THE FREQUENCY OF BLOOD DONATION IN CANADA: AN EXPLORATION OF INDIVIDUAL AND CONTEXTUAL DETERMINANTS

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A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of the Requirements for the Degree Master of Arts

MASTER OF ARTS (2012) McMaster University

(School of Geography and Earth Sciences) Hamilton, Ontario, Canada

TITLE: The Frequency of Blood Donation in Canada: An Exploration of Individual and Contextual Determinants

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NUMBER OF PAGES: v, 73

ACKNOWLEDGEMENTS

I would like to sincerely thank Dr. K. Bruce Newbold for his ongoing guidance and support throughout my studies. Your door was always open when I needed advice, and you made me feel like I was never interrupting (even though I always was). I would also like to thank Dr. Antonio Páez, my unofficial co-supervisor, for his perpetual patience and leadership over the past 2 years. Your door was always closed, but it was because you were in the lab, teaching me and problem-solving. My supervisors provided not only a wealth knowledge and expertise required to complete my work, but also the chance to share it with others at several conferences. I deeply appreciate the opportunities you have given me, and the experiences that I will carry with me beyond student life.

Thank you to Dr. Nancy Heddle for her encouragement and valuable input, and for showing me that my small contribution can have a large impact with effective knowledge translation.

My friends and fellow students were always there to provide necessary comic relief and share stories that made every day a blast, thank you all for that!

A final thank you to my family for your unconditional love and support that makes any achievement possible.

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CHAPTER 1: Introduction

1.1 Rationale

The maintenance of a safe and secure blood supply in Canada is dependent on a relatively small group of donors that volunteer their time and energy for a worthy cause. The balance between the supply and demand of blood products (whole blood, red blood cells, platelets, plasma) must be carefully regulated to ensure that a sufficient number of units of safe blood are available for routine and emergency medical procedures, while limiting the amount of blood that is wasted. Pressures affecting this delicate balance in Canada include advances in medical technologies, a rising proportion of seniors, and an increasing immigrant population.

Focusing on medical pressures, ongoing progress in medical science leads to an improved understanding of the treatment of disease, but it also means that more blood is required, for example in cancer therapy, surgery and trauma remediation (Cobain et al., 2007). For this reason, it is imperative to minimize blood loss, for example by employing minimally invasive surgery, which involves smaller incisions and less bleeding (e.g. Cohn, 1998).

Regarding demographic pressures, as baby boomers continue to drop out of the donor pool in the next decade due to age and health restrictions, they also become significant consumers of the blood supply (Drackley et al., 2011). In addition, immigrant populations have been associated with lower donation rates (Saberton et al., 2009) and the increasing proportion of these populations in Canada puts additional pressure on the blood supply.

1.2 Blood Donor Behavior

In Canada, approximately 3% of the eligible adult population donates blood, and of these donors, many give blood only once a year as shown in Figure 1. In order to increase the number of Canadians that donate blood and encourage donors to return more frequently, it is necessary to understand why some people donate while others do not, and why some donors give blood more often than others. Exploring the determinants of blood donation is a complex endeavor as researchers may focus on the behaviour of donors (Glynn et al., 2002; Veldhuizen et al., 2011), nondonors (Lemmens et al., 2005) or a combination of the two (Clowes and Masser, 2012; Hupfer et al., 2005).

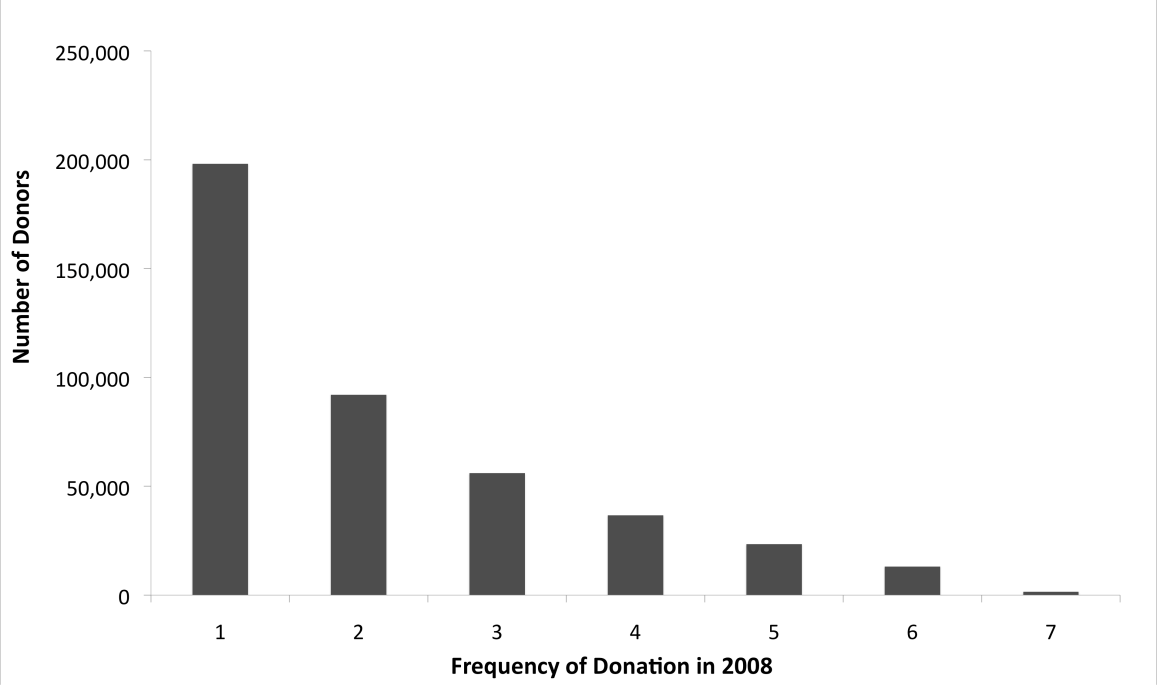

Figure 1. The frequency of blood donation in 2008

Interest in donor motivation has been a topic of discussion for several decades, with studies expanding old ideas and also presenting new perspectives on the subject (e.g. Ferguson et al., 2007; Germain et al., 2007; Oswalt, 1977; Ownby et al., 1999; Steele et al., 2008). Research has focused on donor characteristics such as age, gender, and ethnicity (Guo et al., 2011; Murphy et al., 2009), donor behaviour and attitudes (Ferguson and Bibby, 2002; France et al., 2007), and a combination of demographics and attitudes (Germain et al., 2007). Ultimately, the goal of research focusing on blood donor behaviour is to outline the motivating factors that cause people to donate or not donate, which may be altruistic in nature, for the benefit of the greater good (Glynn et al., 2002), or egotistic, where a sense of personal reward is prevalent (Ferguson et al., 2007).

An influential paper by Oswalt (1977) outlines the characteristics of donors and non-donors, demonstrating that people often donate for the first time between 18-29 years old, and males donate more than females. Subsequent studies add that immigrants are less likely to donate, while those with a higher education status are more likely to give blood (Chliaoutakis et al., 1994; Gillespie and Hillyer, 2002; Ownby et al., 1999; Thomson et al., 1998). Numerous theoretical models exist to identify the motivating factors of human behaviour, the most prevalent in blood donor research being the Theory of Planned Behaviour (TPB)(Ferguson et al., 2007). TPB is a continuous model of behavioural change that is frequently used in health behaviour studies, first developed by Ajzen (1991) and has been successfully applied to blood donor research (Giles et al., 2004; Masser et al., 2008). The theory is based on the principle that 3 independent factors (attitude, perceived norms, and perceived behavioural control) determine a person's intentions of behaviour, which is the ultimate predictor of actual behaviour (Ajzen, 1991).

This has shown to be true in the case of blood donors, where intention is an excellent predictor of donor behaviour. With a focus on factors that influence repeat donation, Godin et al. (2007) found that the older population of new and experienced donors in Canada are more likely to register for donation after indicating intent to donate in the near future. Also, the authors discover that intention becomes less important with increased frequency of donation, a trend that may occur because regular donors behave mainly based on past experience and habit. Results indicate that the older cohort in the study is more likely to take action on their intentions than younger donors, and the authors suggest that this is because the younger population may be living with more instability in their everyday life. Moral norm, facilitating factors (time consuming donation) and anticipated regret (negative feelings towards not donating) are also found to influence donor intentions, and results are consistent with the literature (Hupfer et al., 2005; Lemmens et al., 2005).

A more thorough understanding of the determinants of blood donation is needed in order to explore the relationship of context with individual decision making. This information may be used to improve donor turnout by enhancing marketing and advertising strategies to ensure that the public understands the ease, safety, and importance of donating blood regularly.

1.3 Research Objectives

The aim of this thesis is to identify the factors affecting the decision to donate in Canada, taking into account the individual attributes of donors as well as characteristics of their surroundings. Emphasis is placed on the importance of repeat donors, since most

people donate with a low frequency, with a majority of donors giving blood only once as shown in the Canadian Blood Services 2008 national dataset. Demographic correlates will be explored in relation to their effect on the frequency of donation in ten Census Metropolitan Areas (CMA) to identify why some donors return to blood clinics while others do not. The dependent (frequency of donation) and independent (individual and contextual characteristics) variables are modeled using discrete choice analysis, with a separate model for each location. This means that comparisons cannot be made across the country, but allows for a more effective and detailed result focusing on each CMA.

1.4 Chapter Outline

This thesis is comprised of two research papers, one pilot study focusing on a new approach to studying the correlates of blood donation, while the second paper extends the study to the national level. Chapter 2 contains the first paper, published in *Health & Place* (Cimaroli et al., 2012). In this study, discrete choice analysis was used to investigate the determinants of frequency of donation in the Toronto Census Metropolitan Area to demonstrate the effectiveness of this type of analysis in the field. Chapter 3 shows that based on the success of the pilot study, the analysis could be conducted for many cities across Canada to gain an overall picture of the influences on the decision to donate blood multiple times in a year. There is overlap in the methods and rationale of the two papers. Chapter 4 summarizes the results and contributions of the two papers, and discusses study limitations and possibilities for future work.

CHAPTER 2: Individual and contextual determinants of blood donation frequency with a focus on clinic accessibility: A case study of Toronto, Canada

2.1 Abstract

The balance between supply and demand of blood products is a question of great interest for the long-term prospects of health care systems. Trends that affect this balance include an aging population and increasingly large immigrant communities with lower donation rates. Blood agencies must implement several strategies to ensure a sustained supply of blood products. A better understanding of the determinants of donation frequency is essential to develop strategies that encourage new and existing donors to donate more frequently. In this study, we investigate the individual and contextual determinants of the decision to donate multiple times, with a particular focus on accessibility to clinics. The case study is the Toronto Census Metropolitan Area. Analysis is based on discrete choice models estimated using the attributes of the geocoded donors and clinics, and Census data for contextual variables. The results indicate that higher levels of accessibility increase the probability of donor return and more frequent donations.

2.2 Background

Blood collection agencies all over the world face the challenge of maintaining a sufficient supply to balance the demand for blood products. Rising demand for blood products in the developed world can be attributed to advancements in medical science and technologies, increases in life expectancy, and greater demand for medical procedures (Greinacher et al., 2007; Guo et al., 2011). Blood supply must increase proportionally in order to meet the needs of contemporary health care systems. Several trends conspire to

put mounting pressure on the supply of blood products in many countries and regions. In Canada, for example, an aging population is expected to result in an unprecedented increase in the number of seniors living in the country by 2036 (Statistics Canada, 2010).

In the next few decades, the elderly population will require more transfusions, placing additional demands on Canada's blood supply (Drackley et al., 2011). While it is recognized that most people will require blood products at some point in their lifetime, the fact is that only approximately 3% of Canada's adult population donate blood (Talbot and Mumford, 1999). This situation is not unlike that observed elsewhere in the world (e.g. Heinrich, 1999; Whyte, 1999), and calls for innovative approaches to ensure that blood supply does not falter. The organization with the mandate to manage the supply of blood products in all provinces and territories in Canada (with the exception of Québec) is Canadian Blood Services (CBS). CBS is responsible for collecting, testing and processing each unit of blood for use in transfusion. In addition to these fundamental operations, CBS also actively develops and implements strategies to recruit new donors, to retain existing donors, and to encourage donors to make donation a part of their lifestyles.

In an effort to support blood collection agencies to increase the size of their donor pools, research has been conducted to better understand the determinants of donor turnout rates (see the analysis of Canada of Saberton et al., 2009), and at the individual level, the motivators and deterrents of becoming a blood donor (Boulware et al., 2002; Gillespie and Hillyer, 2002; Mathew et al., 2007; Steele et al., 2008). Equally important is the role of repeat donors. Retention of repeat donors reduces the cost of recruitment and also provides a safer source of blood (e.g. Goncalez et al., 2003). In addition, repeat donors represent an important proportion of the total blood supply. The total number of blood

units collected by Canadian Blood Services in 2008 was 903,014. Of these, 198,087 units came from single-time donors, whereas 704,927 came from 222,700 repeat donors.

Given the importance of blood given by repeat donors, the objective of this paper is to investigate the individual and contextual factors that influence the individual decision regarding the frequency to donate. Analysis is based on Canadian Blood Services data for the Toronto Census Metropolitan Area (CMA), and the use of discrete choice analysis. Demographic factors such as age, gender, and experience giving blood, are known to influence donor behavior, and are important for forecasting purposes. As well, contextual factors can provide valuable information about the social environment of the donors, which can help in the design of outreach and education strategies. However, individual and contextual factors are beyond the control of blood collections agencies. Therefore, the particular focus of our analysis is on the potential influence of geographical accessibility to clinics on return behavior. Determining whether accessibility is significantly related to donation frequency would provide a powerful policy variable, useful to inform planning and operations by blood collection agencies. In this way, the results of the analysis could potentially have important practical implications to guide future efforts to maintain or increase the supply of blood products.

2.2.1 Factors that Influence Donor Behavior

Previous research shows that potentially important gains in collection can be enabled by a better understanding of donation frequency behavior (Flegel et al., 2000). It is not surprising to see that this topic is receiving increased attention that stands in contrast with the state of relative neglect noted by Godin et al. (2007, p. 1607). A brief review of the significance and direction of effects reported in the literature helps to

establish our expectations in terms of the variables analyzed.

A number of studies have strived to assess the determinants of return behavior and donation frequency. After Oswalt (1977), the focus of these has been on characteristics of donors such as age, gender, ethnicity, and donation history (e.g. Flegel et al., 2000; Guo et al., 2011; Murphy et al., 2009; Notari et al., 2009; Ownby et al., 1999; Schreiber et al., 2005; Veldhuizen et al., 2009; Whyte, 1999; Yu et al., 2007), the role of attitudes and intentions (e.g. Ferguson and Bibby, 2002; France et al., 2007; Godin et al., 2007), or a combination of demographic and attitudinal factors (e.g. Germain et al., 2007; Schlumpf et al., 2008).

Our specific interest is in the following individual attributes: age, gender, donation history (e.g. first time donor or previous donation experience), and accessibility.

In terms of age, older donors are more likely to return (Flegel et al., 2000; Notari et al., 2009; Whyte, 1999). Higher donation rates also coincide with increasing age, which is an important concern regarding the future state of the donor pool (Ownby et al., 1999). A similar effect has been observed in Canada, with the addition that the younger cohort of repeat donors have a higher chance of temporarily leaving the donor pool (Germain et al., 2007). Research in China, in contrast, shows that most blood donations come from those aged 25 years and younger (Guo et al., 2011), a trend that may be influenced by the presence of paid blood donors.

Significant gender differences have been reported in the literature. Previous research has shown that males are more likely to donate as well as to make multiple donations (Guo et al., 2011; Ownby et al., 1999; Schreiber et al., 2005). Germain et al. (2007) describe that a large gap (greater than two years) between donations is more

common among return female donors, who may reduce their participation during the reproductive years and menopause.

Donation history has also been investigated in the past. A number of studies emphasize the positive effect of a short time period between the first and subsequent donations (Ownby et al., 1999; Schlumpf et al., 2008). The evidence indicates, in fact, that long-term donation patterns can become established in a relatively short interval following the initial donation (Schreiber et al., 2005; Yu et al., 2007).

Convenience is identified in the literature as a factor that can influence donor behavior (Schreiber et al., 2006). As a key element that determines the convenience of donating blood, clinic accessibility is a topic in need of attention. Schrieber et al. (2006) and Schlumpf et al. (2008), for instance, find that inconvenient locations can prevent younger donors from returning, whereas Saberton et al. (2009) find a significant effect of clinic accessibility on donor turnout rates in Canada.

In addition to individual attributes, an examination of contextual effects (i.e. those describing the social context of donors) can provide valuable information about the behavior of interest (Veldhuizen et al., 2009).

Ethnicity is an important consideration, given Canada's large immigrant population. At the individual level, the existing evidence indicates that immigrants are less likely to donate compared with non-immigrants in Canada and the United States (Chliaoutakis et al., 1994; Gillespie and Hillyer, 2002; Ownby et al., 1999; Thomson et al., 1998). This effect seems to extend to the social context of donors. For instance, Veldhuizen et al. (2009) show that in the Netherlands, donors living in an area with a more homogeneous ethnicity are less likely to withdraw from the donor pool. This result is mirrored in

Canada in the analysis of Saberton et al. (2009), who find that donor turnout rates decrease as the size of the immigrant population grows.

The results with respect to level of education are less conclusive, but worth considering. Ownby et al. (1999) and Schreiber et al. (2006) report that donors with a college education or higher were more likely to donate with a high frequency than less educated donors in the United States. As a contextual variable, Saberton et al. (2009) identify education as a significant positive predictor of donor turnout rates. On the other hand, Guo et al. (2011) find that lower education (middle schoool or less) was positively associated with return donation.

Household income and employment may also be important predictors of donor behaviour. (Saberton et al., 2009) find that neighbourhoods with a higher average household income correlate negatively to the number of donors in large cities. In terms of occupation, it has been shown that the employed population exhibits greater rates of volunteering (Caro and Bass, 1997), which may explain the negative effect of unemployment on donor yield in Canada's voluntary system (Saberton et al., 2009). Few studies have focused on specific occupations, but one study shows that donors living in an area with a high proportion of the population working in health-related occupations are positively correlated with blood donation (Saberton et al., 2009).

2.3 Data

Two sources provide the data for analysis (see Table 1): donor data and clinic data were facilitated by Canadian Blood Services, whereas contextual geo-demographic information was obtained from the Census. Accessibility was calculated based on clinic and population data.

Geo-referenced donor information (at the postal code level) was extracted from the Canadian Blood Services 2008 national dataset. This dataset contains the following information: age and gender of donors, total lifetime donations and date of each donation in 2008. Date of first donation in 2008 is used to identify possible seasonal effects. Donors and clinics were geocoded using the 2006 Postal Code Conversion File for Toronto CMA. The locations of the resulting points were inspected for accuracy using postal code areas from the Canadian Census. A total of 51,239 unique donors were geo-located in Toronto CMA, although a reduced dataset was retained for analysis after refining the temporal scope of the study as indicated below. The distribution of donors varies across the study area, but few DAs in central Toronto contain a high percentage of donors compared to the entire region (Figure 1).

Table 1: Variables and descriptive statistics

Variable	Description	Min	Max	Mean	SD
Individual					
Donations	Individual frequency of donation in 2008	1.000	4.000		
Gender	1 if male, 0 if female	0.000	1.000		
Age	Donor age (in decades)	1.700	7.800	4.101	1.413
First Time	1 if first time ever donating in 2008, 0 otherwise	0.000	1.000		
January	1 if first time donation in 2008 was in January, 0 otherwise	0.000	1.000		
February	1 if first time donation in 2008 was in February, 0 otherwise	0.000	1.000		
March	1 if first time donation in 2008 was in March, 0 otherwise	0.000	1.000		
April	1 if first time donation in 2008 was in April, 0 otherwise	0.000	1.000		
May	1 if first time donation in 2008 was in May, 0 otherwise	0.000	1.000		
June	1 if first time donation in 2008 was in June, 0 otherwise	0.000	1.000		
July	1 if first time donation in 2008 was in July, 0 otherwise	0.000	1.000		
Contextual					
Average Income	Average after-tax household income in DA (in $100,000)	0.000	5.654	0.787	0.348
Education	Proportion of population with bachelor's degree or higher	0.000	0.969	0.404	0.178
Health Occupation	Proportion of population working in a health occupation	0.000	0.324	0.043	0.033
Unemployment Rate	Unemployment rate in DA	0.000	0.500	0.044	0.037
English Only	Proportion of population that speaks English only	0.404	1.000	0.881	0.060
Average Children	Average number of children per Census family in DA	0.000	2.900	1.252	0.317
Single	Proportion of single, never-married population in DA	0.047	0.778	0.321	0.082
USA	Proportion of population by place of origin: USA	0.000	0.151	0.009	0.014
Central America	Proportion of population by place of origin: Central America	0.000	0.230	0.004	0.010
Caribbean	Proportion of population by place of origin: Caribbean	0.000	0.384	0.025	0.034
South America	Proportion of population by place of origin: South America	0.000	0.316	0.019	0.025
Western Europe	Proportion of population by place of origin: Western Europe	0.000	0.392	0.012	0.016
Eastern Europe	Proportion of population by place of origin: Eastern Europe	0.000	0.609	0.036	0.048
Southern Europe	Proportion of population by place of origin: Southern Europe	0.000	0.524	0.052	0.064
Northern Europe	Proportion of population by place of origin: Northern Europe	0.000	0.265	0.034	0.031
Africa	Proportion of population by place of origin: Africa	0.000	0.307	0.017	0.025
WCAME	Proportion of population by place of origin: West Central Asia and Middle East	0.000	0.359	0.024	0.037
Eastern Asia	Proportion of population by place of origin: Eastern Asia	0.000	0.785	0.055	0.099
Southeast Asia	Proportion of population by place of origin: Southeast Asia	0.000	0.522	0.031	0.042
Southern Asia	Proportion of population by place of origin: Southern Asia	0.000	0.777	0.056	0.089
Oceana	Proportion of population by place of origin: Oceania	0.000	0.096	0.002	0.005
Non-Permanent Resident	Proportion of population that is a non-permanent resident	0.000	0.237	0.012	0.021
Non-Immigrant	Proportion of population that is not an immigrant, Canadian origin	0.102	1.000	0.608	0.187
Accessibility					
	Population-based accessibility	0.000	7.597	1.050	0.936

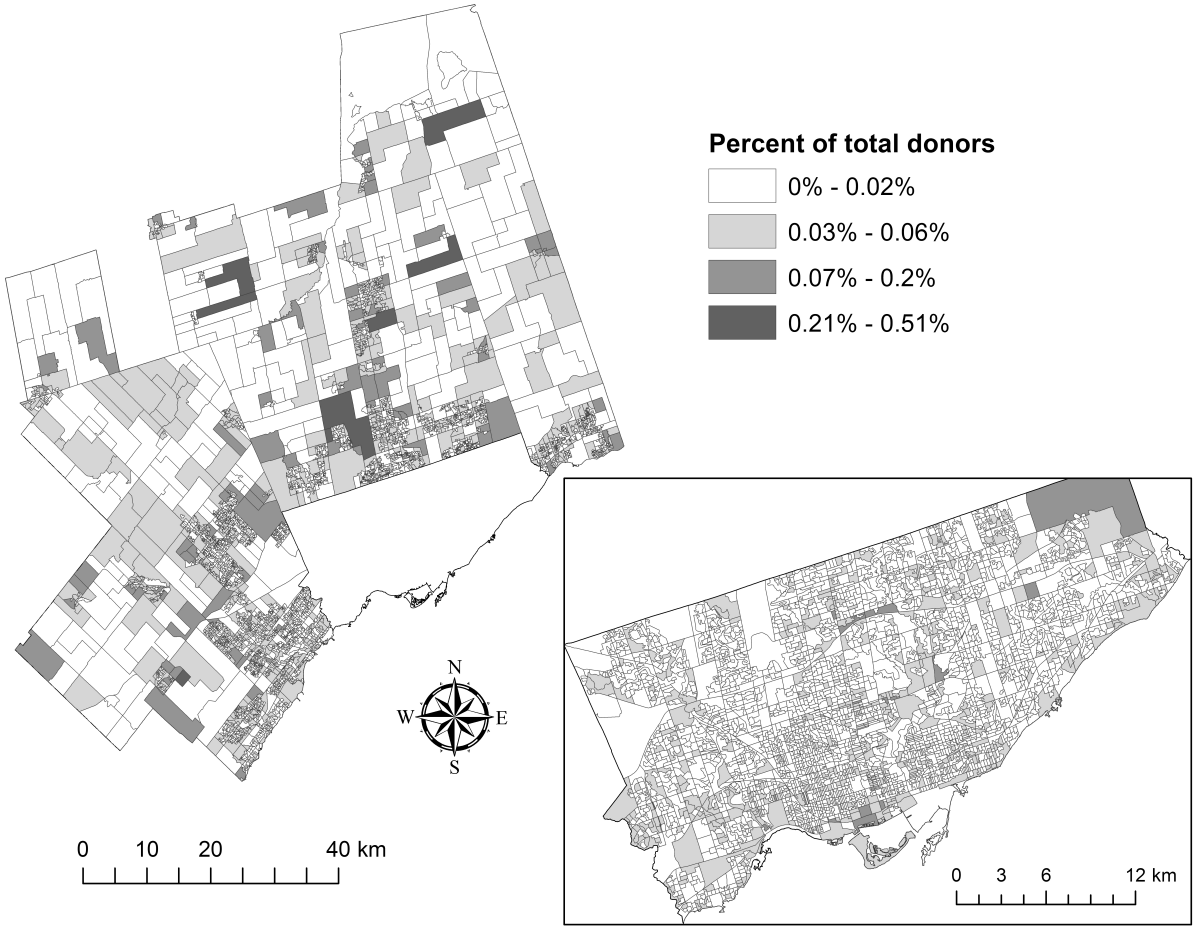

Figure 1. Percent of donors in each Dissemination Area relative to all donors in Toronto CMA

The temporal coverage of the dataset is one calendar year. For the purpose of the analysis, data were selected using a moving time-window approach in order to ensure that all donors had an equal opportunity to make subsequent donations during the year. Specifically, individual donor records were identified using a window based on the CBS donation wait time of 56 days. Donors who made their last donation in 2008 before February 25 were excluded from analysis because they may have previously donated in 2007 and a concrete time period for frequency of donation cannot be defined for these

donors. For donors whose first donation during 2008 was after February 25, a 168-day window from the time of the first donation in 2008 was used. This interval provides the best compromise between possible number of donations (maximum four donations because there are four periods of 56 days in our 168-day window) and usable records for the analysis.[1] Donors whose first donation in 2008 was after July 16 were excluded from analysis, since their maximum time window would be less than 168 days, and therefore their period of opportunity to donate with equal frequency would be reduced.

After implementation of the moving time-windows, the dataset for the analysis included 30,054 unique donors with a maximum possible donation frequency of four. Additional dummy variables were included to investigate the effect of seasonality on frequency of donation, with reports by CBS indicating lower donation rates in spring/summer months. These variables express a donor's month of first donation in 2008 in order to investigate a possible seasonal effect on donation frequency. First-time donors were defined as those individuals who never successfully made a whole blood donation prior to 2008. Donor age (in decades) was included as a continuous variable.

In terms of clinics, a total of 298 unique sites were geo-located in Toronto CMA. Also included are the dates of each blood collection event, the number of beds at each clinic, and the hours of operation. Clinics are generally situated near the urban center of the study area with fewer clinics located in the periphery (Figure 2).

[1] Shorter and longer periods were tested, but their goodness of fit was reduced compared to the 168-day window.

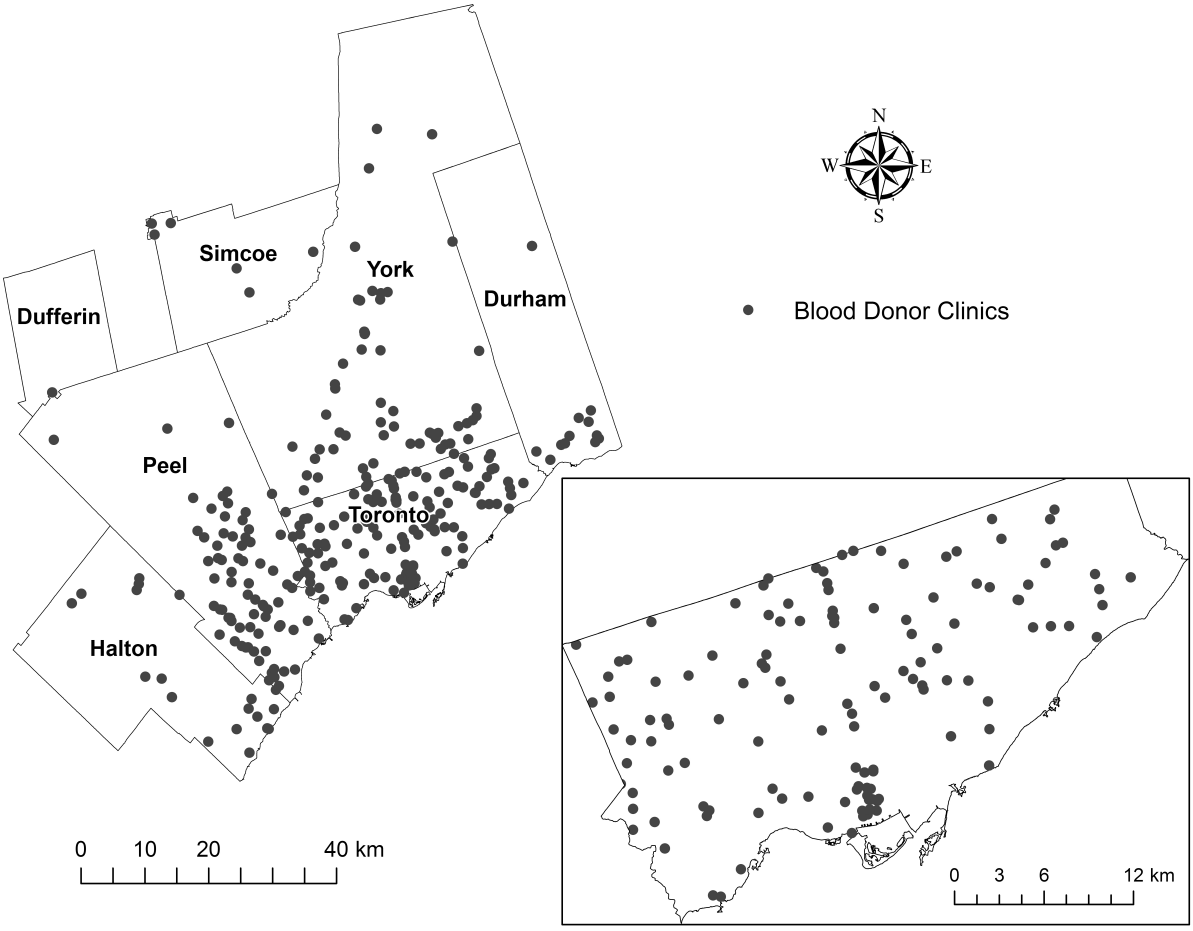

Figure 2. Location of blood clinics in Toronto CMA.

The second source of information was geo-demographic data obtained from the 2006 Canadian Census at the level of dissemination area (DA). Census data provides contextual information that describes the composition of the DA in which donors reside. Average after-tax household income (in $100,000) and unemployment rate are indicators of the economic environment.

Demographic indicators include average number of children per family, and the proportion of a DA population that has a bachelor's degree or higher, works in a health related occupation, speaks English only, or is single. Further, the presence of immigrants

is represented by the proportion of residents whose place of origin is from the United States, Central America, Caribbean, South America, Western Europe, Eastern Europe, Southern Europe, Northern Europe, Africa, West Central Asia and the Middle East, Eastern Asia, Southeast Asia, Southern Asia, Oceania, or are non-permanent residents. For analysis, these contextual variables were integrated with the donor dataset at the individual level.

In addition to variables obtained directly from the two main sources described above, a measure of clinic accessibility was calculated based on the information available from the clinic records and population data. Accessibility in this analysis is implemented by means of the floating catchment areas discussed by Radke and Mu (2000) and Wang and Luo (2005), and used in the analysis of blood donor turnout rates by Saberton et al. (2009). This variable is created in two steps by calculating first the level of service of each clinic relative to the population it serves. Level of service (L_i) is obtained by multiplying the number of beds at each clinic (B_i) and the number of hours (T_i) that it is open, divided by the total population in its corresponding service area (i.e. the sum of the population at distance less than or equal to a predefined threshold d_0):

$$L_i = \frac{B_i T_i}{\sum_{j \in d_{ij} \leq d_0} P_j} \quad (1)$$

Population is in this case assigned to the centroid of the DA. In the second step, accessibility (A_j) is calculated as the total level of service available to a population within a comparable catchment area, in other words, the sum of the level of service available within a given distance (d_0):

$$A_j = \sum_{i \in d_{ji} \leq d_0} L_i \tag{2}$$

To implement the accessibility measure it is necessary to select a threshold distance. This can be done as part of the process of model selection, as indicated below.

2.4 Methods

The selected approach to model the frequency of donation from an individual perspective is random utility theory. This is a canonical approach used to investigate factors that affect human behavior and influence individual decision-making. Random utility theory, implemented in the form of discrete choice models, is widely used in economics for market analysis (Wassenaar et al., 2005), transport studies to determine travel preferences (McFadden, 1974), and health studies to investigate patient preferences for treatment (Scott, 2002). Discrete choice models are appropriate for our analysis because they allow the investigation of individual donor behavior, that is, the decision to donate 1, 2, 3 or 4 times in a 168-day period. This allows the researcher to study the correlates of blood donation looking at *frequency* of donations in a given time period, rather than an overall donation rate. Recent studies also incorporate spatial analysis techniques, where demographic characteristics of blood donors are analyzed using geocoded data to identify spatial patterns in relation to accessibility (Hollingsworth and Wildman, 2004; Saberton et al., 2009). This approach is also utilized in the current study.

Discrete choice models operate based on the principle that individuals select one of *J* discrete and mutually exclusive alternatives, by selecting the alternative that gives them the highest utility (Train, 2003). The utility *U* of decision maker *i* is typically defined by means of a linear-in-parameters function, such as:

$$U_i = \sum_k x_{ik}\beta_k + \varepsilon_i \tag{3}$$

where x_{ik} are explicative variables, and β_k are estimable coefficients. The function incorporates a random utility term $\mathcal{E}_i$, meant to capture idiosyncratic variations in the decision-making process, non-systematic unobserved factors, etc.

In an ordinal process, such as the decision to donate with more frequency, the decision-maker is assumed to select alternative *j* if the value of the utility is in the range λ_{j-1} and λ_j. The threshold values λ are estimable from the data, and for estimation purposes, the following values are set: $\lambda_0 = -\infty$, $\lambda_1 = 0$, (for identification), and $\lambda_J = \infty$. Thus, if the value of the utility is between $-\infty$ and 0, the decision maker selects alternative *j*=1, if between 0 and λ_{12} alternative *j*=2, and so on. Depending on the assumed distribution for the random terms, different models can be derived. If the terms $\mathcal{E}_i$ are assumed to follow the standard normal distribution, the model is the ordinal probit.

The dependent variable, donation frequency in 2008 (if number of donations > 0) during a 168-day period, was separated into 4 classes (since the maximum donation frequency in this dataset is four), creating an ordinal structure. The alternatives are thus the decisions to donate once, twice, three, or four times. Positive coefficients are indicative of a tendency towards a higher frequency of donation, whereas negative coefficients reduce the probability of donating more frequently. A specification search was conducted using a backwards-stepwise approach, beginning with a general model that was reduced to the final model by sequentially removing the least significant independent variable from the full set of variables. At each step, the model was re-estimated to evaluate changes in relationships and/or significance of variables. The

criterion for inclusion in the final model was significance at $p \leq 0.05$. Finally, as noted above, calculating the accessibility measure necessitates the definition of a threshold distance. In order to select a threshold distance, the analysis was repeated for different distances ranging from 1 to 10 kilometers. The model reported below corresponds to the best fit.

2.5 Results and Discussion

The results of the analysis are shown in Table 2. In terms of the individual factors affecting the utility of donation frequency, the coefficient for gender is positively correlated with the frequency of donation, indicating that males are more likely to donate more often in the period examined than females. Also, an older donor is more likely to make multiple donations compared to a younger person. This trend for age holds until approximately age 69 when the utility (and thus the probability) of donating more frequently starts to decline with increasing age as indicated by the negative coefficient for age-squared. This suggests that past a certain age, even if they remain active as donors, individuals may be less willing to donate with a high frequency. This effect of age is not to be mistaken with the results of previous work, which found that the number of donors per population decreases with age (Saberton et al., 2009). The current study shows that even though younger people may be likely to donate once, they are less likely to return multiple times in a year, whereas older donors give blood with a higher frequency.

Previous experience as a donor is also a significant determinant of donation frequency. Being a first-time donor is found to be associated with a negative and relatively large coefficient, which decreases the probability of donating more frequently. A possible explanation for this relationship is that first-time donors have not become

habituated with blood donation, as increased donor return has been associated with a higher number of previous donations (Schreiber et al., 2005). In addition, negative experiences may discourage first-time donors from returning (Zou et al., 2008). Research has shown that occasional donors (less than four previous donations) are less likely to return if they have viewed others fainting or have experienced negative symptoms while donating (Ferguson and Bibby, 2002). Although first-time donors were not isolated in this study on occasional donors, these negative experiences could also be affecting the frequency of donation among first-time donors.

Table 2: Ordered probit model results

Variable	**Coefficient**	**P-Value**
Constant	-0.5165	0.0000
Individual		
Gender (male)	0.2355	0.0000
Age	0.4068	0.0000
Age²	-0.0293	0.0000
First Time Donor	-0.4224	0.0000
January	Reference	
February	-0.1586	0.0000
March	-0.7287	0.0000
April	-0.7535	0.0000
May	-0.8288	0.0000
June	-0.7811	0.0000
July	-0.8895	0.0000
Contextual		
Education	-0.1392	0.0007
Health Occupation	-0.3672	0.0450
Average Number of Children	-0.0628	0.0037
Single	0.3463	0.0001
Non-immigrant	Reference	
Caribbean	-0.6788	0.0015
Southern Europe	-0.2149	0.0245
East Asia	-0.3456	0.0000
Southern Asia	-0.3675	0.0000
Accessibility		
Accessibility to clinics at 5 km	0.0431	0.0000
Threshold Values (λ_1=0 for identification)		
λ_2	1.0474	0.0000
λ_3	2.6270	0.0000

Donors giving blood for the first time in 2008 in the spring/summer months, whether they are first-time or repeat donors, are less likely to make subsequent donations compared to those donating in the winter months. This is shown by the increasingly negative coefficients for March-July. This may be due to donors leaving on vacation and a loss of the positive effect of blood drives during summer break. CBS currently publishes online articles in the summer, reminding Canadians about the importance of giving blood when donation rates regularly drop, but increased awareness is needed to compensate for the lower frequency of donation during this time.

In terms of the contextual variables, donors living in DAs with a high proportion of the population that have a higher average number of children at home are less likely to donate multiple times in a year. A social context where children are present can be reflective of life stage, and associated with a busy schedule and different priorities. The opposite is true for donors living in DAs with a high proportion of the population that is single, with a positive correlation to donation frequency. Donors living in DAs with a high proportion of the population that is highly educated are also less likely to donate more frequently, again, possibly as a reflection of an individual's own socio-economic status and time constraints of a demanding lifestyle.

With respect to immigration profiles, non-immigrants were used as a reference, and thus the results show that donors living in DAs with a high proportion of any of the significant immigrant groups are negatively correlated with blood donation. As a contextual variable, this may signify the existence of cultural influences toward blood donation that are not accounted for in the remaining socio-economic determinants. It is possible that populations not originating in Canada have had negative experiences with

donation in their home countries, or do not feel a sense of belonging and integration that would encourage them to donate. Research shows that Asian and European populations share similar views towards pro-social behavior that may also affect their propensity to donate blood (Alden and Cheung, 2000). Asian and European Americans, for example, express strong feelings toward maintaining body integrity, which corresponds to lower organ donation rates among these ethnicities in the United States (Alden and Cheung, 2000). Distrust in health care professionals in Barbados is also a known barrier to organ donation in the Caribbean and among the Caribbean population living in the UK (Morgan et al., 2010), which may also be affecting their views on blood donation in Canada. Targeted advertising and education geared towards these immigrant groups may reassure these populations that it is safe to donate blood in Canada and their contributions are valued and appreciated.

Interestingly, accessibility is a significant and positive determinant of the frequency of blood donation, with the optimal distance band defined as 5 km. This indicates that individuals are more likely to make multiple donations as their accessibility to clinics within this band increases. This is an important variable because it provides a critical policy handle for CBS to assess the impact of level of service and accessibility on the return behavior of donors. In Toronto CMA, higher accessibility is centered in the core where many clinics exist and donors experience a higher level of service as shown in Figure 3.

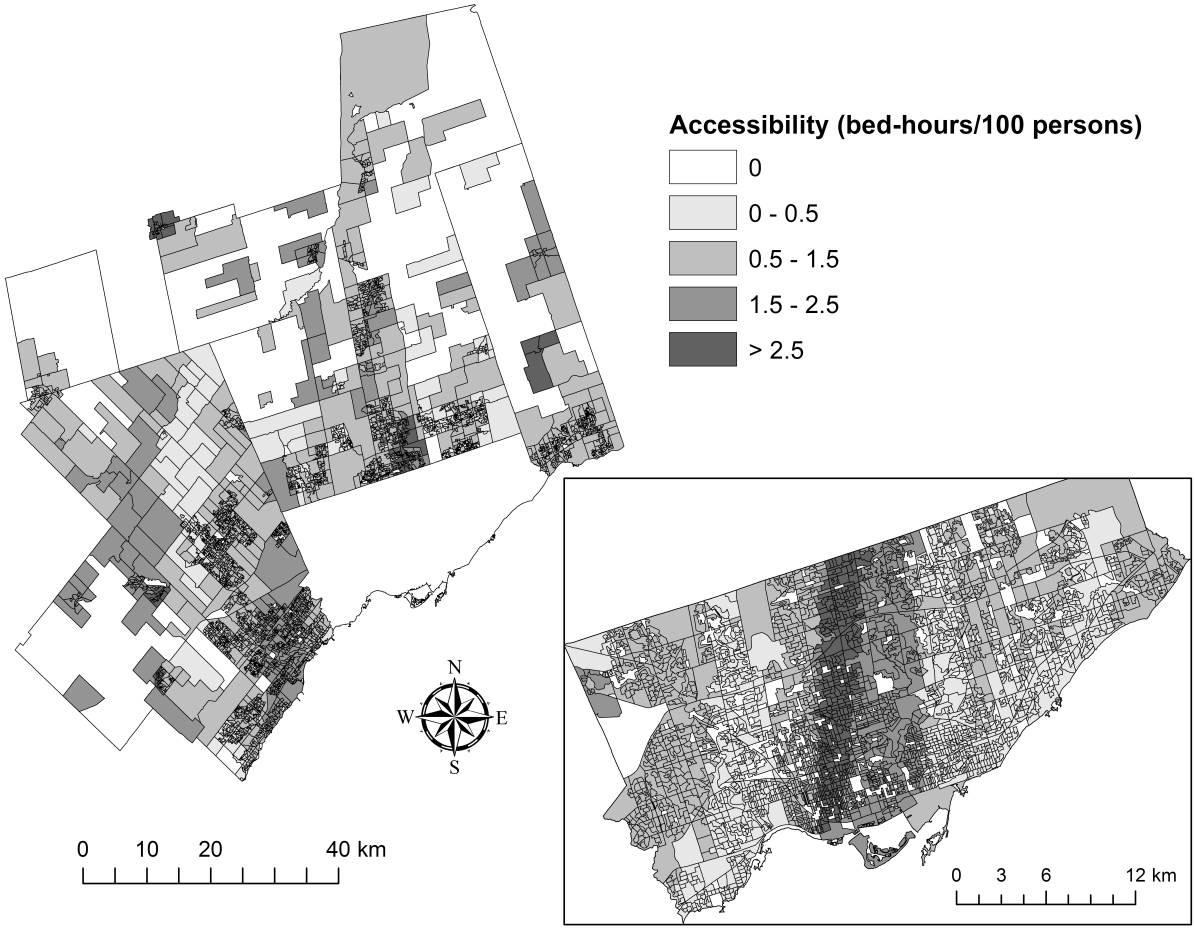

Figure 3. Clinic accessibility in Toronto CMA by DA (bed-hours/person)

In addition to providing insights regarding the determinants of donation frequency, the model can be used to estimate the probability of a donor giving blood with a certain frequency during a 168-day period. Figure 4 shows the estimated probabilities of donation for different ages, using the mean values of other variables as per Table 1 (e.g. accessibility is 1.05), and an index donation in February 2008. Figure 4A displays that there is a high propensity (40-60%) of young first-time donors giving blood once in 2008, compared to a 35% chance of older first-time donors doing so. In terms of multiple

donations, the probabilities that younger first-time donors will give blood two, three, or four times are low, at roughly 18%, 20%, and 1%. On the other hand, there is not as much of a discrepancy between one-time versus multiple donations among first-time older individuals, who have probabilities of 28%, 30%, and 5% for donating two, three, or four times respectively. At this stage in the donor career, donors of all ages may not yet identify with the sense of duty and pride of being a blood donor to the point where it becomes habitual (Schreiber et al., 2005), thus resulting in a relatively lower chance of first-timers making multiple donations.

In contrast, Figure 4B shows that the effect of age is not as dramatic for younger donors who have a previous donation history, where the probability of donating one, two, three, or four times is approximately 38%, 32%, 28% and 3%. The chance that donors give blood only once after doing so in previous years is consistently lower compared to first-time donors. This highlights the importance of encouraging new younger donors to return following their initial donation. The oldest group of donors is still least likely to donate only one time. The probability of an older donor donating one, two, three, or four times after having donation experience in previous years is approximately 25%, 18%, 48% and 12%. It is clear that individuals with a previous donation history are more likely to donate with a higher frequency than first-time donors, which places emphasis on the importance of encouraging donation soon after the first visit in order to increase frequency of donation.

We can also assess the effect of accessibility on the probability of donation frequency. This is shown in Figure 5, where the estimated probabilities are calculated using the mean values of other variables as per Table 1 (e.g. age is 41.01 years), and an

index donation in February 2008. As seen in Figure 5A, there is a relatively steady probability of individuals donating once or multiple times among first-time donors, regardless of the level of service they are experiencing from nearby clinics. The probability that a first-time donor will give blood only once with lower access to clinics is about 38%, while the probability of donating two, three, or four times is 32%, 28%, and 3% respectively. As accessibility rises, the probability of first-time donors giving blood at a given frequency change to 33%, 30%, 33%, 7% for donating one, two, three, or four times. This suggests that the effect of accessibility in the donation frequency of first-time donors is relatively small.

Greater differences are seen in Figure 5B, which displays the effect of accessibility regarding donors with a previous donation history. Here, there is a steady decline in the probability that return donors will make only one donation with higher access to clinics. There is an increasing chance that these donors will give blood two or more times as clinic accessibility improves. The probability that donors with previous experience will return one, two, three, or four times with lower access to clinics is approximately 28%, 33%, 32% and 7%, but with higher access there is a greater chance of donating more frequently at about 22%, 18%, 48%, 13%.

The results indicate that access to clinics is more important for existing donors who are deciding how often to donate blood compared with first-time donors. For the latter, other factors may be more influential in the decision making process of first-timers, such as fear of needles, uncertainty about the blood system, or lost time, rather than proximity to clinics and availability of services. Therefore, improvements to clinic accessibility may significantly enhance donation frequency among existing donors, while

other factors may likely affecting the retention of first-time donors. Nonetheless, we suggest that the effect of accessibility may still be of interest, given that donation history in the months after the initial donation are critical for determining the potential for a longer-term commitment to giving blood. Even small gains in retention, coupled with greater donation rates of return donors, can make an important difference.

2.6 Conclusion

In order to ensure a more secure and safe blood supply it is important to understand the factors affecting a person's decision to give blood. In this study, we used discrete choice modeling to analyze the decision of blood donors to donate with a certain frequency in a set period of time. In addition to individual attributes that have been investigated in the past, in this research we emphasize the importance of geographical factors, including accessibility to clinics and the role of social contextual factors. The results indicate that accessibility exerts a positive influence in the decision to donate more frequently, and thus provides a valuable control in the planning and delivery of services. Variations in accessibility could be examined in future research to assess whether changes in the resources allocated to clinics, or their location, could lead to greater collection rates. In the context of donation experience, it seems that accessibility may also play a role in the retention of first-time donors, since increases in the probability of returning in a relatively short period of time can help to establish long-term donation patterns (Schreiber et al., 2005; Yu et al., 2007).

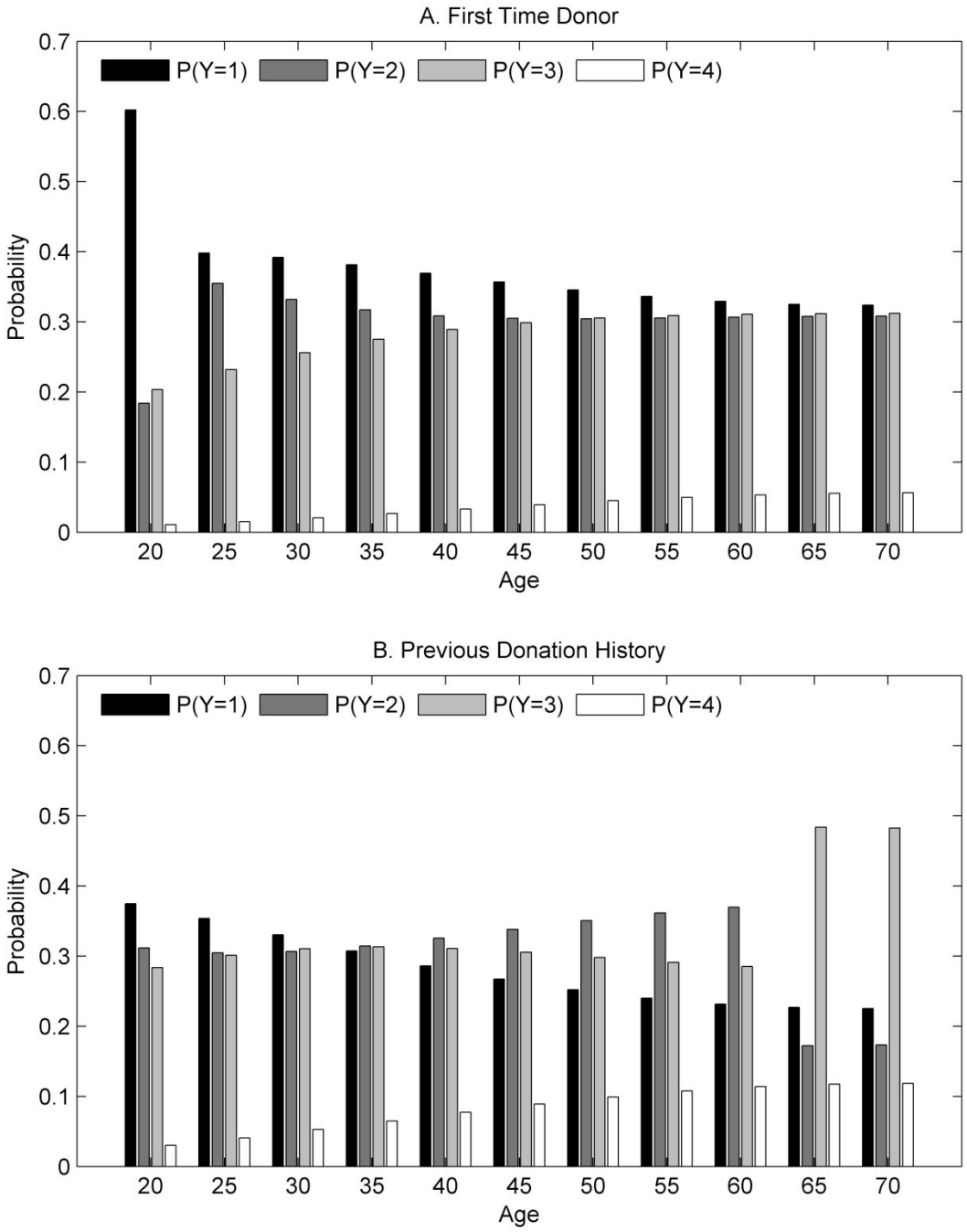

Figure 4. Estimated probabilities of donating Y=1, 2, 3, or 4 times during 168-day period, by age of donor and donation history (**A.** first time ever donating or **B.** previous donation history).

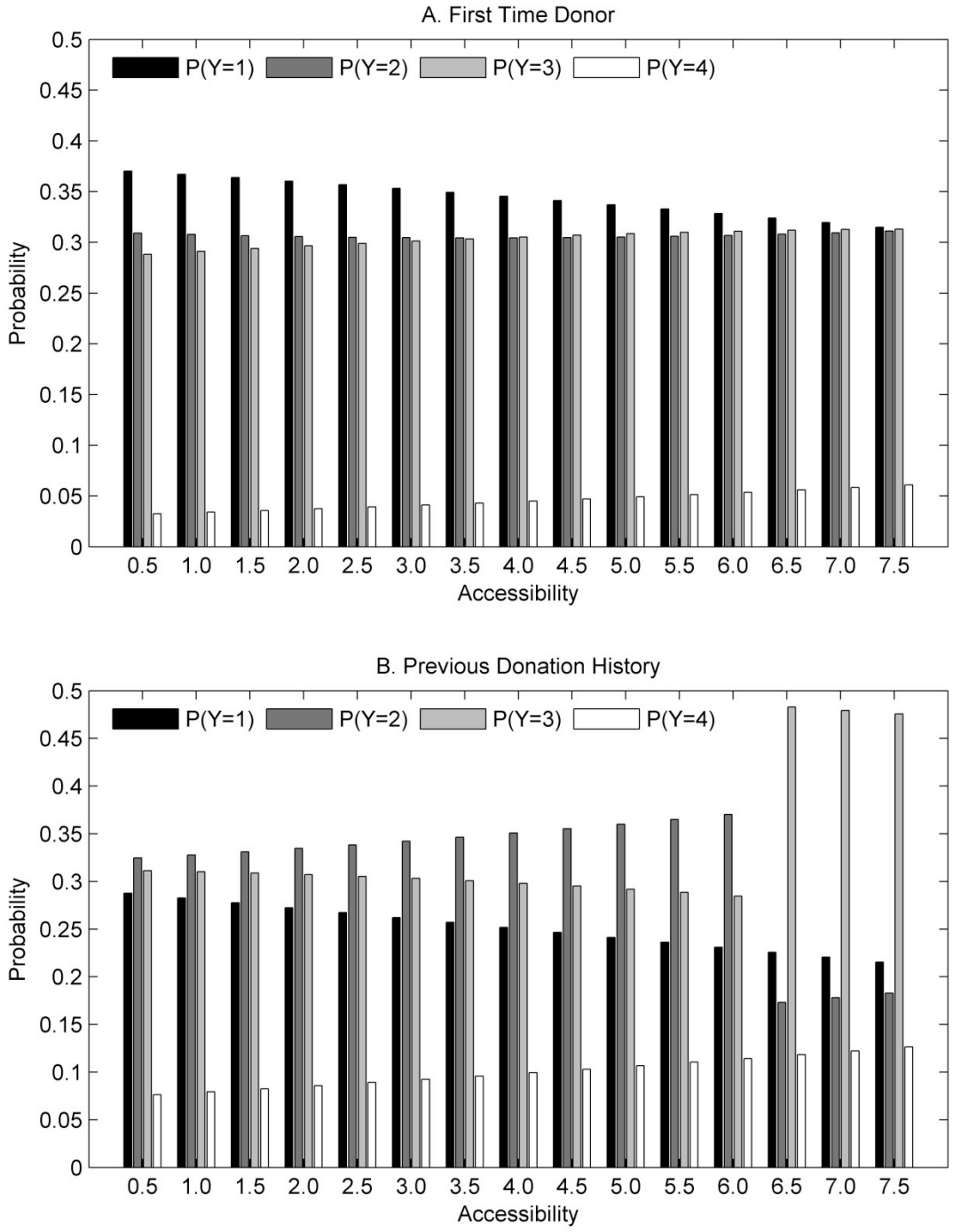

Figure 5. Estimated probabilities of donating Y=1, 2, 3, or 4 times during 168-day period, by level of accessibility and donation history (**A.** first time ever donating or **B.** previous donation history).

Contextual factors are also found to influence donor behavior, including the proportion of immigrants from different origins, the presence of highly educated people, or single population in a given dissemination area. When interpreting these findings, one must not adjudicate the result of an area variable to the individual. Our interpretation, instead, is that area variables of a social nature may be reflective of the tendency of individuals to reside in close proximity to others like them (i.e. homophily), or the existence of social effects (e.g. cultural norms or social influence) that are captured to some extent by area attributes. The analysis is naturally limited by the level of resolution of the variables available, and at this point we can only speculate about the possible mechanisms of operation of such effects. This, however, points to some important data needs, including the collection of additional demographic information from each donor in the pre- donation questionnaire, as implemented by Guo et al. (2011). This would enable a truly individual-level analysis of the various social dimensions discussed. Qualitative research could also be used to further delve into some of the social contextual effects detected by statistical analysis. Other possibilities for further research are as follows. Our analysis has been concerned with a relatively short period of time of 168 day (approximately five months). Extending the time frame based on multiple year data could be extended in a multi-year analysis. While this would shift the focus away from short-term returning donors, it would be possible to capture repeat donors with even lower frequencies. Future work may apply these methods to various cities of interest to form a national comparison. A countrywide study would enhance the recruitment process by providing region-specific knowledge to design and implement appropriate strategies to encourage donors to return. In addition, the donor groups identified as less frequent

contributors, for example, first-time donors may be reminded of the growing importance of their role in maintaining the safety and security of Canada's blood supply.

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CHAPTER 3: An exploration of the correlates on the frequency of blood donation in Canada

3.1 Abstract

A national assessment of blood donor correlates is presented by investigating the effects of demographic determinants and clinic accessibility on the frequency of blood donation in Canada excluding the province of Québec. The stability of Canada's blood supply is influenced by a variety of factors including donor age, gender, and place of origin. Further exploration of these demographic factors in addition to clinic accessibility may help to explain why a limited number of repeat donors are currently contributing, with many donors giving blood only once a year. Blood products are used for transfusion in many routine procedures as well as emergency medical care, and repeat donors are vital to maintain a safe and secure blood supply. Individual donor and clinic information is obtained from the Canadian Blood Services 2008 national dataset, with contextual data from the 2006 Canadian Census. Discrete choice models are used to assess the effects of these variables on frequency of blood donation across selected Census Metropolitan Areas, highlighting the importance of clinic accessibility. Results may contribute to service optimization and targeted advertising, ultimately aiming to encourage the eligible population to donate.

3.2 Background

Just as it can be beneficial for a business to expend resources retaining existing customers rather than continually acquiring new clientele (Berry, 2002), returning blood donors provide a similar positive effect. In addition to requiring less funding for recruitment strategies compared to new donors, repeat donors bring a lower risk of

infectious disease, providing a safer and more secure blood supply (Schreiber et al., 2005). The sobering fact is that a small number of volunteers – only about 3% of the eligible population – donate blood in Canada (Talbot and Mumford, 1999), and of those that donated in 2008, only 53% of them are repeat donors that contributed 78% of total blood units that year (obtained from Canadian Blood Services 2008 dataset). While an influx of first-time donors is helpful to meet short-term demand requirements for blood products, there is a need to retain existing donors and promote frequent donation to ensure supply security in the long term.

Securing a dependable donor base is especially important as Canada's blood supply is facing several challenges including greater demand for blood products due to advances in medical technology, and a shrinking donor pool due to population aging and increased immigration. Another notable issue includes the loss of confidence in the blood system by the Canadian public more than 20 years ago, which was detrimental to blood donorship. This occurred when contaminated blood entered the system, an event that initiated the creation of Canadian Blood Services (CBS) and Héma-Québec. These not-for-profit organizations have been in charge of collecting, testing and distributing blood products ever since. CBS has developed an image of safe practices, and research has focused on enhancing transfusion safety (Callum et al., 2001; Chiavetta et al., 2003; Dzik et al., 2003). Donor turnout has made a gradual improvement, but more donations are required to ensure that the necessary products are available while Canada faces threats to supply levels. This presents a challenge to reinforce public confidence in the blood system across the country while also counteracting the demographic obstacles that will only become more severe given the population structure of the nation.

An increase in the number of repeat donors would enhance the safety of the blood supply, and encouraging more frequent donations would help to maintain adequate supply levels when blood is needed. Potential gains from increased frequency of donation can be significant and the effects of retaining donors are long lasting. For example, this potential was recognized in England where the permitted frequency of donation was recently increased to 4 times a year for males, bringing an expected 100 000 more units of blood every year (NHS Blood and Transplant, 2012). Canadians are able to donate roughly 7 times a year (every 56 days), but less than 23% gave blood 5 or more times in 2008, so the improvements to blood collection could be even more significant with increased knowledge of the influences on donation frequency.

The purpose of this paper is to identify the determinants of frequency of blood donation in Canada using discrete choice analysis. Analysis will be completed for ten Census Metropolitan Areas (CMAs) across Canada. The contribution of this paper is to present a new perspective on studying the potential decision to donate at an individual level while providing results on a national scale. Discrete choice models will be used to determine the probability that an individual makes the decision to donate at a given frequency in a year, based on individual attributes and contextual descriptors.

3.2.1 Literature Review

Repeat donors have the potential to provide large gains to the blood supply with a lower investment on recruitment and advertising by blood collection agencies. Research has shown that intent to donate has emerged as a precursor to actual donation (Godin et al., 2007) and an evaluation of individual attributes as well as the conditions of a donor's

surroundings provides a valuable perspective on blood donor behaviour (Veldhuizen et al., 2009).

The factors affecting donor return behaviour have been explored in many regions as donor retention has been identified as a necessity for any successful blood system. The determinants of blood donation are known to include age, gender, ethnicity, and donation history (Carneiro-Proietti et al., 2010; Flegel et al., 2000; Guo et al., 2011; Murphy et al., 2009; Notari et al., 2009; Oswalt, 1977; Ownby et al., 1999; Schreiber et al., 2005; Veldhuizen et al., 2009; Whyte, 1999; Yu et al., 2007), donor attitudes and intentions (e.g. Clowes and Masser, 2012; Shrein et al., 2011; Ferguson and Bibby, 2002; France et al., 2007; Godin et al., 2007), or demographic and attitudinal factors (e.g. Germain et al., 2007; Schlumpf et al., 2008).

It has been shown that donors behave differently depending on their age. Older donors are often linked to higher donation rates (Ownby et al., 1999) and they are more likely to donate frequently (Flegel et al., 2000; Notari et al., 2009; Whyte, 1999). These age differences are significant given the expected increase of seniors in Canada (Statistics Canada, 2010), a group that will drop out of the donor pool and become recipients of blood. Gender is also a source of variability among blood donors as males are more likely to donate as well make multiple donations (Guo et al., 2011; Ownby et al., 1999; Schreiber et al., 2005). On the other hand, female donors are more likely to stop donating during childbearing age and menopause (Germain et al., 2007) as there is likely a change in priorities and health status.

Previous research has shown that long-term donation patterns may be established when donors return soon after making their first donation (Schreiber et al., 2005; Yu et al., 2007) and a shorter time period is desirable in between donations (Ownby et al., 1999; Schlumpf et al., 2008). Another influence on donor return is the geographic component such as convenience of donating blood. Saberton et al. (2009) has shown that clinic accessibility has a significant effect on donor turnout, and Cloutier et al. (2012) demonstrate that the proximity to blood collection facilities influences donation frequency. Inconvenient clinic locations have also been shown to negatively affect donor return especially in the younger population (Schlumpf et al., 2008; Schreiber et al., 2006).

Immigrants play an integral role in Canada, thus is it necessary to consider the effect of ethnicity on the frequency of blood donation. Donor turnout rates have been shown to decrease with an increasing immigrant population (Saberton et al., 2009) and immigrants and less likely to donate compared to non-immigrants (Chliaoutakis et al., 1994; Gillespie and Hillyer, 2002; Ownby et al., 1999; Thomson et al., 1998). This may be occurring for a number of reasons, including negative experiences in the country of origin and a lack of knowledge of the Canadian blood system, although further investigation is needed to confirm these possibilities.

The effect of education on blood donation is less clear as college educated individuals show a positive association with frequent blood donation in the United States (Ownby et al., 1999; Schreiber et al., 2006), but in China, those with middle school or less are more likely to return. This highlights that donors may behave differently due to variations in lifestyle and social structure in different cultures. Household income and

employment should also be considered since there is evidence of a relationship to blood donation. For example, neighbourhoods with a higher average household income correlate positively to donor turnout rates in Canada, although the relationship may become negative in large cities (Saberton et al., 2009). This suggests that perhaps the fault line between large urban centers and smaller, more rural regions has an effect on blood donation. Focusing on employment, greater rates of volunteering have been seen among the employed population (Caro and Bass, 1997) and a higher unemployed population has been shown to negatively influence blood donor turnout (Saberton et al., 2009), maybe because those with a secure income can afford to expend time and resources to give blood.

3.3 Data

In order to explore the effects of demographic and geographic characteristics on the frequency of blood donation, a combination of individual and contextual data was included. Individual attributes were provided by the Canadian Blood Services 2008 national dataset, containing details regarding donor postal code, age, sex, date of each donation in 2008, and a count of total lifetime donations. This dataset also contained clinic information including postal codes, the number of beds at each location, and hours of operation. Donors and clinics were geocoded using the 2006 Postal Code Conversion File for each CMA. The locations of donors and clinics were inspected and corrected using postal code areas defined by the Canadian Census. Ten CMAs were selected for analysis based on population size while attempting to represent many areas of the country. The selected regions were: Toronto, Ontario; Vancouver, British Columbia;

Calgary, Alberta; Edmonton, Alberta; Winnipeg, Manitoba; Hamilton, Ontario; Regina, Saskatchewan; Halifax, Nova Scotia; St. John's, Newfoundland, and St. John, New Brunswick.

First-time donors were identified as individuals that made the same number of lifetime donations as the number of donations made in 2008. After identifying the first-time donors and the repeat donors, an exclusion protocol was created since data available for this study was one calendar year. A temporal restriction ensured that all donors had an equal opportunity to make subsequent donations in 2008. A moving time window was applied to the dataset using the CBS donation wait time of 56 days. This temporal restriction was employed by removing donors who made their last donation in 2008 before February 25 because previous donations cannot be confirmed following the 56 day time period. A 168-day restriction was then applied based on statistical fit of models with shorter and longer periods (56 days x 3 time periods). If the first donation was made after July 16th, those donors were excluded from the analysis because the time window would become limited to less than 168 days with the first possible donation being January 2nd and last donation on December 31st, 2008. The maximum donation frequency in this time window is four. The number of donors and clinics are shown in Table 1 after adjusting the dataset following the aforementioned constraints.

Table 1: Number of donors and clinics in each CMA

Census Metropolitan Area	Number of Donors	Number of Clinics
Toronto	30 054	298
Vancouver	16 288	40
Calgary	13 695	70
Edmonton	12 672	40
Winnipeg	9 587	55
Hamilton	7075	39
Halifax	4 984	57
Regina	4 664	20
St. John's	3 056	31
St. John	1 699	18

Contextual data were extracted from the 2006 Canadian census. This provided details on a number of demographic characteristics at the Dissemination Area (DA) level, and therefore describes the demographics of small blocks (containing 400 to 700 persons) in which donors are geo-located. Variables included in the analysis were selected based on previous research which indicated possible correlations to blood donation, shown in Table 2 A-E. Indicators of the economic environment are described by the average after-tax household income (in $100, 000) and unemployment rate in each DA. The demographic context is considered in each DA by including the average number of children per family, and the proportion that has a bachelor's degree or higher, works in a health related occupation, speaks English only, or is single. The immigrant population is

described as the proportion of residents whose place of origin is from the United States, Central America, Caribbean, South America, Western Europe, Eastern Europe, Southern Europe, Northern Europe, Africa, West Central Asia and the Middle East, Eastern Asia, Southeast Asia, Southern Asia, Oceania, or are non-permanent residents. These variables were integrated with individual donor attributes by matching the DA in which each donor is located with census data for that DA.

As indicated earlier, convenience of donation plays an important role in blood donor behaviour, thus a measure of clinic accessibility was included in the analysis. A two-stage floating catchment area was applied ((Radke and Mu, 2000; Saberton et al., 2009; Wang and Luo, 2005) using clinic records and population data, where a search radius moved around the study area measuring the attributes at each point. In the first stage, the level of service of each clinic was calculated as the search radius centered on each clinic location. Level of service (L_i) was determined by multiplying the number of beds at each clinic (B_i) and the number of hours (T_i) of operation, divided by the total population in its corresponding service area (i.e. the sum of the population at distance less than or equal to a predefined threshold d_0):

$$L_i = \frac{B_i T_i}{\Sigma_{j \in d_{ij} \leq d_0} P_j} \quad (1)$$

Table 2: Variables and Descriptive Statistics

A)	Toronto				Vancouver			
	Min	Max	Mean	Std	Min	Max	Mean	Std
Individual								
Gender (Male)	0.000	1.000			0.000	1.000		
Age	1.700	7.800	4.101	1.413	1.700	8.300	4.206	1.399
Age^2	2.890	60.840	18.814	11.573	2.890	68.890	19.651	11.797
First Time Donor	0.000	1.000			0.000	1.000		
Contextual								
Average Household Income ($100 000)	0.000	5.654	0.787	0.348	0.000	3.642	0.666	0.237
Education	0.000	0.969	0.404	0.178	0.000	0.946	0.374	0.161
Health Occupation	0.000	0.324	0.043	0.033	0.000	0.303	0.054	0.037
Unemployment Rate	0.000	0.500	0.044	0.037	0.000	0.330	3.956	3.643
English Only	0.404	1.000	0.881	0.060	0.474	1.000	0.878	0.063
Average Children	0.000	2.900	1.252	0.317	0.000	2.200	1.115	0.332
Single	0.047	0.778	0.321	0.082	0.064	0.762	0.334	0.096
USA	0.000	0.151	0.009	0.014	0.000	0.191	0.012	0.016
Central America	0.000	0.230	0.004	0.010	0.000	0.165	0.005	0.012
Caribbean	0.000	0.384	0.025	0.034	0.000	0.091	0.003	0.008
South America	0.000	0.316	0.019	0.025	0.000	0.118	0.005	0.011
Western Europe	0.000	0.392	0.013	0.016	0.000	0.146	0.016	0.018
Eastern Europe	0.000	0.609	0.036	0.048	0.000	0.295	0.018	0.023
Southern Europe	0.000	0.524	0.052	0.064	0.000	0.282	0.016	0.025
Northern Europe	0.000	0.265	0.034	0.031	0.000	0.247	0.038	0.032
Africa	0.000	0.307	0.017	0.025	0.000	0.207	0.012	0.021
West Central Asia and Middle East	0.000	0.359	0.024	0.037	0.000	0.452	0.015	0.032
Eastern Asia	0.000	0.785	0.055	0.099	0.000	0.844	0.117	0.139
Southeast Asia	0.000	0.522	0.031	0.042	0.000	0.643	0.042	0.053
Southern Asia	0.000	0.777	0.057	0.089	0.000	0.651	0.039	0.079
Oceana	0.000	0.096	0.002	0.005	0.000	0.229	0.010	0.019
Non-Perm Resident	0.000	0.237	0.012	0.021	0.000	0.396	0.016	0.029
February	0.000	1.000			0.000	1.000		
March	0.000	1.000			0.000	1.000		
April	0.000	1.000			0.000	1.000		
May	0.000	1.000			0.000	1.000		
June	0.000	1.000			0.000	1.000		
July	0.000	1.000			0.000	1.000		
Accessibility	0.195	2.091	1.078	0.393	0.000	2.860	1.690	0.751
Number of Beds	3.000	13.000	5.064	2.108	4.000	9.000	6.228	1.718
Hours of Operation	3.000	7.000	4.920	1.185	5.000	8.000	6.593	0.401
Population	0.000	16360	728.759	729.409	52.000	5881	633.580	325.387

B)	Calgary				Edmonton			
	Min	Max	Mean	Std	Min	Max	Mean	Std
Individual								
Gender (Male)	0.000	1.000			0.000	1.000		
Age	1.700	7.600	4.159	1.299	1.700	7.800	4.114	1.369
Age^2	2.890	57.760	18.987	10.755	2.890	60.840	18.799	11.361
First Time Donor	0.000	1.000			0.000	1.000		
Contextual								
Average Household Income ($100 000)	0.000	4.100	0.828	0.400	0.000	2.911	0.723	0.275
Education	0.000	0.943	0.381	0.169	0.000	0.947	0.293	0.173
Health Occupation	0.000	0.225	0.053	0.033	0.000	0.224	0.062	0.038
Unemployment Rate	0.000	0.200	0.029	0.027	0.000	0.293	0.032	0.031
English Only	0.000	1.000	0.900	0.065	0.000	1.000	0.904	0.066
Average Children	0.000	2.300	1.100	0.312	0.000	3.000	1.100	0.309
Single	0.000	0.750	0.335	0.104	0.000	0.868	0.337	0.107
USA	0.000	0.115	0.010	0.013	0.000	0.089	0.008	0.011
Central America	0.000	0.155	0.004	0.011	0.000	0.148	0.003	0.009
Caribbean	0.000	0.111	0.004	0.009	0.000	0.135	0.004	0.010
South America	0.000	0.148	0.006	0.013	0.000	0.145	0.005	0.010
Western Europe	0.000	0.191	0.013	0.015	0.000	0.158	0.014	0.016
Eastern Europe	0.000	0.183	0.019	0.022	0.000	0.210	0.017	0.020
Southern Europe	0.000	0.193	0.011	0.017	0.000	0.200	0.010	0.019
Northern Europe	0.000	0.175	0.029	0.023	0.000	0.209	0.023	0.021
Africa	0.000	0.193	0.014	0.021	0.000	0.386	0.010	0.021
West Central Asia and Middle East	0.000	0.223	0.010	0.018	0.000	0.196	0.008	0.017
Eastern Asia	0.000	0.770	0.038	0.051	0.000	0.469	0.023	0.037
Southeast Asia	0.000	0.323	0.029	0.039	0.000	0.242	0.024	0.035
Southern Asia	0.000	0.531	0.022	0.046	0.000	0.425	0.016	0.036
Oceana	0.000	0.160	0.003	0.008	0.000	0.109	0.003	0.009
Non-Perm Resident	0.000	0.291	0.010	0.019	0.000	0.471	0.009	0.031
February	0.000	1.000			0.000	1.000		
March	0.000	1.000			0.000	1.000		
April	0.000	1.000			0.000	1.000		
May	0.000	1.000			0.000	1.000		
June	0.000	1.000			0.000	1.000		
July	0.000	1.000			0.000	1.000		
Accessibility	0.000	5.568	2.862	1.805	0.000	43.108	3.055	5.148
Number of Beds	6.000	16.000	9.922	1.873	6.000	15.000	10.079	2.306
Hours of Operation	4.000	11.000	5.657	1.884	3.000	9.000	6.657	2.288
Population	0.000	8264	684.758	615.52	0.000	10798	674.308	601.263

C)	Winnipeg				Hamilton			
	Min	Max	Mean	Std	Min	Max	Mean	Std
Individual								
Gender (Male)	0.000	1.000			0.000	1.000		
Age	1.700	7.800	4.043	1.482	1.700	7.700	1.468	4.168
Age^2	2.890	60.840	18.541	12.057	2.890	59.290	12.085	19.527
First Time Donor	0.000	1.000			0.000	1.000		
Contextual								
Average Household Income ($100 000)	0.000	2.970	0.601	0.223	0.000	2.926	0.252	0.717
Education	0.000	0.930	0.312	0.158	0.000	0.900	0.153	0.292
Health Occupation	0.000	0.299	0.069	0.041	0.000	0.314	0.040	0.061
Unemployment Rate	0.000	0.368	0.031	0.036	0.000	0.357	0.037	0.039
English Only	0.209	1.000	0.869	0.100	0.000	1.000	0.051	0.918
Average Children	0.000	2.700	1.120	0.290	0.000	2.500	0.289	1.150
Single	0.098	0.767	0.325	0.099	0.000	0.673	0.071	0.293
USA	0.000	0.068	0.007	0.011	0.000	0.099	0.013	0.009
Central America	0.000	0.097	0.004	0.010	0.000	0.123	0.009	0.003
Caribbean	0.000	0.109	0.005	0.011	0.000	0.167	0.014	0.007
South America	0.000	0.230	0.009	0.019	0.000	0.121	0.011	0.005
Western Europe	0.000	0.099	0.013	0.016	0.000	0.159	0.022	0.020
Eastern Europe	0.000	0.191	0.020	0.027	0.000	0.200	0.027	0.025
Southern Europe	0.000	0.292	0.015	0.025	0.000	0.416	0.057	0.047
Northern Europe	0.000	0.129	0.018	0.019	0.000	0.227	0.034	0.049
Africa	0.000	0.431	0.007	0.019	0.000	0.267	0.015	0.007
West Central Asia and Middle East	0.000	0.220	0.004	0.013	0.000	0.303	0.024	0.011
Eastern Asia	0.000	0.441	0.009	0.023	0.000	0.328	0.021	0.011
Southeast Asia	0.000	0.458	0.030	0.062	0.000	0.252	0.021	0.009
Southern Asia	0.000	0.225	0.010	0.025	0.000	0.406	0.029	0.014
Oceana	0.000	0.048	0.001	0.004	0.000	0.041	0.004	0.001
Non-Perm Resident	0.000	0.462	0.006	0.020	0.000	0.303	0.018	0.006
February	0.000	1.000			0.000	1.000		
March	0.000	1.000			0.000	1.000		
April	0.000	1.000			0.000	1.000		
May	0.000	1.000			0.000	1.000		
June	0.000	1.000			0.000	1.000		
July	0.000	1.000			0.000	1.000		
Accessibility	0.000	39.403	3.457	2.510	0.000	23.650	2.592	2.904
Number of Beds	4.000	18.000	8.539	3.772	3.000	14.000	4.802	2.117
Hours of Operation	3.000	11.500	5.956	2.143	3.500	10.500	6.217	2.555
Population	0.000	4414	576.290	258.972	0.000	3462	605.827	308.606

D)	Halifax				Regina			
	Min	Max	Mean	Std	Min	Max	Mean	Std
Individual								
Gender (Male)	0.000	1.000			0.000	1.000		
Age	1.700	7.700	4.259	1.348	1.700	7.500	3.890	1.501
Age^2	2.890	59.290	19.960	11.256	2.890	56.250	17.385	11.895
First Time Donor	0.000	1.000			0.000	1.000		
Contextual								
Average Household Income ($100 000)	0.000	1.764	0.597	0.179	0.000	1.406	0.647	0.227
Education	0.000	0.958	0.353	0.181	0.000	0.809	0.322	0.172
Health Occupation	0.000	0.277	0.069	0.041	0.000	0.236	0.064	0.039
Unemployment Rate	0.000	0.212	0.042	0.035	0.000	0.472	0.029	0.036
English Only	0.538	1.000	0.874	0.059	0.613	1.000	0.931	0.049
Average Children	0.000	2.100	1.013	0.266	0.000	2.300	1.115	0.293
Single	0.156	0.803	0.334	0.116	0.118	0.765	0.337	0.099
USA	0.000	0.102	0.008	0.012	0.000	0.064	0.006	0.011
Central America	0.000	0.046	0.000	0.004	0.000	0.115	0.001	0.006
Caribbean	0.000	0.050	0.001	0.005	0.000	0.068	0.002	0.007
South America	0.000	0.036	0.001	0.004	0.000	0.071	0.002	0.008
Western Europe	0.000	0.058	0.006	0.009	0.000	0.054	0.006	0.011
Eastern Europe	0.000	0.094	0.004	0.010	0.000	0.087	0.006	0.012
Southern Europe	0.000	0.102	0.004	0.012	0.000	0.157	0.006	0.013
Northern Europe	0.000	0.160	0.020	0.020	0.000	0.108	0.010	0.015
Africa	0.000	0.254	0.004	0.011	0.000	0.163	0.007	0.018
West Central Asia and Middle East	0.000	0.146	0.008	0.018	0.000	0.105	0.002	0.010
Eastern Asia	0.000	0.254	0.005	0.015	0.000	0.229	0.009	0.018
Southeast Asia	0.000	0.089	0.002	0.007	0.000	0.192	0.009	0.019
Southern Asia	0.000	0.172	0.004	0.013	0.000	0.125	0.006	0.014
Oceana	0.000	0.074	0.001	0.005	0.000	0.044	0.001	0.004
Non-Perm Resident	0.000	0.162	0.005	0.017	0.000	0.274	0.006	0.025
February	0.000	1.000			0.000	1.000		
March	0.000	1.000			0.000	1.000		
April	0.000	1.000			0.000	1.000		
May	0.000	1.000			0.000	1.000		
June	0.000	1.000			0.000	1.000		
July	0.000	1.000			0.000	1.000		
Accessibility	0.000	36.832	2.839	3.365	0.000	5.319	4.798	1.321
Number of Beds	4.000	12.000	6.326	1.351	3.000	12.000	6.101	1.436
Hours of Operation	2.500	8.000	3.977	1.637	2.500	8.000	4.558	1.501
Population	0.000	2863	653.624	319.612	62.000	3475	535.525	251.496

E)	St. John's				St. John			
	Min	Max	Mean	Std	Min	Max	Mean	Std
Individual								
Gender (Male)	0.000	1.000			0.000	1.000		
Age	1.700	7.500	4.139	1.414	1.700	7.200	4.107	1.399
Age^2	2.890	56.250	19.132	11.522	2.890	51.840	18.820	11.424
First Time Donor	0.000	1.000			0.000	1.000		
Contextual								
Average Household Income ($100 000)	0.000	1.801	0.567	0.163	0.000	1.662	0.559	0.196
Education	0.000	0.895	0.290	0.161	0.000	0.703	0.249	0.157
Health Occupation	0.000	0.250	0.073	0.041	0.000	0.256	0.072	0.051
Unemployment Rate	0.000	0.273	0.078	0.051	0.000	0.294	0.060	0.054
English Only	0.610	1.000	0.929	0.047	0.594	0.989	0.833	0.069
Average Children	0.200	1.800	1.102	0.192	0.000	1.900	1.059	0.230
Single	0.125	0.646	0.347	0.075	0.175	0.667	0.302	0.091
USA	0.000	0.095	0.005	0.010	0.000	0.132	0.008	0.013
Central America	0.000	0.026	0.001	0.004	0.000	0.050	0.000	0.003
Caribbean	0.000	0.032	0.001	0.003	0.000	0.024	0.001	0.003
South America	0.000	0.053	0.001	0.006	0.000	0.064	0.001	0.006
Western Europe	0.000	0.074	0.002	0.008	0.000	0.061	0.004	0.009
Eastern Europe	0.000	0.041	0.001	0.004	0.000	0.063	0.002	0.009
Southern Europe	0.000	0.045	0.001	0.005	0.000	0.042	0.003	0.007
Northern Europe	0.000	0.087	0.007	0.013	0.000	0.081	0.013	0.016
Africa	0.000	0.124	0.002	0.007	0.000	0.063	0.001	0.005
West Central Asia and Middle East	0.000	0.040	0.001	0.004	0.000	0.118	0.003	0.015
Eastern Asia	0.000	0.081	0.003	0.010	0.000	0.088	0.003	0.011
Southeast Asia	0.000	0.029	0.001	0.003	0.000	0.094	0.002	0.007
Southern Asia	0.000	0.083	0.003	0.011	0.000	0.054	0.002	0.008
Oceana	0.000	0.020	0.000	0.001	0.000	0.021	0.000	0.002
Non-Perm Resident	0.000	0.284	0.005	0.023	0.000	0.389	0.010	0.038
February	0.000	1.000			0.000	1.000		
March	0.000	1.000			0.000	1.000		
April	0.000	1.000			0.000	1.000		
May	0.000	1.000			0.000	1.000		
June	0.000	1.000			0.000	1.000		
July	0.000	1.000			0.000	1.000		
Accessibility	0.000	38.394	4.346	4.728	0.000	29.530	3.148	4.657
Number of Beds	4.000	9.000	5.103	1.744	2.000	9.000	2.987	1.694
Hours of Operation	2.000	9.000	5.416	1.355	2.500	9.000	5.310	2.606
Population	162.000	1964	571.287	244.785	117.000	1300	512.025	179.101

In the second stage, the search radius surrounded each DA, and a summation of the total level of service available to the population gives the accessibility measure within a given distance (d_0):

$$A_j = \sum_{i \in d_{ji} \leq d_0} L_i \tag{2}$$

The population was assigned to the centroid of each DA. A threshold distance was established as a part of the process of model selection for each city as described below.

3.4 Methods

Random utility theory is useful to investigate the effect of various factors on individual decision-making. Discrete choice models implement random utility theory and these models are most commonly employed in economic and transportation research (Pettersson and Schmöcker, 2010). Used in the context of blood donation, an estimate of the probability donating with a given frequency (1, 2, 3, or 4 times) may be explored. In this case, the ordered probit model is appropriate because it allows the use of an ordered choice set to assess the patterns among variables and allows uneven preferences among the choice set.

In discrete choice models, individuals select one of *J* discrete and mutually exclusive alternatives by selecting the one that provides the highest utility (Train, 2003). The utility *U* of decision maker *i* can be defined as:

$$U_i = \sum_k x_{ik}\beta_k + \varepsilon_i \tag{3}$$

where x_{ik} are explicative variables, and b_k are estimable coefficients. A random utility term $\mathcal{E}_i$, is meant to capture individual variations in the decision-making process that are not easily measured.

The function incorporates a random utility term $\mathcal{E}_i$, meant to capture idiosyncratic variations in the decision-making process, non-systematic unobserved factors, etc.

In an ordinal process, such as the decision to donate with more frequency, the decision-maker is assumed to select alternative *j* if the value of the utility is in the range λ_{j-1} and λ_j. The threshold values λ are estimable from the data, and for estimation purposes, the following values are set: $\lambda_0 = -\infty$, $\lambda_1 = 0$, (for identification), and $\lambda_J = \infty$. Thus, if the value of the utility is between $-\infty$ and 0, the decision maker selects alternative *j*=1, if between 0 and λ_{12} alternative *j*=2, and so on. Depending on the assumed distribution for the random terms, different models can be derived. If the terms $\mathcal{E}_i$ are assumed to follow the standard normal distribution, the model is the ordinal probit.

Donation frequency in 2008 (dependent variable) was separated into 4 classes since the maximum donation frequency in the 168-day period is four. This creates an ordinal structure where the alternatives are defined as the decision to donate once, twice, three, or four times. The results of this model are interpreted by positive coefficients that indicate a tendency towards a higher frequency of donation, and negative coefficients that indicate a reduced probability of frequent donations. A general model was first specified including variables with possible interactions with donation frequency, and the model was reduced using a backwards-stepwise approach. This means that the least significant variables were removed one at a time, and the model was re-estimated to evaluate changes in relationships and/or significance of variables. The final model contains

variables significant at $p \leq 0.05$. In order to determine the optimal threshold distance for the accessibility measure, the analysis was repeated for distances ranging from 1 to 10 kilometers and the best-fit distance was selected for each city based on the reported log-likelihood value.

Discrete choice theory is useful in this case to investigate donor motivation by assessing the probability that an individual will donate with a high frequency. These methods are prevalent in economic research and present valuable information when used in the blood donor context as shown in a previous case study (Cimaroli et al., 2012). This sheds light on donor motivation and investigates the impact of geographical-contextual factors on the frequency of blood donation across the nation. Research exists to study the correlates of blood donation focusing on human behaviour (Ferguson et al., 2007) demographics and geographical influences (Saberton et al., 2009).

3.5 Results and Discussion

The results of the analysis shown in Table 3 A-D display a number of similarities as well as differences across the country. Relationships between independent variables and the frequency of blood donation will be discussed in terms of general patterns nationwide, but direct comparisons between cities are highly complex in this type of model, therefore one must refrain from inferring higher or lower levels of correlation between cities. In other words, variable coefficients may display stronger/weaker relationships with frequency of blood donation within a CMA, but the values of these coefficients are not relatable across regions.

Focusing on individual level variables, sex emerges as a significant predictor of

high frequency of donation, indicating that in all regions, males donate more often than females. This is corroborated by previous literature which highlights that females are more likely to drop out of the donor pool during child bearing age and are more likely to be deferred due to low iron levels (Shaz et al., 2010). In addition, differences in behaviour and beliefs of men and women may affect their propensity to donate blood (Veldhuizen et al., 2011) although this is certainly a complex topic.

Age is positively correlated with a higher frequency of blood donation, and this variable is significant in all cities except Edmonton and Regina. This means that donors are typically more likely to give blood with a high frequency as they get older. Research has shown that a large number of young individuals may donate one time, perhaps due to peer pressure in school or among friends (Hupfer et al., 2005) but do not return as often as older donors. Godin et al. (2007) demonstrated that people that donated in the past have a stronger intention to donate in the near future, although donor intentions become weaker as time passes after the last donation. This is an important consideration especially for young donors because perhaps they are more apt to incorporate blood donation into their lifestyle if they are encouraged to donate soon after the first visit to a blood clinic.

Focusing on first-timers, individuals are less likely to give blood frequently if they made a donation for the first time in 2008, and this is true in all cities where this variable is significant (all except St. John).

Table 3: Ordered Probit Model Results

A)	Toronto		Vancouver		Calgary	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Constant	-0.5165	0.0000	-0.0358	0.4100	0.5684	0.0000
Individual						
Gender (male)	0.2355	0.0000	0.2504	0.0000	0.1622	0.0000
Age	0.4068	0.0000	0.1444	0.0000	0.1328	0.0000
Age^2	-0.0293	0.0000				
First Time Donor	-0.4224	0.0000	-0.4393	0.0000	-0.3497	0.0000
January	(Reference)		(Reference)		(Reference)	
February	-0.1586	0.0000	-0.0688	0.0037	-0.1612	0.0000
March	-0.7287	0.0000	-0.6435	0.0000	-1.0075	0.0000
April	-0.7535	0.0000	-0.7147	0.0000	-1.0747	0.0000
May	-0.8288	0.0000	-0.8062	0.0000	-1.1508	0.0000
June	-0.7811	0.0000	-0.7282	0.0000	-1.0674	0.0000
July	-0.8895	0.0000	-0.8268	0.0000	-1.2917	0.0000
Contextual						
Avg HH Inc ($100 000)			-0.1056	0.0042	0.0742	0.0036
Education			-2.844	0.0000		
Health Occupation						
Unemployment Rate						
English Only			0.4109	0.0060		
Avg No. Children	-0.0628	0.0037			-0.0952	0.0046
Single	0.3463	0.0001			0.2678	0.0094
Non-immigrant	(Reference)		(Reference)		(Reference)	
USA					-1.3211	0.0413
Central America						
Caribbean	-0.6788	0.0015	2.7980	0.0067		
South America						
Western Europe						
Eastern Europe			-0.7974	0.0146		
South Europe	-0.2149	0.0245				
Northern Europe						
Africa						
WCAME						
East Asia	-0.3456	0.0000	-0.1734	0.0075	-0.5304	0.0032
Southeast Asia					0.4847	0.0302
Southern Asia	-0.3675	0.0000	-0.5686	0.0000		
Oceana						
Non-Perm Resident						
Accessibility	5km		3km		8km	
Accessibility to Clinics	0.0431	0.0000	0.0036	0.026	0.0115	0.0026
Threshold Values (λ_1=0 for identification)						
λ_1	1.0474	0.0000	1.0116	0.0000	1.2064	0.0000
λ_2	2.6270	0.0000	2.2661	0.0000	2.8809	0.0000

B)	Edmonton		Winnipeg		Hamilton	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Constant	0.8582	0.0000	0.1982	0.0318	-0.1464	0.1748
Individual						
Gender (male)	0.1705	0.0000	0.2297	0.0000	0.2474	0.0000
Age	0.0569	0.1117	0.3795	0.0000	0.4188	0.0000
Age^2	0.008	0.0751	-0.023	0.0001	-0.0273	0.0000
First Time Donor	-0.3178	0.0000	-0.3572	0.0000	-0.3157	0.0000
January	(Reference)		(Reference)		(Reference)	
February	-0.2118	0.0000	-0.1714	0.0000	-0.2204	0.0000
March	-1.0543	0.0000	-1.1364	0.0000	-1.0298	0.0000
April	-1.2402	0.0000	-1.2116	0.0000	-1.1813	0.0000
May	-1.3338	0.0000	-1.2249	0.0000	-1.1712	0.0000
June	-1.155	0.0000	-1.2365	0.0000	-1.2563	0.0000
July	-1.291	0.0000	-1.1631	0.0000	-1.2663	0.0000
Contextual						
Avg HH Inc ($100 000)	-0.0715	0.0376	-0.2074	0.0001		
Education						
Health Occupation	-0.6158	0.0146				
Unemployment Rate						
English Only						
Avg No. Children						
Single					0.6413	0.0023
Non-immigrant	(Reference)		(Reference)		(Reference)	
USA						
Central America					-3.0079	0.0212
Caribbean						
South America						
Western Europe	1.3067	0.0214				
Eastern Europe					-1.0881	0.0175
South Europe	1.2068	0.0118				
Northern Europe					1.3898	0.0005
Africa						
WCAME						
East Asia						
Southeast Asia						
Southern Asia	0.7619	0.0036				
Oceana					-5.4056	0.0443
Non-Perm Resident					-1.3557	0.0471
Accessibility	5km		3km		9km	
Accessibility to Clinics	0.0029	0.1222	-0.0059	0.0331	0.0163	0.0312
Threshold Values (λ_1=0 for identification)						
λ_1	1.2333	0.0000	1.2595	0.0000	1.2036	0.0000
λ_2	2.9311	0.0000	2.7829	0.0000	2.8008	0.0000

C)	Halifax		Regina	
	Coefficient	P-value	Coefficient	P-value
Constant	-0.6428	0.0001	1.0779	0.0000
Individual				
Gender (male)	0.2029	0.0000	0.1304	0.0000
Age	0.7599	0.0000	0.018	0.3994
Age^2	-0.0677	0.0000	0.0169	0.0256
First Time Donor	-0.2089	0.0000	-0.7471	0.0000
January	(Reference)		(Reference)	
February	-0.3946	0.0000	-0.2883	0.0000
March	-1.0417	0.0000	-0.9082	0.0000
April	-1.0296	0.0000	-1.0801	0.0000
May	-0.9765	0.0000	-0.995	0.0000
June	-1.0142	0.0000	-0.7836	0.0000
July	-1.0838	0.0000	-0.9826	0.0000
Contextual				
Avg HH Inc ($100 000)			-0.1744	0.0063
Education			0.2342	0.0169
Health Occupation				
Unemployment Rate				
English Only				
Avg No. Children	-0.1525	0.0075		
Single				
Non-immigrant	(Reference)		(Reference)	
USA				
Central America			-5.5238	0.0286
Caribbean				
South America			6.748	0.0007
Western Europe				
Eastern Europe				
South Europe				
Northern Europe				
Africa	-2.8922	0.0268		
WCAME				
East Asia	-2.7072	0.0077	-1.8913	0.0213
Southeast Asia				
Southern Asia				
Oceana				
Non-perm Resident				
Accessibility	4km		3km	
Accessibility to Clinics	0.0038	0.1147	-0.0049	0.0226
Threshold Values (λ_1=0 for identification)				
λ_1	1.195	0.0000	1.1717	0.0000
λ_2	2.6597	0.0000	2.7036	0.0000

D)	St. John's		St. John	
	Coefficient	P-value	Coefficient	P-value
Constant	0.3072	0.0552	-0.9771	0.0112
Individual				
Gender (male)	0.1773	0.0000	0.1292	0.0104
Age	0.284	0.0010	0.5311	0.0000
Age^2	-0.0142	0.1000	-0.0426	0.0021
First Time Donor	-0.1021	0.0622		
January	(Reference)		(Reference)	
February	-0.4808	0.0000	-0.2831	0.0009
March	-1.2156	0.0000	-1.2728	0.0000
April	-1.1704	0.0000	-1.1799	0.0000
May	-1.1838	0.0000	-1.3421	0.0000
June	-1.2073	0.0000	-1.1958	0.0000
July	-1.3324	0.0000	-1.4381	0.0000
Contextual				
Avg HH Inc ($100 000)				
Education				
Health Occupation				
Unemployment Rate				
English Only			0.9564	0.0094
Avg No. Children				
Single				
Non-immigrant	(Reference)		(Reference)	
USA				
Central America				
Caribbean				
South America				
Western Europe				
Eastern Europe				
South Europe			-7.4253	0.0279
Northern Europe				
Africa				
WCAME				
East Asia				
Southeast Asia				
Southern Asia				
Oceana				
Non-perm Resident			2.5144	0.0003
Accessibility	3km		9km	
Accessibility to Clinics	0.0026	0.201	0.0205	0.0157
Threshold Values (λ_1=0 for identification)				
λ_1	1.3048	0.0000	1.2716	0.0000
λ_2	2.9312	0.0000	2.947	0.0000

This highlights the importance of improving the first-time donor experience and encouraging these individuals to return. One way to combat this is by increasing reminders as research shows that first-time donors are more likely to return if they receive a phone call reminder (Godin et al., 2011). In order to improve the first-time donation experience, minimize negative reactions may be minimized by training phlebotomists to pay close attention to warning signs. For example, France et al. (2012) demonstrated that discussing fears before drawing blood might help to identify first-timers that are likely to encounter vasovagal reactions. A caveat to consider is that since the current study is limited to data from one year in all provinces except Québec, there is a constraint to the conclusions that can be made on the topic of first-time donors as some individuals may have returned in subsequent years or may have previously donated in Québec.

Moving on to the contextual variables, a number of positive relationships are present in terms of the effects on frequency of blood donation. In Calgary, donors living in a DA with a larger proportion of the population with a high after-tax household income are more likely to donate with a high frequency. A high proportion of highly educated population is positively correlated to frequency of donation in Hamilton. A high population that speaks English only is positively correlated with frequency of donation in St. John and Vancouver. These three variables may be describing the effects of more time and money to spare, a higher education and more generous income often go hand in hand, and those that speak only English in the household may encounter fewer language barriers and possibly a better understanding of literature regarding blood donation. A high proportion of singles is positively correlated to blood donation in Calgary, Hamilton and Toronto, which is expected considering that the single population may in some cases have a more flexible schedule and ability to visit clinics more often.

Variables that show a negative correlation to frequency of blood donation include after-tax household income in Vancouver, Edmonton, Regina, Hamilton, Winnipeg, and St. John's. A highly educated population is negatively correlated to frequency of blood donation in Toronto and Vancouver. Donors in a DA with a high proportion of population working in health occupations display a negative relationship to frequency of blood donation in Edmonton and Toronto. These effects on blood donation may be occurring because as opposed to areas where a positive relationship was seen, a higher income and education may mean that demanding jobs and longer work hours are preventing frequent donation. Donors in a DA with a large proportion of the population with high average number of children are less likely to donate with a high frequency in Calgary, Halifax and Toronto. This relationship may be justified by considering the lifestyle of a typical family with children where the focus is more internal on the family, compared to single/never married individuals that may have more time and drive to be altruistic.

Generally, donors living in a DA with a high proportion of immigrants are less likely to donate with a high frequency compared to non-immigrants. As the proportion of these immigrant groups increases, the probability of donating more frequently decreases. DAs with a high proportion of the population originating from the USA, Caribbean, Africa, Oceana and Non-Permanent Residents are less likely to donate with a high frequency in each of Calgary, Toronto, Halifax, and Hamilton respectively. In addition, negative correlations are seen for donors living in DAs with high populations of Central Americans in Hamilton and Regina, Eastern Europeans in Hamilton and Vancouver, Southern Europeans in Toronto and St. John, Eastern Asians in Toronto, Vancouver, Calgary, Regina, and Halifax, and Southern Asians in Toronto and Vancouver. A high proportion of the population from the USA, South

America, Western Europe, Northern Europe, Africa, Southeast Asia, and Oceana does not significantly impact the frequency of blood donation in all but one CMA, with the significant CMA varying as indicated above. DAs with a high proportion of population from West Central Asia and the Middle East showed that these variables were not significant in all locations.

On the other hand, certain immigrant groups correlate positively to frequency of donation, although this is most often an isolated relationship seen in few CMAs. A high proportion of Western Europeans, Southern Europeans, and South Asians is positively correlated with frequency of blood donation in Edmonton. Donors living in a DA with a large proportion from the Caribbean, South America, Northern Europe, Southeast Asia, and Non-Permanent Residents are positively correlated with a high frequency of donation in one of Vancouver, Calgary, Regina, Hamilton and St. John respectively. Research has shown that overall, minority groups are underrepresented in the blood system due to higher deferral rates because of travel behaviour and infectious disease risk (Shaz et al., 2010). Increasing donation among immigrant groups may be possible by providing information available in a variety of languages so that potential donors may learn about the safety of blood donation and the need for blood in Canada.

Variables that were not significant include average household income in Halifax, St.John's and St. John. Education is not significantly correlated to a high frequency of donation in Calgary, Edmonton, Regina, Winnipeg, Halifax, St Johns and St John. Unemployment rate was not significant across the country; perhaps these effects are better represented by the previous socioeconomic variables. Although one would expect those working in a health related occupation to be more conscious of the need for blood, this variable was not significant in every CMA except Toronto and Edmonton, indicating

that the remaining socioeconomic descriptors such as education and income are more influential. The variable describing the population that speaks English only was not significant in all regions except Vancouver and St. John. DAs with a high average number of children in the family were not significant in Vancouver, Edmonton, Regina, Winnipeg, Hamilton, St John's, and St. John. A high proportion of singles is not significantly correlated to blood donation in Vancouver, Edmonton, Regina, Halifax, Winnipeg, St. John's and St. John.

The coefficients for the month of first donation are generally more negative in the spring and summer months compared to January and February, indicating that individuals giving blood for the first time in the spring are less likely to return that year. Individuals normally donating at school/work blood drives may not be visiting their usual blood clinics, and others may leave on vacation, forgetting about donating. Seasonal differences would be better explained if the timeline of this study extended beyond one year so that each month could be represented in the analysis rather than considering only January to July.

Variations exist in the effect of clinic accessibility across the nation. Increased access to clinics is positively correlated to a high frequency of blood donation in Toronto, Calgary, Hamilton, St. John and Vancouver but there is a negative association in Regina and Winnipeg. This variable was not significant in Edmonton, Halifax and St. John's although the relationship to frequency of donation is still positive. Population size as well as the clinic resources available to the population may influence the differences seen in the effect of access to clinics on the frequency of blood donation. Clinics accessibility has been shown to increasingly affect blood donor turnout in larger population centers (Saberton et al., 2009) perhaps because these clinics serve a larger number of people

which has a positive implication for service planning as improvements to clinic resource allocation have the potential to reach a larger number of people. Additional information regarding how far donors are traveling to reach clinics and their mode of transport would be useful to evaluate this measure in detail. More detailed data would also be valuable to determine whether donors are visiting different locations during the year, for example as the convenience of a clinic during the school year may change when students move off campus for the summer.

3.6 Conclusion

Repeat donors are an essential component to a safe and secure blood supply, and although the arrival of many new donors at promotional events helps to meet short-term demand requirements, long-term gains are achieved by retaining these donors. Factors that influence the frequency of blood donation have been isolated for the major CMAs in Canada, and this information is useful to inform plans for donor recruitment and retention. An important consideration is the incorporation of individual level data with broader scale data at the DA level. This presents a challenge in the interpretation of results because one may wrongly assume that relationships at the DA scale will also apply to the individual. Therefore, careful consideration of results is necessary when relating the attributes of a large group to the individual. To overcome this issue it would be necessary to collect more detailed demographic information from donors at the time of donation, but this may increase the time it takes to donate and entails data privacy issues.

Donor return is influenced by first year donation patterns and access to clinics, as well as their surrounding environment. For this reason, it is of utmost importance to improve the experiences of those donating blood, especially first-timers, by optimizing clinic locations and resources, minimizing negative reactions, lowering wait time, and

increasing donor comfort. Increased communication between blood clinics and donors would ensure that donors understand when they are able to donate as temporary deferral reduces the frequency of donation among first-time and experienced donors (Hillgrove et al., 2011). In a recent report exploring the effect of unremunerated participation in a blood donation study, a higher frequency of donation is seen among donors that were enrolled in the study (Bahrami et al., 2011). This suggests that heightened awareness and involvement may increase donor frequency, also considering possible sampling bias as frequent donors might be more interested in such a study.

Due to the complex nature of the analysis presented here, it is impossible to directly compare the models across space, thus each CMA must be interpreted separately. A dummy variable describing city size could be included to further understand how relationships change across the country, but in previous research this has resulted in the inclusion of many city-specific variables. This is an indicator that the contextual differences between regions are large enough that individual models may be actually be more descriptive without them. Regardless of this limitation, the results of this study provide necessary knowledge to blood centers and medical professionals to improve current services and marketing operations. Future work may capture additional individual-level attributes and incorporate qualitative research to enhance donation frequency modeling. This would allow a better understand of how the correlates of blood donation identified here are shaping the current and future blood supply.

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CHAPTER 4: Conclusion

4.1 Overview

The aim of this project was to outline the factors that affect a donor's decision to give blood with a given frequency, focusing on the attributes of the individual as well as a donor's surroundings. Analysis was performed on ten CMAs across Canada to identify the relationship between frequency of blood donation and a host of explanatory variables. A more thorough understanding of the determinants of blood donation is useful to inform policy makers and medical professionals to aid in the development of effective marketing strategies and service improvements. These improvements would ultimately serve to encourage donors to return regularly, promoting a safe and reliable supply of blood.

4.2 Summary of Major Findings

Chapter 2 presented a case study of the Toronto CMA to demonstrate the utility of discrete choice models in blood donor research focusing on the frequency of donation. The ordered probit model is beneficial in this setting because it allows the exploration of the effects on donation frequency with discrete classes that can be singled out for more detailed analysis as shown in the comparison of variation in donation frequency with age and accessibility. The results highlight a number of factors that influence the frequency of donation in Toronto, including the positive influence of age and sex (male), and negative effect of place of origin, education, and marital status (single). Another important discovery was the influence of clinic accessibility on the decision to donate. Repeat donors may consider the distance to clinics and available clinic resources when deciding how often to donate, as opposed to first-time donors where access to clinics is not a strong contributing factor. A fear of needles and adverse reactions have been identified as common reasons that individuals avoid donating blood (Hupfer et al., 2005), and perhaps

first-time donors have not yet overcome these fears.

Chapter 3 uses the same variables and methods to investigate the effects on frequency of blood donation in ten CMAs, including Toronto. An ordered probit model was estimated for each CMA, and the results identified a number of significant relationships shown to impact the frequency of donation in Canada. In terms of the strength of relationships, there is no clear answer as to which correlates have the strongest impact on frequency of donation, but there are some variables that appear significant in most of the study areas. For example, sex and age are both positively correlated to a high frequency of donation in all ten CMAs, and first-time donors return less often than those with a previous donation experience. Focusing on the effect of the time of year on the number of times donors give blood, the results show that the coefficients for the spring/summer months are consistently more negative than the winter months (January and February), meaning a lower frequency of donation is seen. Perhaps a seasonal effect is described here where donors are enjoying vacation time or traveling, and students are out of school. This means that there are less people at work or on campus where mobile blood drives gain attention.

4.3 Study Limitations

In this study, individual donors were associated with additional demographic information based on the DA in which they are located. This works because it allows researchers to obtain a large amount of information about the study area from the Canadian Census, without spending copious amounts of time collecting survey data. On the other hand, limitations exist when using aggregate data to explore individual donor behaviour. For example, one cannot assume that a donor gives blood with a high frequency if they are Canadian born, because this detailed demographic information is not

available in the CBS 2008 national dataset. Instead, this independent variable describing the proportion of population by place of origin represents a DA of 400 to 700 people. Therefore, it must not be assumed that these contextual conditions are directly tied to the individual, but the associations here are based on the idea that people living close together follow similar behavioral patterns.

Also, the information obtained in this project provides details on the return behaviour of donors, but does not consider the factors affecting non-donors. Therefore, we cannot speculate the reasons people do not donate blood, and are only able to say that existing donors associated with certain characteristics are more/less likely to donate with a higher frequency.

From the current dataset, it is impossible to identify whether the donors are traveling from home, work or school. The addresses provided to CBS are presumably home locations, but trip-based data including the origin and mode of transport are unavailable. This lack of information is a limitation because a more accurate measure of clinic accessibility could be obtained by calculating the distance and time that donors spend traveling to clinics.

4.4 Future Research

As mentioned earlier, considerable limitations arise in the interpretation of results when drawing conclusions about individuals from DA-level data. In the future, donors could complete an optional questionnaire providing additional demographic details as well as describing motivating factors at the time of donation. This could provide a supplement to the current quantitative analysis, confirming or refuting speculations that would allow the improvement of subsequent models. Additional qualitative research

would be a valuable addition to create a well-rounded picture of the factors affecting blood donation across the country.

Extending the time period of the study to include several years of data would eliminate the need for the narrow time constraint that was applied in this study. This would also expand the maximum frequency of donation, and donors could then be separated based on whether they are a first-time donor, new donor (e.g. 2-4 donations), or experienced donor (e.g. more than 4 donations). Another possibility for future research is to further investigate the influence of permanent versus mobile clinics to determine if there is a preference among first-time or repeat donors, perhaps due to convenience. This would highlight possible discrepancies between types of blood clinics, if any, informing advertising efforts with an aim to improve donor return.

4.5 Concluding Remarks

The results of this study provide guidance to CBS to take a number of actions that could improve the frequency of donation. Although CBS currently employs several strategies to increase public awareness in times of need, increased emphasis on the demographic groups outlined in this study could improve the effectiveness of marketing campaigns. Some of the current efforts targeting specific groups include public appeals reminding Canadians to donate in the summer when the supply falls short, and recruitment events employing the help of various businesses, schools, and sports organizations to encourage donation. The findings in this study highlight that younger and inexperienced donors should be targeted promote subsequent donations, and improving the first-time donation experience would be beneficial. Focusing on immigrants, this information may be used to cater marketing resources and send a positive message to

newcomers regarding the importance of donating in Canada. Sharing information and educating the public is key, an approach that has proven to effectively increase blood donation (France et al., 2010) with the appropriate advice to maximize the success of these marketing tools. Additionally, CBS may re-evaluate clinic services to make locations more accessible to existing donors knowing that they may return more frequently.

In an ideal system, all blood donors would be repeat donors with a history of safe blood returning many times a year. This would mean that every unit collected could be used to save lives; minimizing waste; and a constant supply of blood products would arrive to meet demand. Although this sounds like an impossible endeavor, through continuing research we will understand more about the motivators and deterrents to blood donation, coming one step closer to the most safe and secure blood system possible.