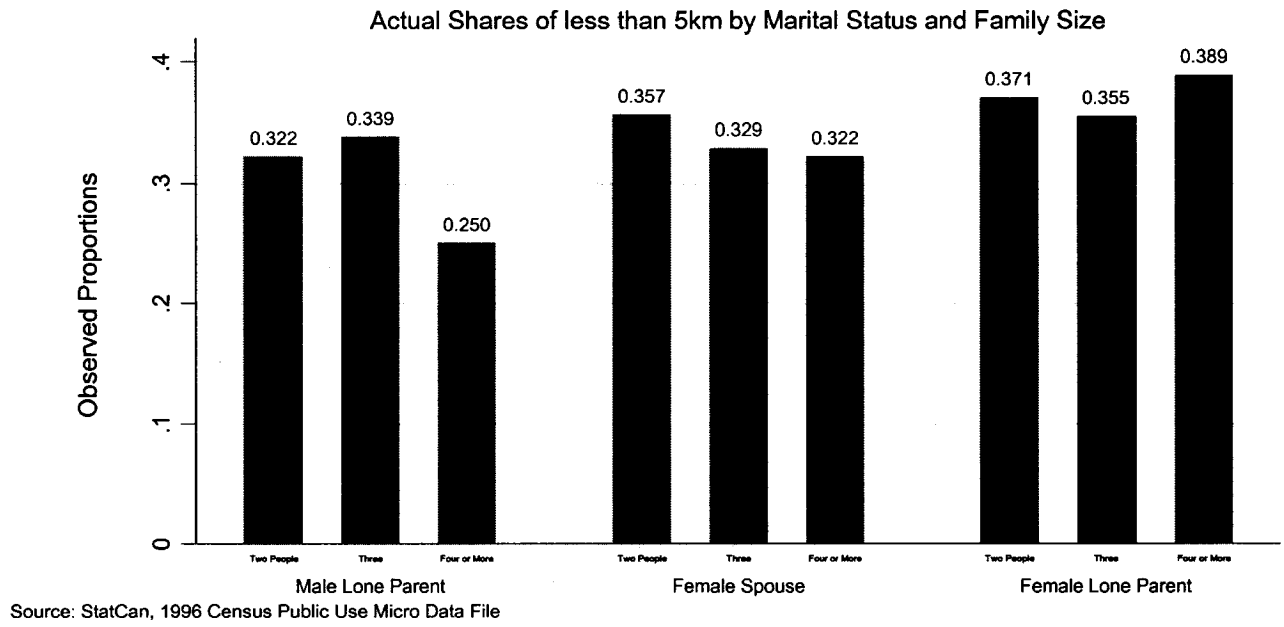


Fig. 39: Actual Shares of Less than 5km by Marital Status and Family Size

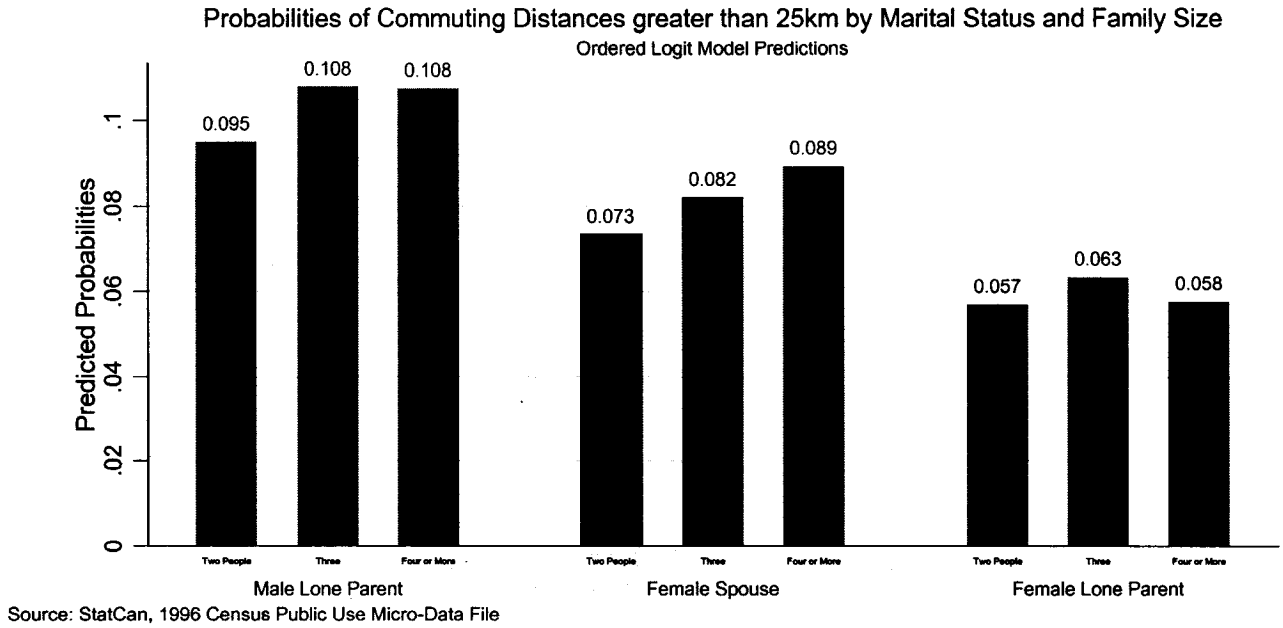


Fig. 40: Probabilities of Commuting Distances greater than 25km by Marital Status and Family Size

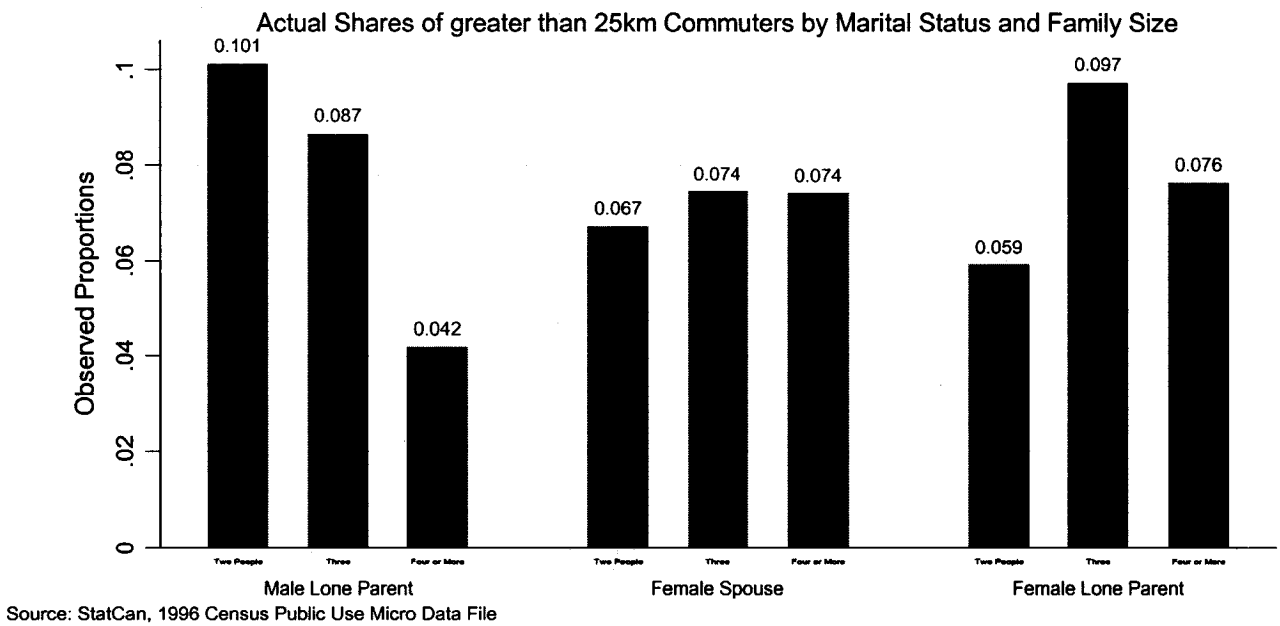


Fig. 41: Actual Shares of greater than 25km Commuters by Marital Status and Family Size

Finally, figures 38 to 41 present commuting distances by family size. These values are only displayed for single mothers, single fathers and female spouses. The predictions vs. actual data show that of all three sets of analyses conducted, this last one is the area where the model performs the poorest. In this estimation, errors are the largest, ranging from less than 1 to 10% in absolute values. Another weakness of the model is that it does not predict patterns correctly for single fathers. That is, the model does not follow the histogram trends for increasing family sizes for single fathers. However these trends are correctly predicted for both single mothers and female spouses.

Although single mothers are slightly more likely to commute in distances smaller than 5km compared to female spouses, the shares for these two groups do not vary much around 38 and 32% respectively. Female spouses commute distances greater than 25km in proportions averaging 7%. For the same distance ranges, single mothers show a little more variance in proportions, but still, these never exceed 10%. Finally for single fathers, the data show that of all three groups (single fathers, single mothers and female spouses), their proportions show the most variance, especially for distances greater than 25 km. While model predictions indicate that the probability of commuting distances greater than 25 km increase with increasing family sizes, the data show the exact opposite, that is, larger family sizes deter single fathers from commuting distances greater than 25 km.

As we did for the multinomial logit model, we present a table evaluating the goodness-of-fit of the partial proportional odds model presented in this chapter. The success index indicates that the odds of predicting commuting distances correctly are better with the model than by chance only. The model is especially better at predicting small and very large distances but perform less well for intermediate ranges. Overall, a third of the predictions made by the model are correct, which is significantly less than the proportion correctly predicted by the multinomial model. Nonetheless, the model is deemed acceptable because commuting distances are generally harder to predict than mode choices.

...But were predicted to commute...

	Less than 5km	5-15km	15-15km	25km and over	*Row Total*	*Actual Share*
Less than 5km	[redacted]	4882.732	1705.013	1030.175	*13169.31*	*=13169.31/40440 =32.57%*
5-15km	4884.707	[redacted]	2873.369	1508.715	*16587.1*	*=16587.1/40440 =41.02%*
15-15km	1725.031	2869.505	[redacted]	807.5965	*6875.73*	*=6875.73/40440 =17.00%*
25km and over	1013.876	1506.459	808.0212	[redacted]	*3807.87*	*=3807.87/40440 =9.42%*
Column Total	*13175*	*16579*	*6860*	*3826*	*40440*	

[redacted]

Total Percent Correct = (5551.385+7320.304+1473.597+479.5137)
= 36.67%

Table 18: Partial Proportional Odds Model-Overall Goodness-of-Fit Table

Conclusions

Commuting is a daily ritual for most workers. It sets the rhythm of urban flows and conditions our participation in economic and social activities. The time going to and coming from work is often argued to be a mere extension of our work schedules. But the commute experience varies significantly across genders, across ethnic groups and across family structures. To analyze how and why they differ across these entities was the goal of this dissertation.

The analysis relied on both actual data analysis and econometric models to understand the many aspects that interplay to influence commuters' choices. The exploratory data analysis section has suggested different commuting patterns between single mothers and other women, between low-income individuals and the non-poor; and finally between minorities and non-minority groups. The development of econometric models has confirmed the existence of some (but not all) divergences in patterns.

1. Models and Data Summary

First, the mode split model has shown that, controlling for all socio-demographic variables, time spent in family related-activities and family size do not impact commute choices or distances. These two variables are often cited in the literature as critical components of women's trips. We have found no evidence to support this hypothesis. However, gender was found to be significantly related to trips patterns, with women traveling shorter distances, relying more on transit and less on car drive than men. As a matter of fact, being a woman, being of minority or being single all decrease the odds of driving vs. using transit.

Single mothers are found to rely less on car than single fathers or married spouses but more than single women living alone. Of all three groups studied, they are arguably the most disadvantaged for a number of reasons: the absence of a second income earner in the household, lower personal incomes due to lower levels of education (of all three groups they were contrasted with, they were on average the less educated), their gender (being a woman is found to greatly influence commuting patterns) and finally the presence of children, who weigh heavily on already reduced economic resources. Although single mothers get

significantly more child support than married spouses, their incomes do not compare to those found in households with two income earners.

An interesting finding in the mode split model suggests that, controlling for socio-demographic variables, there exist differences in mode splits between minorities and non-minorities. Minorities are found to rely less on car and more on transit than non-minority groups. But what do those findings imply, exactly? Is this enough evidence to prove that minorities are disadvantaged? The answer is rather complex.

Firstly, both statistics and our tabulations show that there is a slightly higher proportion of university educated individuals among minorities than among non-minorities. This should strengthen the hypothesis that there is indeed enough evidence to support the theory of disadvantage. But the commuting distance model discussed further in the next section shows that non-minority groups are more likely than minorities to commute longer distances.

Secondly, while there is evidence of higher levels of education among minorities, the proportion of *Canadian* university degrees within these minorities, or the amount of *Canadian* work experience minority workers have are still unknown. These factors play a critical part in determining work wages and eventually the choice of commute modes. Unfortunately, these could not be accounted for in the model, due to the absence of variables in the dataset controlling for them.

Thirdly, while higher rates of transit were found among minorities, this could be due to the concentration of minorities in high density residential areas where transit access is better and transit availability higher. Of all three points raised above, this is the one with most implications in transportation policies, because it suggests the concentration of minorities in geographic clusters of high density at worst, in the central city at best.

The commuting distance model on the other hand has demonstrated that the prediction of commuting distances was a far more complex task than the prediction of mode choices. People live far from home for various reasons: the decision to trade longer commutes for more housing, the inability to reduce commutes due to the clustered nature of certain industries (agriculture and other primary industries), the change in marital status from single to married; all of these are found to influence commuting distances to various degrees. But certain hypotheses are hard to verify: hence, while we have found evidence that non-minorities had greater odds than minorities to drive to work, we have also found that non-

minorities had greater odds to commute longer distances than minorities. Therefore, because higher shares of car use are associated with longer commutes among the Whites, it becomes hard to assert for certain whether differences in commuting patterns between the Whites and the minorities are a sign of disadvantage and should be addressed, or whether they just reflect personal preferences within groups not defined by ethnicity, but rather defined by their residential location. Do the Whites and minorities living in the same geographical area commute similarly? Or are there still differences, even when controlling for residential densities? Our analysis could not answer to these questions because the lack of geographic information on where people live and where they work have prevented us to control for such variables as residential density, transit access, density at the workplace...The incorporation of these variables in the models could have enabled us to get a clearer picture on the implications of ethnicity on commute distances and mode choices by isolating the effects of urban form.

2. Concluding Remarks

To conclude, a few words need to be said about the importance of data in transportation studies. While twenty years ago, computing power was the daunting task to confront in transportation modelling studies (a multinomial logit model easily done in a couple minutes now used to take much longer then), today the paucity of data researchers are faced with can only but rebuff the most enthusiastic of them.

Today, computing power, memory and processing speed come, relatively, cheap. Data, however, have not progressed quite as steadily. They are aggregated to protect the confidentiality of respondents, and when available, expensive to get for various political reasons. And yet, one can hardly overstress their importance in social sciences. This dissertation has tried to show the importance of detailed data in the field of transportation, data that provide information on both the individual (age, income, ethnicity...) and its habitat (density, transit access, distance from CBD). The models, especially the multinomial logit model, have returned relatively good results. But while these models included socio-demographics of commuters, hence controlling for their effects, the absence of variables related to urban form has prevented us to test for certain hypotheses, especially those related to minorities. Future research that can integrate both these types of data will surely produce results appropriate for policy applications.

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