HOW GENEROUS ARE WE? FORECASTING AND DEMOGRAPHIC CORRELATES OF BLOOD DONATION

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By

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ABSTRACT

BACKGROUND: Canada's population is rapidly aging. This process of demographic change is expected to increase the demand for health care services in general, and blood products in particular. Relatively little is known about the blood supply and usage trends in a Canadian context, or the Canadian donor pool, which prompts an investigation of the province of Ontario to accomplish two objectives. 1) Produce a supply and demand forecast to the year 2036. 2) Find population-level demographic correlates of blood donorship in the Toronto Census Metropolitan Area.

STUDY DESIGN AND METHODS: A provincial forecast for Ontario was created using the Ministry of Finance Reference Scenario as a basis for population change through 2036. Multiple linear regression analysis of the proportion of donors per Dissemination Area within the Toronto Census Metropolitan Area (CMA) will find possible neighborhood socio-demographic correlates of donation.

RESULTS: Potential shortfalls of supply related to demand are forecasted to occur as soon as 2014. The multiple linear analyses revealed that population-level socio-economic factors and immigrant status appear to be the largest drivers of blood donation rates in the Toronto CMA.

CONCLUSION: Important age and gender differences in blood donation and usage patterns are identified for the province of Ontario, with the forecast highlighting potential shortfalls as soon as 2012. The regression analyses highlight demographic and socioeconomic differences in blood donation patterns, allowing for better informed future research and policy development.

ABBREVIATIONS: CBS = Canadian Blood Services, HQ = Héma-Québec, WB = Whole Blood, RBC = Red Blood Cell, FT = First Time (Donor), CMA = Census Metropolitan Area, DA = Dissemination Area, CT = Census Tract, CIHI = Canadian Institute for Health Information, MTRP = McMaster Transfusion Research Program, DAD = Discharge Abstract Database, NACRS = National Ambulatory Care Reporting System

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CHAPTER ONE: Introduction

1.1 RATIONALE

The maintenance of a safe, consistent, and adequate national blood supply is a priority for any nation. As the age and cultural landscapes of Canada are anticipated to change rapidly and drastically over the next twenty-five years, the demand for blood products will grow in response to a larger population with increased health needs. The low rates of blood donorship typically observed across Canadian society emphasize the importance of adding current and detailed donor demographic studies to the existing body of literature. The eventual goal of such research is to help guide effective policy made by policymakers to increase overall rates of blood donorship in Canada.

1.2 ALTRUISM VS. INCENTIVE

Existing research on blood donor motivation has focused on two non-exclusive categories: Altruism and incentive. Their difference, as defined by Alfred Titmuss[1], is that the former perspective views blood donation as a service, and the latter as a market transaction. Should gratuity-based blood collection prove insufficient for fulfilling Canada's need for blood products, questions arise regarding whether paying donors for blood products would provide the incentive necessary to increase donorship, while maintaining a low risk of unsafe blood donations.

Testing donated blood for blood-borne infection entails a financial cost. Whenever a blood product is screened and discarded due to being unsafe, this cost is unrecoverable. As a result, the most cost-effective approach to blood collection is one in which the initial source of supply has the lowest risk of infection. Titmuss described this in detail at a time when the need for low-risk donors in the blood system was necessary to prevent the contamination of national blood products with serum hepatitis. He explained that by fostering donation from altruistic donors who donate for personal reasons related to performing a task for the sole benefit of others, the system will naturally receive a lower-risk subset of the donor population than would a paid-donor system. Titmuss believed that such paid systems would attract higher-risk donors by exploiting socioeconomically disadvantaged groups within society.

While Titmuss presents a strong ethical argument, studies have shown that paid donors do not necessarily present a greater risk for disease-related deferral than do volunteer donors. As Strauss explains, volunteer donation pools are more likely to contain one-off donors than are paid donation pools, whose monetary incentive to return leads to their becoming repeat donors[2]. It is known that increasing the donation rates of repeat donors who are known continuously provide safe blood products represents the safest way to increase national supplies[3].

Ideally, the safety of national blood supplies should never be compromised in the face of demand. Regardless, when faced with low donorship rates, incentive-based donation has been introduced in parts of the United States. In support of this approach, Eckert explains with regards to donor solicitation that while "some communities may respond better to [altruistic] non-cash solicitation... the opposite may be true elsewhere"[4]. A 2001 study by Sullivan et al. found that 91% of survey-responding clinics in the United States used approved non-cash incentives to foster return donation, and most of these clinics considered their use to be successful[5]. Additional research by Glynn et al.[6] and Sanchez et al.[7] support that these non-cash incentives do not carry the danger of attracting non-safe donors. Additional studies by Glynn et al. in 2003 and 2006 note demographic differences in the appeal of incentives, particularly with regards to gender, age, and ethnicity[8,9].

1.3 RESEARCH OBJECTIVES

This research seeks to complete two main objectives. The first objective is to forecast how Canada's aging population can be expected to affect the donation and transfusion of blood products within Ontario over the next thirty years. By estimating the anticipated sufficiency of the provincial blood supply in the face of increasing overall demand, we can better justify the importance of continued research. To complete this task, donation prevalence within age cohorts will be derived from a 2008 national dataset provided by Canadian Blood Services (CBS). Transfusion prevalence within the same age cohorts will be derived from 2008 provincial data provided by the Canadian Institute for Health Information. The resulting prevalences will be forecasted through to 2036 in relation to projected age cohort populations developed by the Ontario Ministry of Finance.

The second objective is to use the 2008 CBS data to investigate possible population-levle socio-demographic correlates between 2006 Census data and donor prevalence within the Census Metropolitan Area of Toronto. By using Multiple Linear Regression analysis, two segments of the donor pool can be independently observed in relation to the socio-demographic profiles of their neighbourhoods, as defined by their respective Dissemination Areas:

1. Overall Donors: The overall percentage of age-eligible individuals who donated at least once throughout 2008 within a given Dissemination Area.

2. Multiple Donors: The overall percentage of age-eligible individuals who donated more than once throughout 2008 within a given Dissemination Area.

Although it could be misleading to directly infer donor characteristics through population data, this approach has been notably used to provide insight into the environmental correlates of blood donor populations in a Dutch study by Veldhuizen et al.[10], an Australian study by Hollingsworth and Wildman[11], and a prior Canadian study by Saberton et al.[12]. By understanding to what extent different segments of the Canadian population are motivated to donate by traditional CBS recruitment and retention efforts, new policies can be developed to i) increase annual donations from established donor groups, and ii) target underrepresented but growing segments of the population.

1.4 CONTRIBUTIONS

The most valuable contribution of this literature is contemporary information related to the Canadian blood donor population. Conclusions related to possible future supply shortfalls in the face of rising demand serve to raise a flag to researchers and policymakers that drastic changes to the recruitment, motivation, and retention of Canadian blood donors will be necessary in the future.

Forecast studies have surfaced in other countries anticipating blood supply shortages resulting from drastic population shifts within the next century, notably a 2010 study by Ali et al. showing substantial age-driven demand increase for Finland and other developed nations[13], a 2007 study by Greinacher et al. forecasting statewide shortfalls for the Mecklenburg-West Pomerania region of Germany[14], and even national shortfalls forecasted within the United States by Vamvakas and Taswell in 1994[15]. With the CBS estimate that an 8% annual increase in hospital demand will be accompanied by a 4%

annual increase in supply[16], a more detailed national forecast for Canada would contribute greatly to the growing body of literature suggesting that age-driven supply shortages are a looming concern of developed nations.

As previously mentioned, studies exploring areal-level demographic information as a correlate of blood donation rates have previously been undertaken in Australia by Hollingsworth and Wildman in 2004 and in the Netherlands by Veldhuizen et al. in 2009. Within Canada, a 2009 study by Saberton et al. used aggregated Census Tract level data to explore correlates within the Toronto CMA, and our study seeks to confirm and expand Saberton's model at a smaller areal unit scale due to the availability of individual-level data. By preparing a strong DA-scale model for Toronto, future studies can seek to apply it to other major cities in Canada.

1.5 CHAPTER OUTLINE

This thesis consists of four chapters including this introductory chapter. Chapters 2 and 3 are comprised of two separate research papers, and the fourth chapter is a brief conclusion of findings.

Chapter 2 contains a provincial supply and demand forecast for Ontario, created using the Ministry of Finance Reference Scenario as a basis for population change through 2036. Potential supply shortfalls related to demand are forecasted to occur as soon as 2012. This chapter also contains age- and gender-based logistic regression results for Ontario blood donors as derived from the individual-level CBS data.

Chapter 3 contains multiple linear regression analyses of the neighbourhood socio-demographics of 2008 blood donor populations within the Toronto Census Metropolitan Area. While similar neighbourhood factors drive both overall donor rates and multiple donor rates, neighbourhood socio-economic factors and immigrant status appear to be the largest drivers of blood donation rates in each category respectively within the Toronto CMA.

Chapter 4 contains a brief summary of findings and research limitations. The major conclusions of this research are summarized, and future directions that blood donor research in Canada could pursue are recognized.

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CHAPTER TWO: Forecasting Ontario's Blood Supply and Demand into 2036

2.1 INTRODUCTION

In Canada, two organizations are cooperatively responsible for the collection, maintenance, and distribution of blood products. The larger of the two, Canadian Blood Services (CBS), manages donation efforts within all Canadian provinces and territories with the exception of Québec, where Héma-Québec operates with exclusivity. For both agencies, maintaining a safe and adequate blood supply is the highest priority, developing and following strict criteria of who can, and cannot, donate blood. Canadians can begin donating blood at age 17. Barring any deferrals related to health, they will continue to be eligible to donate every 56 days until age 71, at which point they must satisfy certain physician-approved health criteria to continue donating. While this means that approximately 60% of Canadians are considered eligible to donate blood[1], additional deferral criteria bring this proportion into question.

A multitude of age and health-related factors including sexual history, drug use, and recent travel experience may result in deferrals of potentially high-risk individuals, preventing them from donating blood for a specified period of time or indefinitely. Even short-term deferrals, which allow the would-be donor to return at a later date, have been found to reduce the likelihood of return, with Custer et al. finding at one blood center that only 25% of individuals deferred and not recontacted following their first attempt at donation returned to donate within the subsequent five years, as opposed to the overall 47% return rate for non-deferred First Time (FT) donors in the United States[2].

Additional studies regarding estimated eligibility in the United States are imminently applicable to Canada as both countries share similar sets of deferral criteria.

Riley et al. estimated that only 37.8% of the US population was actually eligible to donate blood, and not 60.2% as conventionally stated[3]. In 1998, Linden et al.[4] also found that previous estimates of the size of the eligible donor pool may not be as high as generally thought. Regardless of whether the eligible Canadian population is as reduced as Riley's estimate, it was found in 2005 that following restrictions on age, health and other deferrals, less than 4% of eligible Canadians actively donate blood each year[5].

While essential to maintaining the safety of Canada's blood supply, deferrals impact the size and demography of the donor pool. These additional restrictions are increasingly problematic, as the absolute population of the oldest age cohorts continues to grow due to population aging. The absolute size of these cohorts in turn increases the demand for blood products used in age-related medical procedures. Compounding this demand, these same older cohorts progressively age out of donation eligibility, despite currently having the highest donation frequency compared to other age groups in Canada. As a result, the loss of older donors typically means a loss of frequent repeat donors, a group identified repeatedly in the literature as being vital for a safe and reliable donor pool[6,7,8]. In an attempt to avoid the loss of Canada's most productive blood donors, Canadian Blood Services and Héma-Québec removed their upper age limit on blood donation in Canada in 2004, allowing individuals over the age of 71 to continue donating with a physician's consent[9].

Repeat donors have been identified from our 2008 CBS data as contributing approximately 85% of all blood donations nationwide. In this way, the Canadian blood supply is much more reliant on FT donors than Germany, with 91.1% of donations made by repeat donors[10]. Without motivating the FT donors who provide 15% of the national blood supply to become long-term donors, a sizable portion of the donor pool is potentially lost. Immigrants and visible minorities have been typically found in other western countries to be less likely to donate blood than the general population[11,12,13,14,15,16,17], and first- and second-generation immigrants were already found to comprise 47% of Canadians as of 2008[18]. The proportion and absolute number of this group are expected to continue to grow in the future.

With the combined effects of an aging population with greater health demands, a growing immigrant population underrepresented in the donor pool, and a proportionally large reliance on FT donorship, it is therefore possible that the Canadian blood supply will be stressed in the near future. Indeed, Canadian Blood Services has identified the potential for demand to outpace supply as recently as 2002, with an internal study anticipating an 8% annual increase in demand coupled with a comparatively meager 4% annual increase in supply[19]. These concerns emphasize the need for detailed knowledge regarding the potential future of Canada's blood supply.

Against this backdrop of demographic change, the purpose of this paper is to project the future of blood supply and demand, and contrast the resulting "Business as usual" forecast against several scenarios representing changes in provincial donation patterns. For purposes of data reliability and availability, as discussed below, projections are limited to the province of Ontario.

2.2 MATERIALS AND METHODS

2.2.1 Setting

Similar to other Western countries, there are growing concerns that changing demographics will challenge the ability of CBS and HQ to collect and produce an adequate supply of blood products from Canadians. A notable German study by Greinacher et al. forecasted a local case of age-driven blood shortage, finding that in the state of Mecklenburg-West Pomerania, patients over the age of 70 will require 50.2% of all Red Blood Cell (RBC) transfusions in that area by 2015, coupled with a 27-33% decrease in blood donations compared to the beginning of the forecast in 2004[20].

In the Canadian setting, the first baby boomers will begin to retire by 2011, and the number and proportion of the old (aged 65+) will grow significantly thereafter. From approximately 4.2 million seniors in 2005, Canada's senior population is projected to increase to 9.8 million by 2036, representing 25% of the total national population[21]. The Canadian population will continue to age between 2036 and 2056, but at a slower pace, with the number of seniors projected to increase from 9.8 million to 11.5 million, with their share of the population growing from 24.5% to 27.2%[22]. Although the proportional share of the older-old (aged 85+) is expected to remain relatively constant over the short-term (approximately 1.5% of Canada's population), the number of people aged 85-plus is expected to increase to 800,000. Between 2021 and 2056, however, this group is expected to increase to 2.5 million as the baby boomers continue to age, and the share of those 85-plus is expected to grow to 5.8% of the total population.

Coupled with population aging is the increased need for medical intervention with age. A 1997 study by Rosenberg and Moore found that the use of medical services by individuals tends to increase rapidly from the age of 74, regardless of previous patterns of health[23]. We can then anticipate that as older Canadians continue to age, they will also increase demands on health services and blood supplies. While we can observe a gradual increase in the average number of annual donations per donor by age group based on the

2008 data (Figure 5), we lack the longitudinal data to conclusively say whether this increase is a natural progression for donors as they age, or are a generational effect for which replacement by younger cohorts is not necessarily guaranteed with time.

A second significant shift in Canada's demographic profile is reflected in the increased diversity of the population. Few Canadian studies detailing the relationship between blood donation and race/ethnicity exist, but one recent study by Saberton et al. has found that overall donation rates in Canada tend to be lower in areas where there are high proportions of immigrants[24]. Literature from the United States corroborates that donation rates are typically lower amongst visible minorities as compared to Caucasians[25], and while research by Wu et al. shows that, perhaps predictably, the overall number (if not proportion) of Asian, Black and Hispanic donors in some areas of the United States are increasing[26], Schreiber et al. found that minority donors are less likely to return than white donors[27]. Despite race-based differences in return donation patterns, Gillespie and Hillyer explain in their summary of literature that while in 1965 only 10% of the donor pool in the United States was nonwhite, between 1991 and 1996 this number had encouragingly grown to 26%[28]. A French study by Grassineau et al. explores the interactions of immigrants and blood donation in Marseille, itself a major immigrant destination, and found that the underrepresentation of immigrant populations in the donor pool is closely related to language and income barriers, traditional beliefs, and religious concerns. Grassineau concluded that in order to overcome these barriers, recruitment campaigns targeted to these groups had to be tailored specifically to address these concerns[29].

2.2.2 Data Sources

In order to project blood supply and demand into the future, three datasets are required; (i) age- and gender-specific rates of donation, (ii) age- and gender-specific rates of transfusion, and (iii) projected populations by age and gender for the province of Ontario. Further to these goals, four distinct data sources were used for the purposes of forecasting blood supply and demand.

Supply Data: Individual level blood donation (Supply) data was provided by Canadian Blood Services (CBS) for the 2008 calendar year. The dataset contained attribute information on donors, donations and clinics as illustrated in Figure 1. All donations were linked to the respective donor in the donor dataset and clinic in the clinic dataset. The total data set contained 903,014 Whole Blood (WB) Donations made by 420,787 individuals at approximately 15,254 WB Clinics across Canada.

Total counts of all donations collected at Ontario Clinics, as determined by CBS Region, were used to establish the amount of WB units collected in Ontario. Additional information regarding donor type could be drawn out of the dataset through inference; Donors who began donating in 2008 could be identified by comparing the number of 2008 donations assigned to that donor against the "Total Donations" attribute which tracks donations by donors since they began donating. In cases of a match, it could be responsibly inferred that these donors had only begun donating in 2008.

The amount of WB collected within Ontario was derived by counting the number of units donated at Ontario clinics rather than the number of units donated by donors with Ontario Postal Codes. This was done to avoid cases where donations were being made out of province and, as a result, not contributing to the provincial supply. Ontario Clinics were identified by the "CBS Region" attribute, which excludes 20 clinics that operated within Northwestern Ontario when geocoded by Postal Code. The 1,806 WB units collected at these 20 locations are part of the Winnipeg CBS Region, and as such are sent to bordering Manitoba for processing and distribution. As a result, they are rightly not included in Ontario provincial totals.

The final Ontario blood supply dataset used in this study was comprised of 420,755 WB units donated by 195,160 individuals at 8,176 WB clinics operating within Ontario CBS Regions throughout 2008. From this subset we calculated blood donation rates by five-year age cohort for inclusion into the forecast.

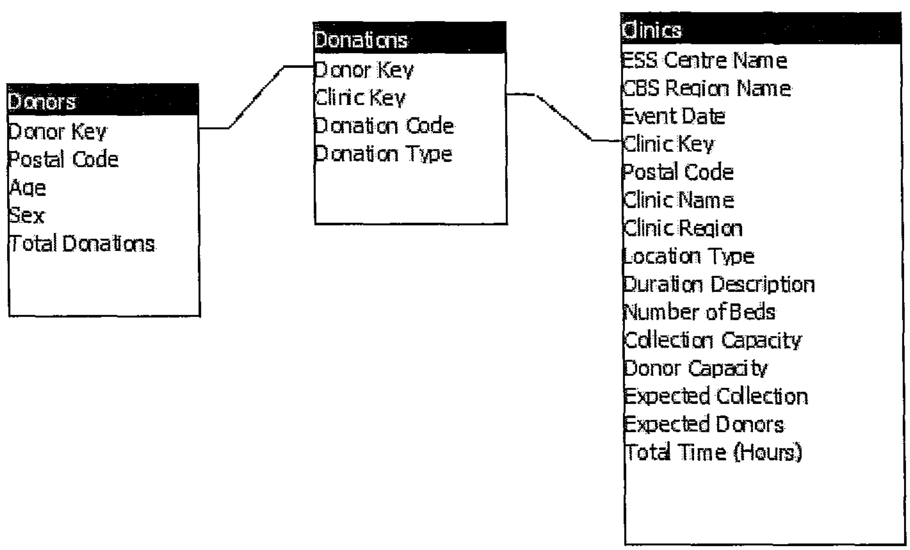

Figure 1: Canadian Donor, Donation, and Clinic Data and Attributes in the Supply data provided by CBS

Blood Demand Data: Transfusion data was purchased from the Canadian Institute for Health Information (CIHI), supplemented with information provided by the McMaster Transfusion Research Program. The CIHI data was comprised of two discrete datasets, (i) the Discharge Abstract Database (DAD), which captures "same day surgeries, long-term care, [and] rehabilitation"[30], and (ii) the National Ambulatory Care Reporting System (NACRS) data, which captures "[A]ll ambulatory care visits in Canada including SURG D/N, ED, outpatient community clinics and facility based public or private clinics"[31]. Both of these datasets were pre-processed by CIHI so as to only contain records for RBC-transfused patients at Ontario clinics and hospitals (Figure 2). Between these two datasets, all individuals in Ontario who received *at least* one RBC transfusion have been captured. In addition, both datasets included the general age of each donor, within five-year age blocks, and their Forward Sortation Area (FSA), which are the first three characters of the patient's Postal Code of residence.

Due to the fiscal year format of the DAD/NACRS data, and the calendar year format of the CBS data, only patients whose admission/discharge dates overlapped any period between January 1st 2008 and December 31st 2008 were retained for the forecast. While this may result in an overestimation of usage, as it is unlikely that patients discharged at the beginning of 2008 actually used any blood products collected in 2008, it should be balanced by the likelihood that discarded patients from early 2009 drew from the 2008 blood collection pool.

From this dataset, only donors who received an allogenic RBC transfusion were retained. Comprising 95% of total blood product usage in both datasets, RBC units were determined to be a quality indicator of overall blood supply, as well as having been used as the indicator of supply in the Greinacher et al. forecast[32].

This approach resulted in 104,284 patient records extracted from both datasets, including patients who are residents of the United States or are from out of province as determined by the attached FSA data, but who still received RBC transfusions in Ontario from the provincial pool.

MTRP Data: Third, neither the DAD nor NACRS databases contained complete information on the total number of RBC units transfused per patient, only an indicator that the patient had received such a transfusion. As such, the exact number of units transfused per patient on average based on the CIHI data had to be inferred from the total number transfused throughout the province in 2008.

In order to properly account for total demand, including loss as a result of blood screening between blood collection and blood shipment, and due to shelf life once arriving at hospitals, the McMaster Transfusion Research Program provided the total number of RBC units transfused at Ontario Health Centers in 2008 (394,573), and how many RBC units were initially shipped to these Health Centers in 2008 for use (411,990). The difference between these figures can be attributed to loss through screening and out-of-date products. In other words, 97.9% of RBC units donated in Ontario were shipped to hospitals, with a 2.1% loss. Of the amount shipped, 96.6% of these units were transfused, resulting in a further 3.5% loss due to shelf life. Overall, 93.7% of RBC units donated in

Ontario were transfused in Ontario for calendar year 2008. Based on the number of patients in the NACRS and DAD data, and the total number of units transfused in the MTRP data, we were able to estimate the average number of RBC units transfused per patient in Ontario as being approximately 3.78 units per patient.

Ministry of Finance Data: Fourth, data related to Ontario's predicted population growth was gathered from Canadian Ministry of Finance Population Projections for Ontario[33], which tracks (i) population growth by five-year age cohorts annually from 2008 to 2036, and (ii) population growth by gender and five-year age cohort for selected years during the same period. Both are used due to our observation of potentially important gender-based differences for donation and usage.

DAD
Province
Fiscal Year
FSA
Gender
Age Group
Admission Date
Entry Code
Discharge Date
Blood Transfusion Indicator
Red Blood Cell Indicator
Platelets Indicator
Plasma Indicator
Albumin Indicator
Other Blood Component Indicator
Autotransfusion Indicator
Analytical Institution Type
Major Clinical Category Code
Major Clinical Category Name
Case Mix Group Code
Case Mix Group Name

NACRS
Province
Fiscal Year
FSA
Gender
Age Group
Date of Registration
Disposition Date
MIS Functional Centre
Scheduled ED Visit Indicator
Blood Transfused?
Red Cell Transfusion Indicator
Red Cell Transfusion Number
Platelet Transfusion Indicator
Platelet Transfusion Number
Plasma Transfusion Indicator
Plasma Transfusion Number
Albumin Transfusion Indicator
Albumin Transfusion Number
Other Transfusion Indicator
Other Transfusion Number
Autologus Transfusion?
Major Ambulatory Cluster Code
Major Ambulatory Cluster Name
Comprehensive Ambulatory Classification System Code
Comprehensive Ambulatory Classification System Name

Figure 2: Ontario Patient Data and Attributes for DAD and NACRS

2.2.3 Analysis

The data was assembled according to the decision tree in Figure 3. The total number of donations from each five-year age group was divided by the population of that age group according to the 2008 population forecast, resulting in five-year age-specific donation rates. The rate for blood usage was calculated slightly differently than the rate for donation: the number of patients who received a transfusion based on identification in the DAD and NACRS databases were divided into the total number of units transfused at Ontario hospitals in 2008, resulting in an average number of units consumed per patient overall, as opposed to by specific age cohort as made possible by the Donation data. This introduces a degree of error in the forecast, as it can be assumed that different age groups, being affected by different age-specific ailments, would require different amounts of transfused blood on average as a result. Regardless, the overall average number of 3.78 units per patient in Ontario was retained, despite being conservative compared to a claim by CBS that the average number of units used per transfusion is 4.6[34]. This larger average likely reflects (i) a longer-term average, and (ii) average Canadian (as compared to Ontarian) blood use.

Based on these data sources, the calculated five-year age-specific rates of donation and demand were applied to the projected Ontario population for each year through 2036. Concurrently, gender-specific rates of donation and demand were generated using the same methods and applied to the gender-specific population projection, which only covers seven selected years of the forecast (2008, 2011, 2016, 2021, 2026, 2031, and 2036). In both forecasts, projections assume that donation and demand rates by age group will not change in the future. With regards to transfusion rates, the projections do not account for the possibility that new medical procedures will reduce the demand for RBC units. Conversely, with regards to donation, the projections do not account for the possibility of additional deferrals being introduced or the age limits on donation changing, among other possible factors. It can be confirmed that new deferrals due to emerging diseases are introduced annually (e-mail communication from Kathryn Webert, Investigator, McMaster Transfusion Research Program, April 2010), potentially restricting supply even further.

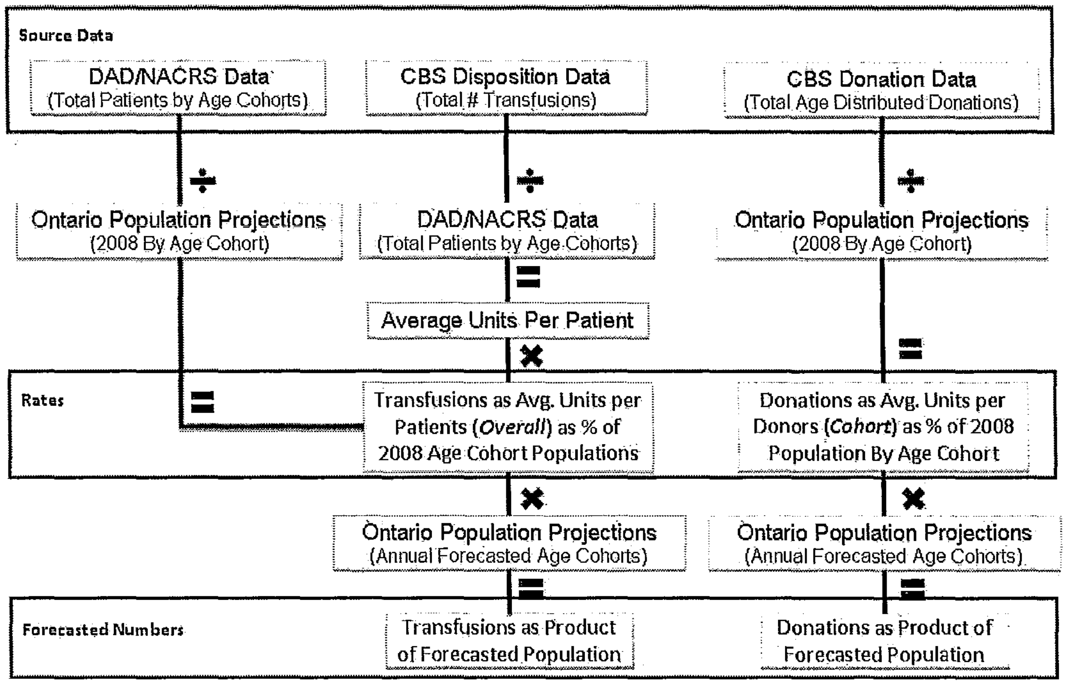

Figure 3: Stepwise Generation of Final Rates

2.3 RESULTS

2.3.1 Donation Patterns

We start by considering age and gender donation patterns based on the 2008 CBS data (Figure 4). A number of important distinctions can be made between the donation patterns of these groups. Within the "Children of Baby Boomers" cohort, the high percentage of eighteen year old donors is strikingly evident. Taken with Figure 5, however, it can be seen that the majority of this cohort is donating once annually, resulting in a very low number of average donations per donor. This may be characteristic of an age group who donates due to their newfound ability to donate, or is particularly receptive to social pressure, rather than a personal dedication to the actual need for blood.

This trend does not appear to continue into early adulthood, with individuals (irrespective of gender) quickly donating with less frequency as they approach middle age, though this trend is less severe in women. This may possibly be a result of the shifting personal priorities of these age groups, who may be more concerned with personal needs such as careers and family than with broader social needs.

Resurgence in donation frequency occurs for Baby Boomers. This may possibly be due to shifting personal priorities, or due to friends and family of similar age beginning to require blood themselves, thereby making the social need for blood a personal issue. Interestingly, the percentage of donors within a cohort appears to fluctuate with the size of the cohort itself. The nature of this relationship is difficult to qualify, and further study into donation as related to social networks may help in explaining this possible correlation.

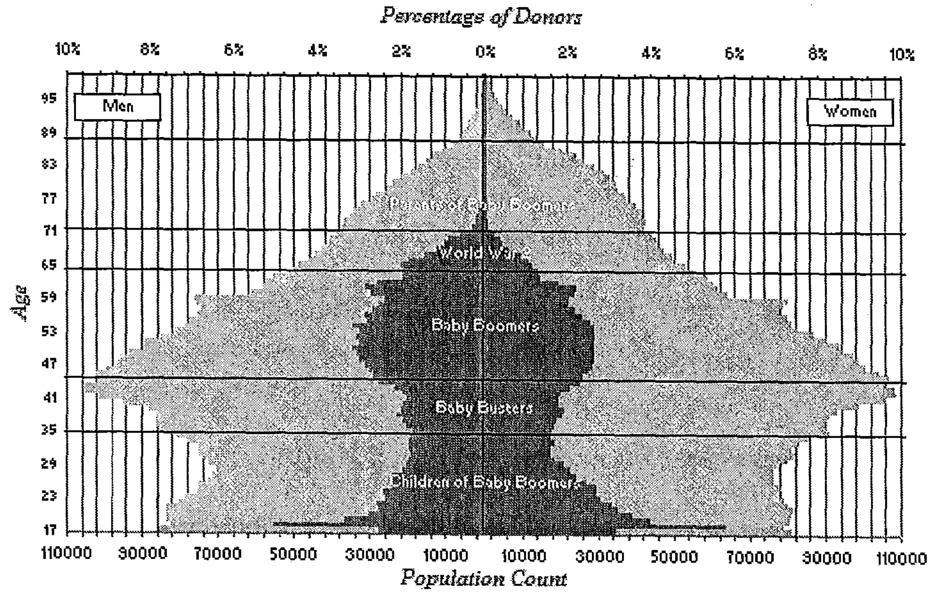

Figure 4: Donors as a percentage of the Ontario population by age and gender (2008 CBS Data) superimposed onto Population by Age Group (2006 Census Data)

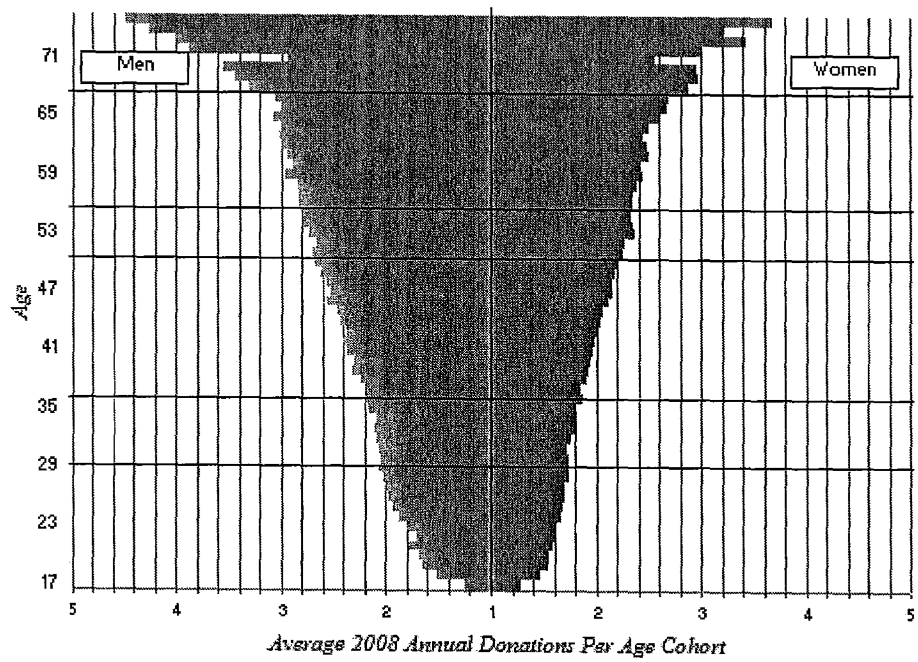

Figure 5: Average annual donations of Ontario donors by Age and Gender

Older ages are more likely to make multiple donations over the year (approximately 3-4 times), irrespective of gender. In comparison, younger ages, 17 to 29 in particular, donate only approximately 1-2 times over the year. These frequencies are consistent with findings elsewhere in the literature, with older cohorts typically being more likely to become repeat donors, even when entering the system as FT donors[35].

Modest variations in frequency of donation by gender are also noted, with men donating 2.36 times per year on average over their lifetime, and women donating 1.95 times per year on average over their lifetime. The age distribution of this difference can be followed in Figure 5, with women initially donating more frequently than men, but quickly donating less frequently in ages typically associated with having children. A Dutch donor demographic study by Veldhuizen et al. speculated that a similar pattern was associated with women permanently dropping from the donation pool upon becoming pregnant rather than delaying it temporarily, and furthermore that menstruating women are more often deferred for low haemoglobin levels than are men[36].

2.3.2. Logistic Regression

We further consider donation patterns by gender and age through a series of exploratory logistic regressions (Table 1). Overall, men are slightly more likely to donate multiple times throughout the year than women, and are slightly less likely to become FT donors than women. Age trends show what can be seen previously in figure 5; that the likelihood to donate multiple times throughout the year increases with age cohort, but inversely, likelihood of entering the system as an FT donor is much more likely with younger age cohorts. Gender-based differences are also revealed. Overall, men are more likely than women within all four age cohorts to donate multiple times throughout the year. Additionally, while likelihood to become a first time donor is relatively equal for genders within the 17-24, 25-39, and 65+ age groups, men are significantly less likely than women to become first time donors between the ages of 40 and 64.

Table 1: Age- and Gender-based Logistic Regression Results: Ontario, 2008

Variable	n	R^2	% Conc	Likelihood Ratio	95% Wald Confidence Lower	95% Wald Confidence Higher	Unadjusted Odds Ratio
Multiple annual donations	195160	0.0633	55.3	12753.23			
Men	***99631***				***1.278***	***1.326***	***1.302****
25-39	***45261***				***1.712***	***1.809***	***1.760****
40-64	***102201***				***3.153***	***3.308***	***3.230****
65+	***6387***				***5.685***	***6.421***	***6.042****
First-Time Donation	195160	0.1132	65.2	23447.02			
Men	***99631***				***0.882***	***0.924***	***0.90****
17-24	***41311***				***33.378***	***46.714***	***39.487****
25-39	***45261***				***10.403***	***14.570***	***12.311****
40-64	***102201***				***4.633***	***6.483***	***5.480****
Multiple Annual Donation: Age & Sex							
Men (17-24)	***19147***	***0.0016***	***27.1***	***65.14***	***1.137***	***1.234***	***1.184****
Men (25-39)	***22388***	***0.0059***	***29.0***	***265.7590***	***1.311***	***1.412***	***1.360****
Men (40-64)	***54011***	***0.0045***	***28.5***	***463.0215***	***1.287***	***1.354***	***1.320****
Men (65+)	***4085***	***0.0038***	***27.1***	***24.2181***	***1.195***	***1.511***	***1.344****
First-Time Donation: Age & Sex							
Men (17-24)	19147	0	24.9	0.0415	0.966	1.044	1.004
Men (25-39)	22388	0.0001	25.5	2.9106	0.920	1.006	0.962
Men (40-64)	***54011***	***0.0017***	***28.4***	***171.2484***	***0.741***	***0.801***	***0.771****
Men (65+)	4085	0	-†	0.0010	0.703	1.407	0.994

Bold Italics denotes significance at the 0.05 Significance Level
†: Measures of association between observed and predicted values were not calculated because the predicted probabilities are indistinguishable when they are classified into intervals of length 0.002.

2.3.3 Demand Patterns

Figure 6 illustrates age and gender differences in blood use, with two apparent trends. First, between ages 20 to 50, and 80 to 90, women generally comprise a larger portion of the transfusion-receiving patient pool than men. Closer inspection of patient records reveals that this is largely attributable to transfusions related to "Pregnancy and Childbirth" (MCC Code 13) and "Diseases and Disorders of the Female Reproductive System" (MCC Code 12) according to the DAD/NACRS data, which together comprise 33% of all Female NACRS and DAD Patients receiving an allogenic RBC transfusion between the ages of 20 and 49. Second, older males represent a larger number of patients between 50 and 79 years of age. While again, the numbers of RBC units attributed to each age cohort are estimated, the trend appears very consistent with Greinacher et al.'s 2006 age group-specific transfusion distribution, increasing confidence in this approach[37]. When the age cohorts in Figure 6 are controlled for by the population of each age group, shown in Figure 7, a much clearer picture emerges regarding the large proportional discrepancies in gender-based need for Ontario's aging population.

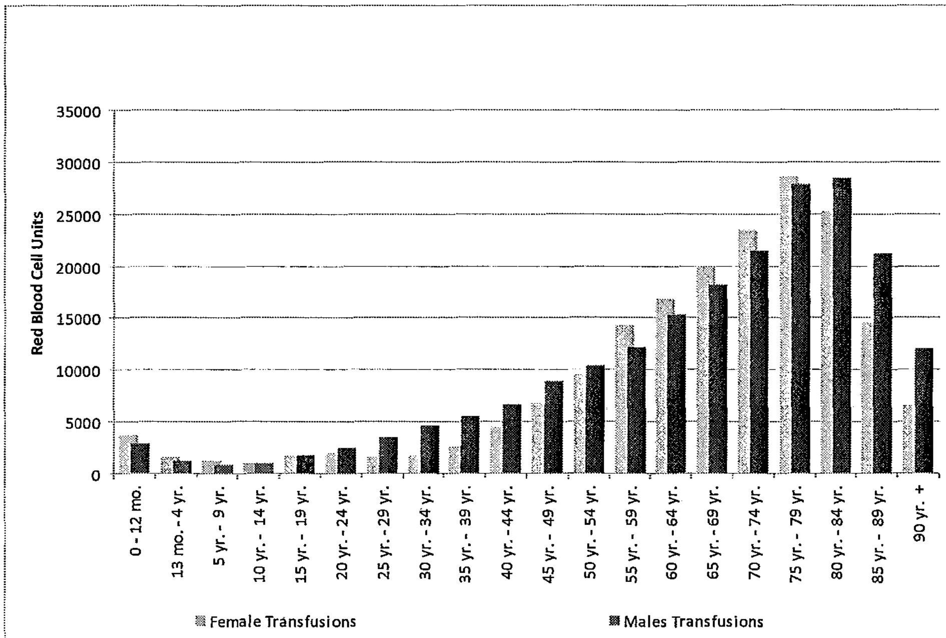

Figure 6: Estimated Transfusions by Gender and Age Group for Ontario Age Cohort

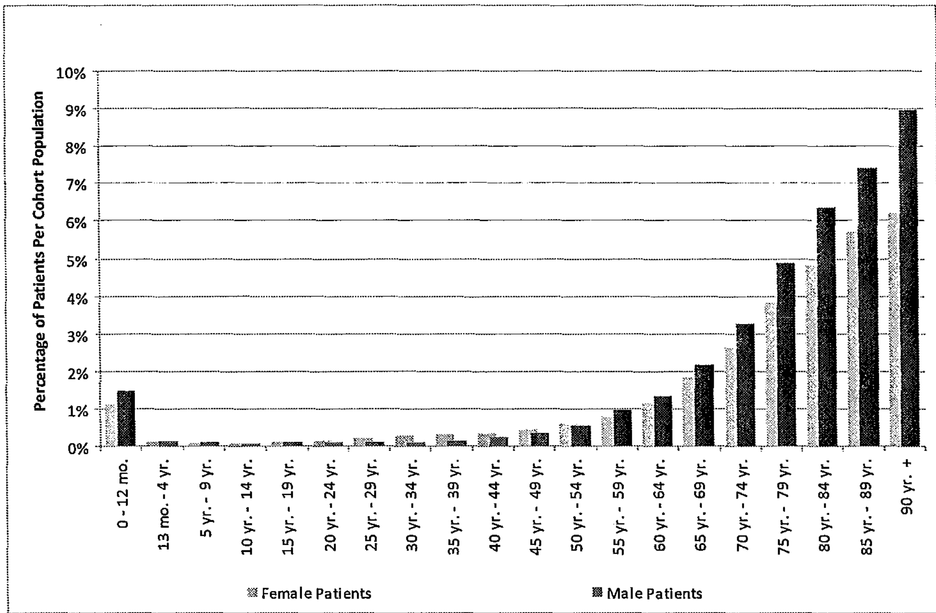

Figure 7: Patients as a Percentage of 2008 Ontario Age Cohort

2.3.4 Forecasting Blood Demand and Supply in Ontario

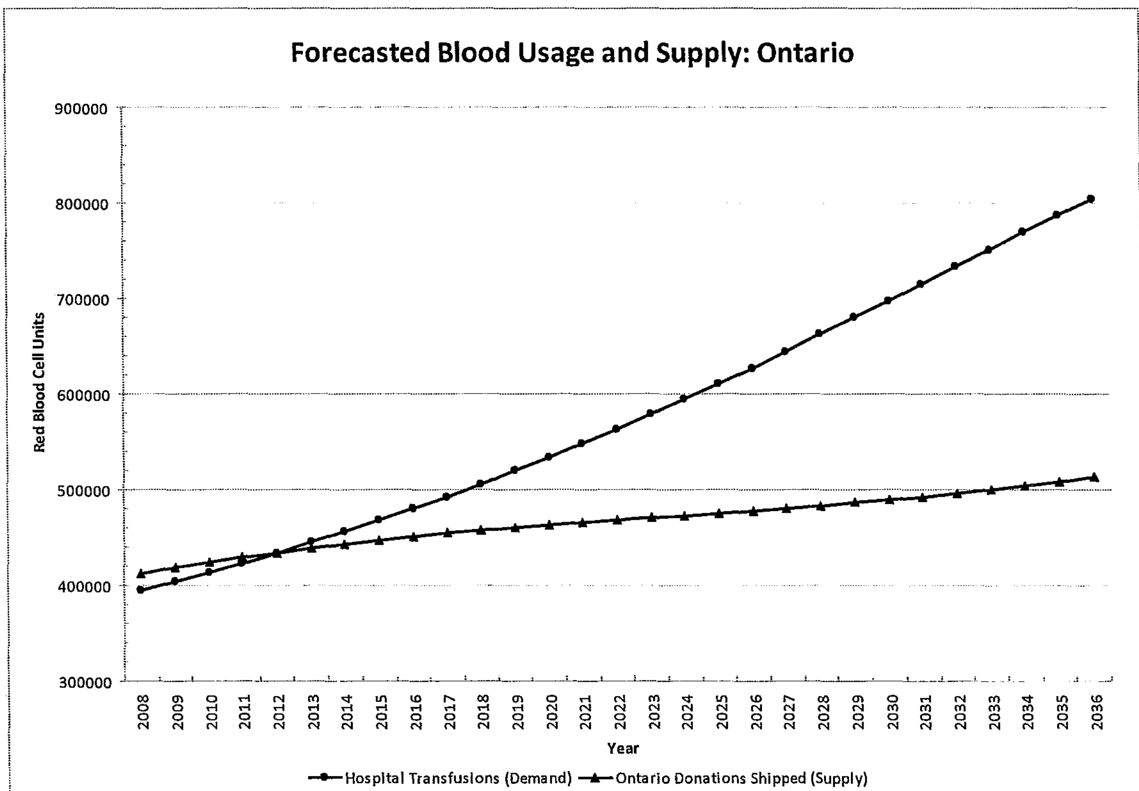

Figure 8: Blood Usage and Supply Trends

Based on current trends, as shown in Figure 8, supply exceeds demand at the start of the projection in 2008. However, assuming no changes in rates of supply or demand, RBC demand is forecasted to outstrip supply as soon as 2012 based solely on population aging. Controlling for gender using the gender-based population projection, the shortfall is forecasted to occur at generally the same time despite the observed differences in donation and usage rates between genders. While transfusion rates are due to medical factors which are more difficult to change than population donation rates, it should be noted that no capable and responsible blood collection agency would allow for the growth of drastic gaps in supply without pursuing additional measures to increase donation in order to match or exceed demand.

Both the Total Supply and Total Demand curves are shown stratified by age group in Figures 9 and 10 respectively, with the percentage rate of change over the course of the forecast labelled along the right axis. The supply strata in Figure 9 shows that extremely moderate growth of younger age cohorts in Ontario over the next 28 years will result in equally moderate percentage increases in the annual number of donations that can be expected to be supplied by these groups. While the oldest sizable donor cohort (65-69 years) is expected to increase its donations by 90% over the forecast, this small benefit is caused by the younger tail of the aging baby boomer age cohort expected to be the driver of increased demand.

The demand curve of Figure 10 shows much more significant percentage gains over the course of the forecast. As these age cohorts already receive high rates of transfusions per person, and are expected to grow in size as baby boomers age, the accompanying growth of their percentage demand presents the upwards driving force of the curve. As a result, RBC transfusions of the 70+ Age group is forecasted grow from approximately 53% of all RBC transfusions in 2008 (209,515) in 2008 to 68% (546,996) by 2036.

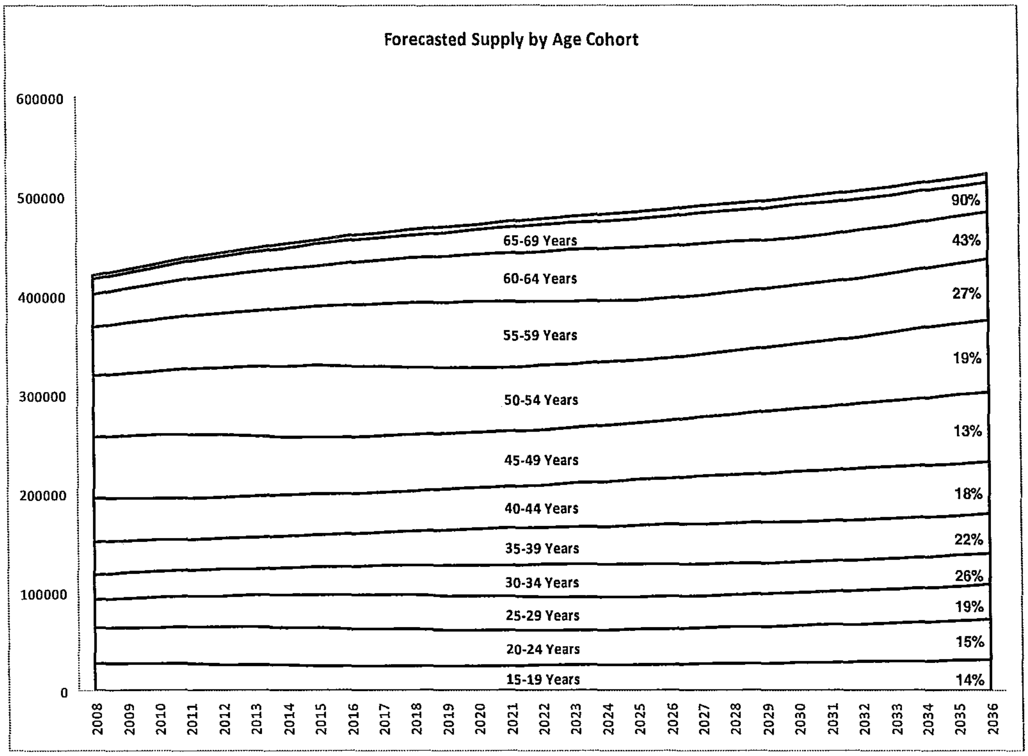

Figure 9: 2008 Supply forecast stratified by five-year age cohort

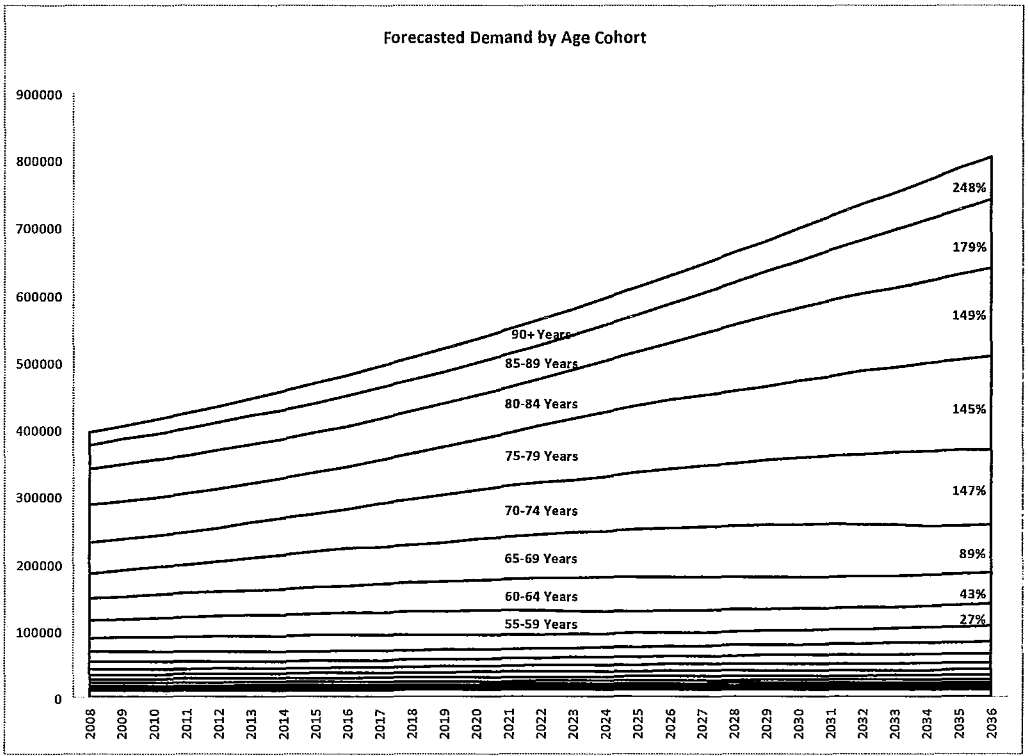

Figure 10: 2008 Demand forecast stratified by five-year age cohort

2.3.5 Scenarios

Using the forecasts derived from the 2008 data, several "What-if" scenarios involving changes to Canadian blood donation patterns can be examined. Scenarios to be considered in the following section include:

a) What happens if overall donation is increased by 2% annually?

b) What happens if donations are increased by 2% annually in,

(i) The 17-24 age cohort?

(ii) The 35-50 age cohort?

c) What happens if we double the number of RBC units collected amongst those who donate only 1 time per year, as per introduction of apheresis machines which collect two RBC units per donation?

d) From a demand perspective, what happens if total RBC use flatlines by 2015?

e) What rates of annual donor growth in Ontario are necessary to match annual forecasted demand assuming 2008 rates and an average 2.16 units/donor?

2.3.5.a.

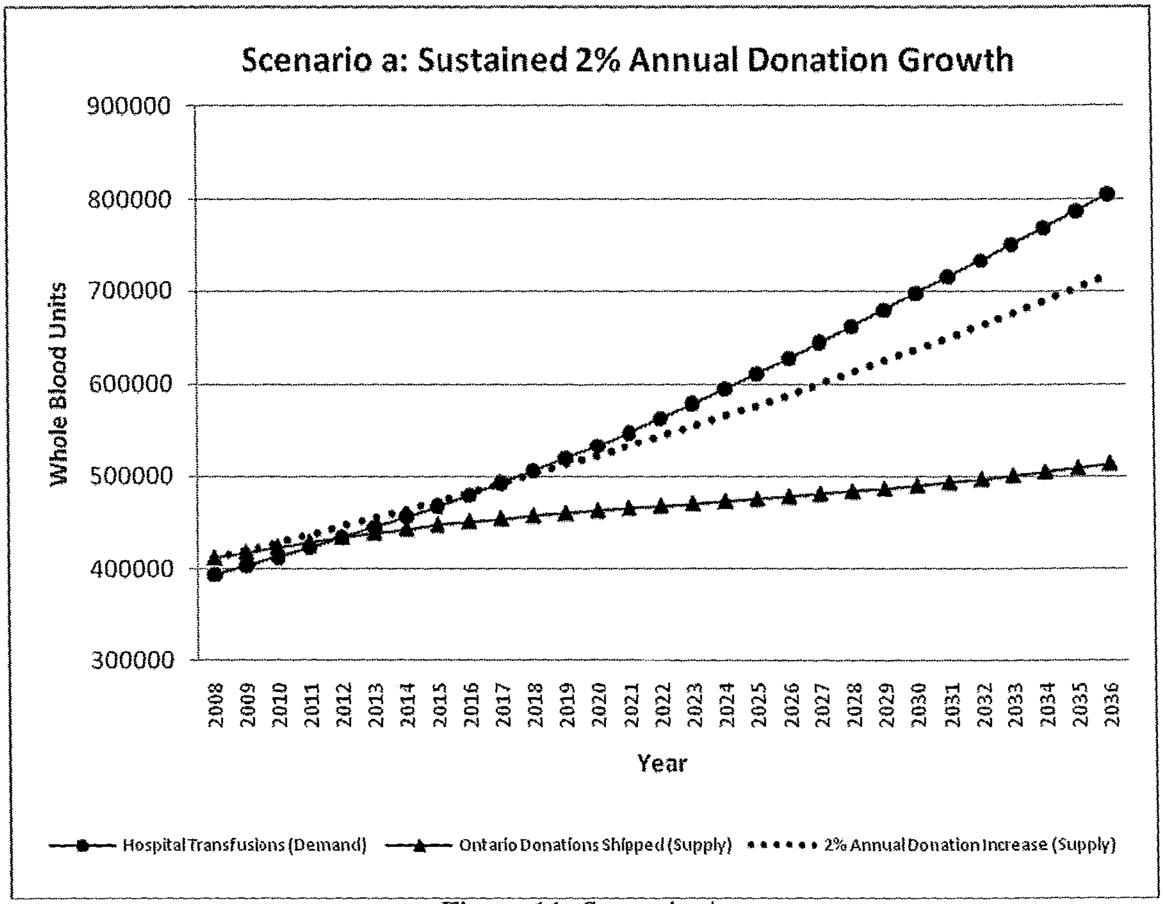

Figure 11: Scenario A

The results of Scenario a) show us that with 2008 supply and demand rates, given a sustained annual 2% increase in the number of donations received by CBS over the course of the forecast, demand will be forecasted to outpace supply by 2018. This 2% growth rate is based upon a compromise between the 4% annual growth anticipated by CBS in 2002[38], and the low (0.5%-1.5%) supply growth rates identified by the forecast.

2.3.5.b.

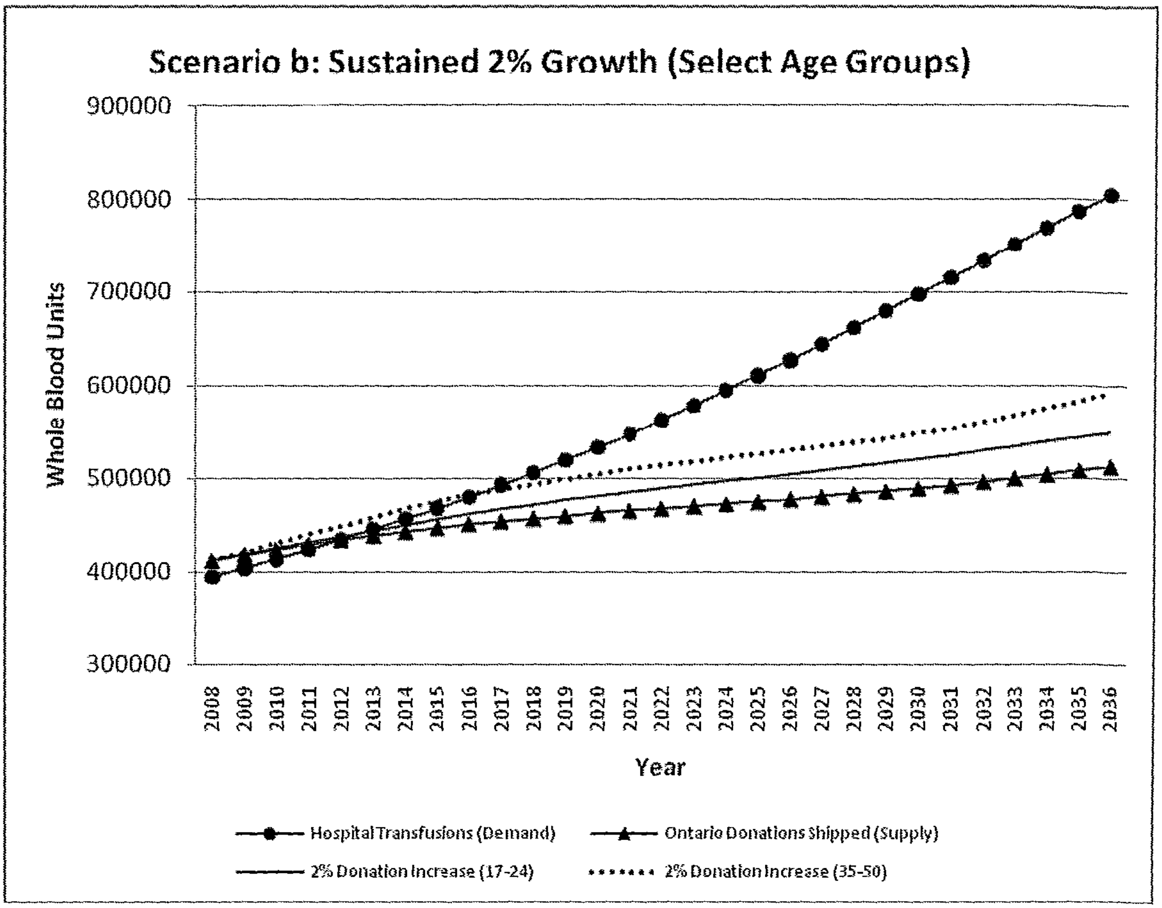

Figure 12: Scenario B

Scenario b) takes the annual 2% increases used in scenario a) and applies them only to select age groups to see where efforts could be most effectively targeted. As show in Figure 12, targeting the larger 35-50 age group to achieve 2% annual growth in donations results in demand outpacing supply by 2017, as opposed to 2013 for the 17-24 age group.

2.3.5.c.

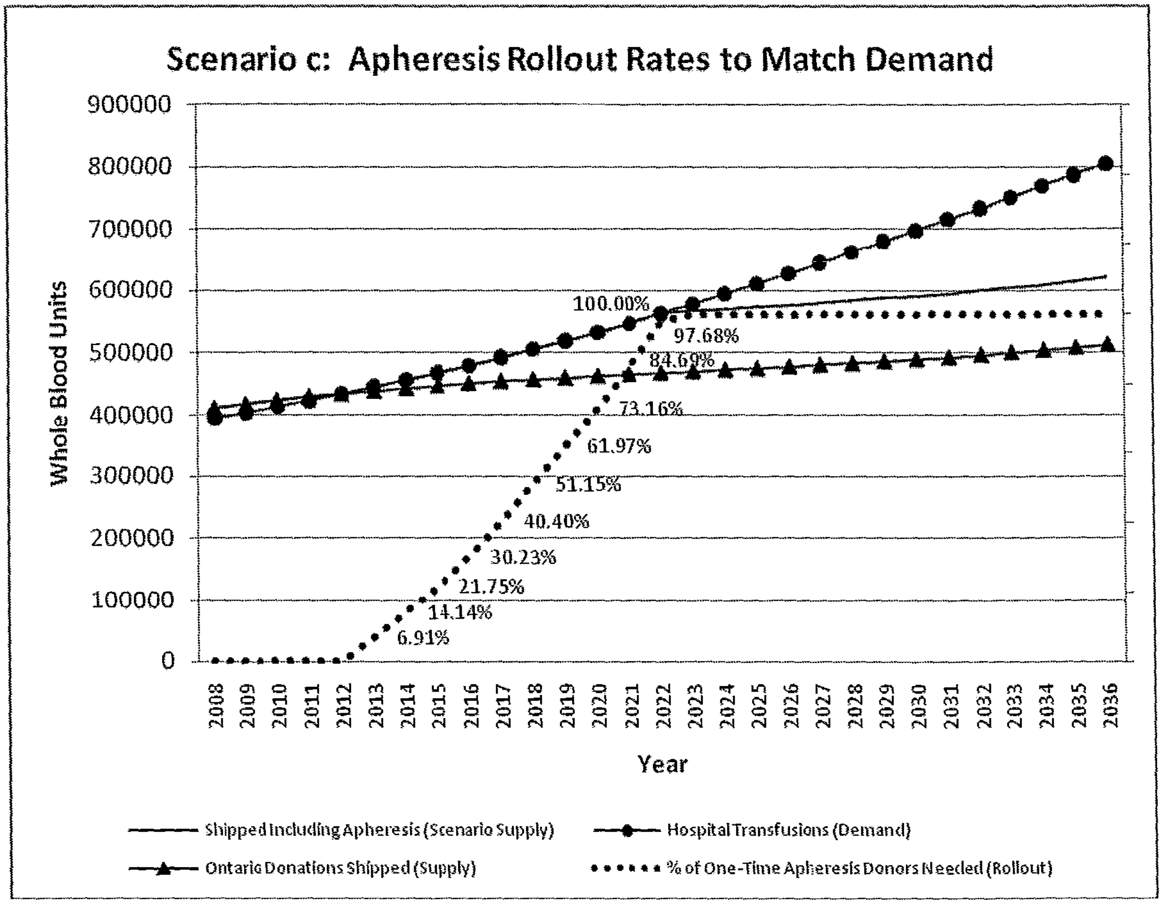

Figure 13: Scenario C

Scenario c) assumes the gradual introduction of apheresis double RBC donations in Canada. As the recovery time between donations by apheresis machine for donors is twice as long, the largest gains in its introduction would come from targetting donors who would typically only donate once annually. In this case, if the annual rollout of apheresis technology is set by the percentage of one-time donors undertaking apheresis donations needed to close the forecasted gap between supply and demand based on 2008 rates, introducing the new technology at the pace shown in figure 13 between 2012 and 2023 should cover this difference. By 2023, assuming that all forecasted one-time donors are undertaking apheresis donation, supply can be increased to meet demand by increasing population donor percentages by the annual amounts specified in Table 1.

Table 2: Post-Apheresis Population Donor Rate Increases

Year	Increase
2023	2.03%
2024	2.75%
2025	2.73%
2026	2.70%
2027	2.74%
2028	2.72%
2029	2.67%
2030	2.63%
2031	2.54%
2032	2.49%
2033	2.44%
2034	2.38%
2035	2.34%
2036	2.23%

2.3.5.d.

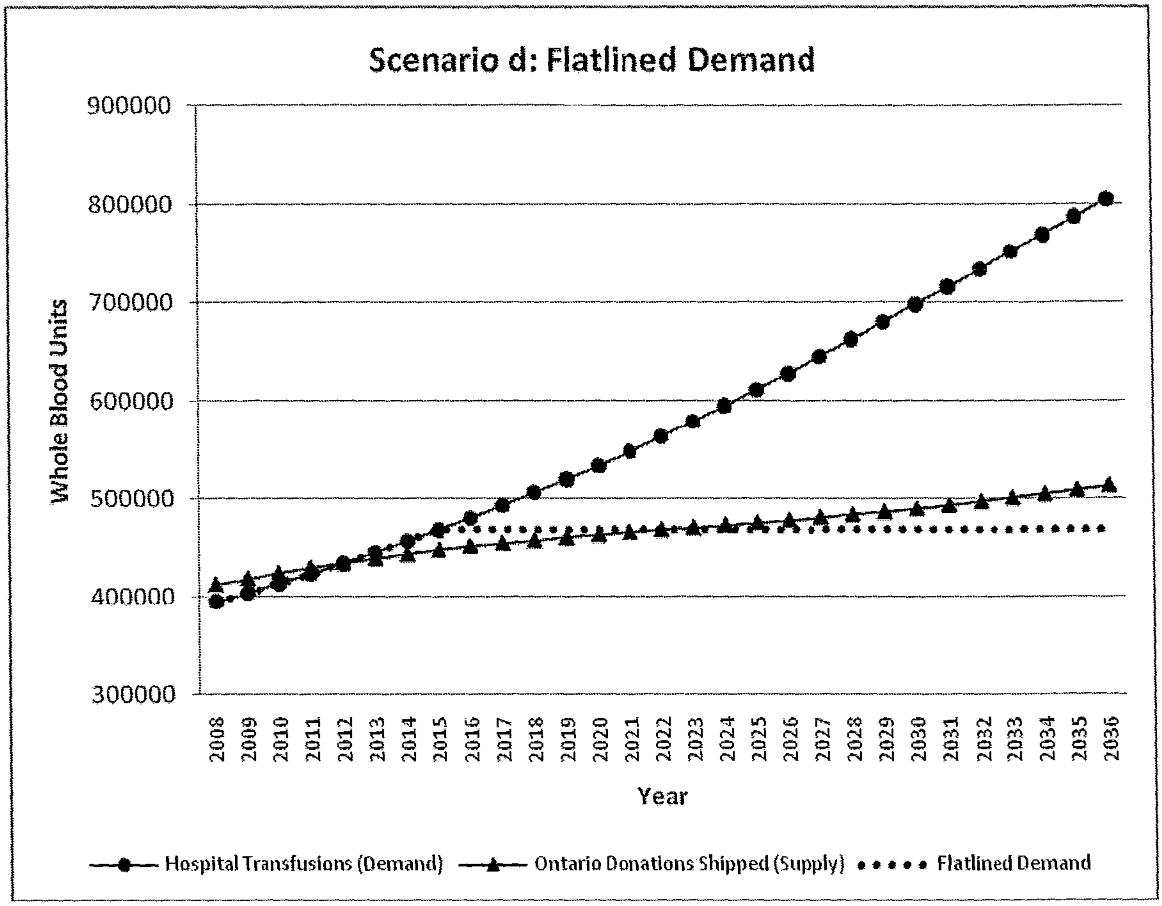

Figure 14: Scenario D

Scenario d) takes into account information from CBS stating that, according to successive 52-week averages of transfusion rates, the annual numbers of transfusions are gradually levelling off[39], and even reporting a recent annualized (52-week average) drop of 3,000 units. Assuming that the annual number of transfusions required in Ontario stabilizes and flatlines within the near future, with a forecasted demand of 467,765 transfusions by 2015, supply would be forecasted forecasted to regain sufficiency by 2022.

2.3.5.e.

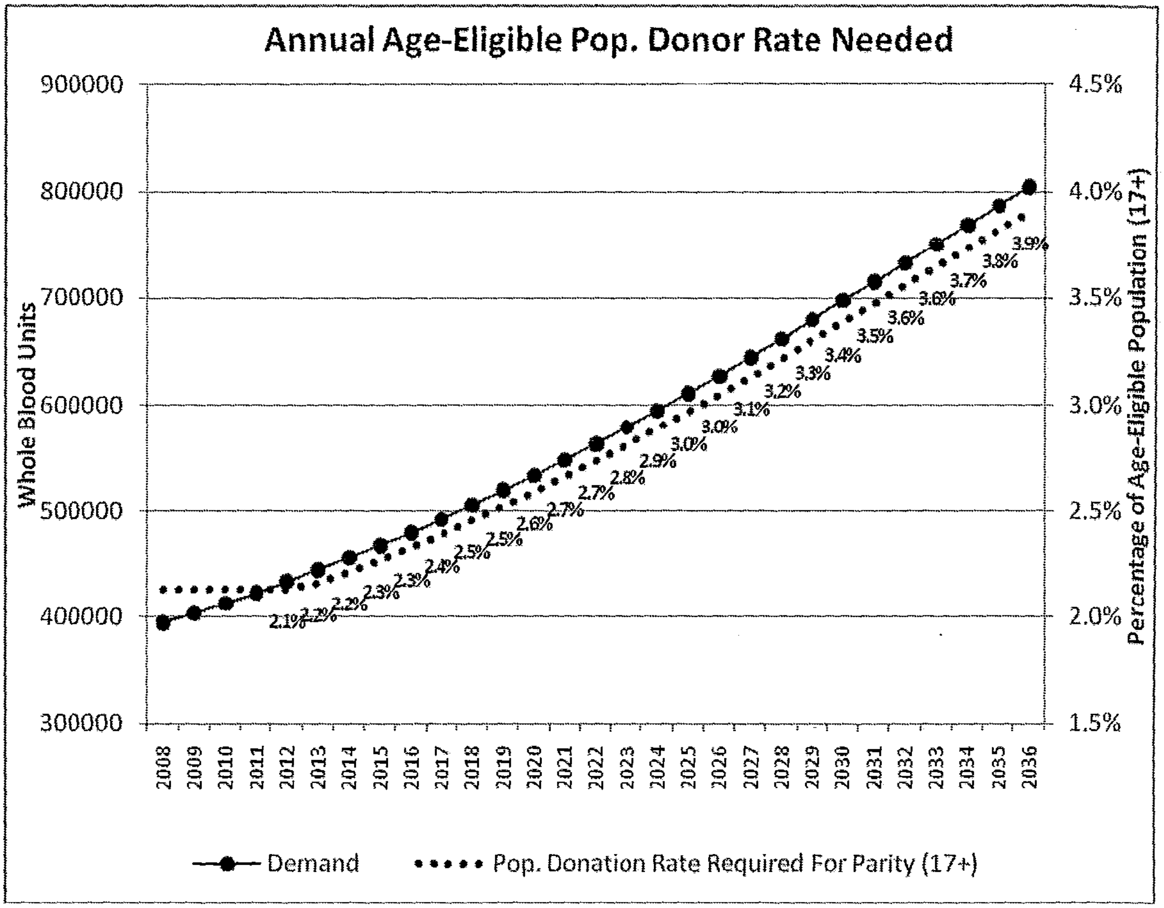

Figure 15: Scenario E

As show in figure 15, scenario e) tracks the annual growth rates amongst the age-eligible population necessary to match forecasted demand estimates, beginning in 2012. At annual 2-3% increases each year between 2012 and 2036, an overall 83.4% increase over the number of donations forecasted to be collected in Ontario in 2012 would be necessary to reach demand.

2.4 DISCUSSION

2.4.1 Assumptions and Limitations

Due to the CIHI and MTRP data being limited to Ontario, the entire forecast was necessarily limited to the province. As Ontario has both the largest population of all provinces across Canada, and is responsible for 420,755 of the 903,014 blood donations across Canada (excepting Québec) in 2008, it was decided that such a limited forecast would still be a strong indicator of national blood supply. Furthermore, Ontario acts as a closed system in many respects, being bordered to the south by the United States, which operates independently for blood products; to the east by Québec, which operates its own blood supply under Héma-Québec and for which transfer between provincial supplies is not undertaken except in times of shortage; and to the west by Manitoba along an often remote and rural border that limits the transfer of blood products.

It should be kept in mind, however, that while the blood demands of Ontario represent a significant portion of national demand, its blood collection rates are notably different from the rest of the country, according to CBS, and imported approximately 15,000 RBC units from outside the province in 2009. Even Ontario's blood transfusion rates, when compared those of British Columbia for 2008 and using the same age-specific transfusion rates, are relatively high, especially with regards to older cohorts. As a result, while the results of this study are likely not generalizable to the rest of Canada, the proportion of Ontario to the population of Canada is such that as goes the demands of Ontario, so goes the nation.

The forecast itself is reasonably conservative, with important caveats. First, while we have reasonably accurate supply and demand profiles, the projection does not account for the ability to move blood products across provincial borders, and the potential for somewhat higher donation rates in some regions (i.e., Atlantic Canada), to offset shortages in others[40]. Second, it is assumed that donation and demand rates by age will remain constant over the projection period: only the absolute population of these age cohorts will change. While this is a reasonable assumption for making projections, it is also somewhat problematic. As younger cohorts age, they are not necessarily guaranteed to begin donating at the same frequencies currently observed amongst older cohorts, but this has been identified by Canadian Blood Services as being an important and largely predictable trend in the donor life cycle[41]. Additionally, changes in the demographic makeup of Ontario, specifically related to a growing immigrant population, brings with it possible cultural changes which may challenge the traditionally altruistic philosophy of blood donation in Canada. Individuals arriving from countries with paid donor systems or systems which were not considered safe may not donate with the same age-based frequency as we currently observe. Hollingsworth and Wildman identify this effect as being related to "social capital", stating that new immigrants "may not feel suitably integrated to join in the collective action of blood donation at the moment"[42]. Third, there are also unknowns on the demand side: improvements in medical technology may, for example, result in procedures that use less blood products. For instance, the introduction of apheresis machines have the potential to increase supply, while innovations in surgery (i.e. bloodless surgery techniques) will decrease demand.

Nevertheless, from the outset of the forecast there is only a small difference between the amount being donated and the amount being transfused in the province, with the projection illustrating that all else remaining the same, demand for blood products is expected to outpace supply in the very near future. The shortages anticipated by this forecast will require swift action to improve provincial donation rates. As other provinces are expected to face similar demographic issues, national changes are required as well.

2.5 CONCLUSIONS

This paper demonstrates that the looming demographic shift points for a very real need in the immediate future for increased blood donation rates in Canada, development of medical alternatives that require less blood products, or alternate sources/substitutes of blood products. Different countries have dealt with blood shortages in a number of ways. Titmuss reports on the use of cadaver blood being excised in the Soviet Union as recently as 1970, a progressively rarer practice in the western world at the time[43]. Eckert explains that France, due to its strict ban on cash donations, has dealt with blood shortages by extracting placental blood from births[44].

With regards to increasing Canada's donor pool with new donors, several studies have focused on the effectiveness of targeted donor advertising to appeal to specific groups, and the efficacy of different messages tailored to these populations[45,46,47]. Hupfer's work regarding agentic vs. communal need may provide valuable insight into how the Canadian population may be best encouraged to donate. Additionally, the importance of studying how advertising and recruitment campaigns may be best targeted towards specific groups within Canadian society would be important to examine, once it is determined which groups are presently underrepresented. Within all groups, engendered differences should be anticipated. A study by Hupfer of University-aged donors found that male donors were more motivated by peer pressure and expectation to donate, while female donors were more motivated by humanitarian outcomes, despite greater stated expectations of physical pain[48].

Answers to the call for targeted approaches can be seen by grassroots campaigns such as 'Other Half', an ethno-specific bone marrow donation initiative targeted towards the Chinese-Canadian community. The success of community-based approaches extends to blood donation as well, with the Canadian Tamil Congress initiating an ongoing blood donation and awareness campaign, citing a desire to "give back" to Canada by donating 650 units in 2010 from within the community[49].

With Custer et al.'s conclusion that increased deferrals lead to decreased rates in return donorship[50], the unknown effect of increasing blood borne diseases requiring screening and deferral annually will have serious effect on donation rates as they arise. When the new deferral policies for a variant of Creutzfelt-Jakob Disease (CJD) was introduced in October 2001, bringing with it strict screening standards excluding individuals who had received a blood transfusion in the United Kingdom since 1980, lived in the United Kingdom or France for a cumulative of three months since 1980, or lived in Western Europe for a cumulative of five years since 1980, deferrals due to CJD sharply increased from 269 in August to 1,461 in October. While the system adapted and deferrals progressively declined over the following months, CBS estimated a loss of 3% of donors across Canada, approximately 15,000 individuals in total, due to deferrals, including donors who would incorrectly defer themselves[51]. Although donations are screened regardless of whether or not donors report themselves as high-risk, these screenings do not come without cost, and Wilson and Hebert (2003) explain that the cost-efficacy of ensuring the safety of a national blood system may be a necessary case of diminishing returns[52].

With the knowledge that 15% of blood donors in 2008 were new or previously lapsed donors, the importance of retaining a significant portion of these new donors throughout their lifetimes is evident, preferably at a rate matching or exceeding the number of donors excluded annually due to age. Schreiber has found that frequent donations during the first year of blood donation carries a high chance of subsequent long-term donation patterns, and advocates that "[e]fforts to encourage early repeat donations from most donors, through frequent contact and follow-up, may help blood centers to convert more first-time donors to repeat donors"[53]. Piliavin advanced the importance of this approach, stating that after three to four blood donations, blood donors become psychologically addicted to the altruistic act of donating[54].

The need for recruitment of donors in order to meet potential shortfalls is recognized in this paper, and CBS is continuously working to meet annual needs through a variety of efforts. For instance, the potential for increased donation rates in the 35-50 year age cohort has been identified and will be actively targeted in future recruitment programs. Double-RBC donation via apheresis machine has been observed as successful in the United States, and their use in Canada is currently being considered, a move which is expected to increase supply. First and foremost, collection plans are developed by CBS to meet, and not exceed, forecasted levels of demand in order to avoid wastage. As a result, constant refinement of CBS appeals and targeting mean that its ability to influence and attract new donors in the future should not be underestimated.

These potential avenues for change and growth must be considered for future research and policy, and effective solutions need to be discovered. With an anticipated 278,336 RBC unit gap by 2036 that needs to be filled by Ontario donors, the looming shortfall calls for more than simply increasing awareness of the problem, but developing a new paradigm answering why Canadians should donate blood. With recent research focusing on the differing receptiveness of groups within Canadian society to donation appeals, perhaps this paradigm lies in recognizing the transitioning nature of Western society: Instead of defining themselves by and fostering a single national culture, these nations are now collections of independent cultures living within a preexisting national entity. Rather than the long-anticipated population changes driving the Supply/Demand gap, this new paradigm is the looming shift needed to ensure the safety of Canada's future blood supply.

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CHAPTER THREE: Correlates of Blood Donation in the Toronto CMA

3.1 INTRODUCTION

In Canada, blood collection, management, advertising, and outreach is performed by two non-profit organizations: Héma-Québec, which operates in the province of Québec, and Canadian Blood Services (CBS), which operates in the rest of Canada. In 2008 alone, CBS oversaw collection of 903,014 units of whole blood (WB), from 420,787 individuals.

While these numbers appear significant, the transfusion demands of an aging population have been forecasted to create potential supply shortages in Ontario over the next 30 years[1]. While increases in transfusion demand due to aging are largely unavoidable, less is known regarding the effects of Canada's changing socio-demographic landscape on blood donation. Studies examining these characteristics of the Canadian donor pool are largely absent from the literature, and are useful to identify systemic under-representation of segments within Canadian society, underscore the need for targeted recruitment and retention, and better predict the stability of the national blood supply in the future.

It has long been observed in the literature that the burden of blood donation is not shared equally by society, largely with regards to socio-demographic factors such as gender[2,3], age[4,5], education[6,7], and ethnicity[8,9,10]. As a result, increasing the volume of donations, particularly amongst under-represented groups, continues to be difficult. In Canada's gratuity-based system, where individuals are encouraged to donate for personal reasons which may simply not be shared to the same degree by all members of society, attracting individuals from underrepresented groups requires intuitive outreach strategies, effectively providing targeted reasons why these individuals should donate. In demonstration of these strategies, a mass mailing of sickle-cell anemia information packets to a predominantly African-American Zip Code in St. Louis, Missouri, resulted in a 75% increase of First Time (FT) donorship from that area[11]. Wu et al. found that generally, the number of FT immigrant donors in the United States is increasing relative to the anticipated population growth of these groups, attributing the increased numbers of Hispanic donors to a targeted outreach campaign.[12].

Non-white groups have generally been found to have lower donation rates in France and the United States[13,14], and it has been shown that high proportions of immigrants in are correlated negatively with the number of donors, although the importance of accessibility in such studies has not been generally considered as a factor[15,16]. Regardless, the most drastic anticipated demographic change in Canadian society is a rapidly increasing proportion of recent and visible minority immigrants. Historically, the practice of widespread blood donation in Canada was, much like in other Western countries, a result of wartime blood collection practices initiated during World War 2[17,18], and the reasons to donate into such a system are traditionally rooted in sentiments of shared nationality, communal need, and notions of civic duty. In a multicultural society where new Canadians define themselves by their new nationality as much as by international cultural identities, and whose priorities may not immediately extend into the civic realm, the basic motivations which the Canadian blood system was developed to foster may quickly become less relevant.

The need to properly respond to these changes by soliciting donations from different groups within Canadian society, instead of advertising to Canadians as a whole, becomes apparent. The benefits of increasing donations from Canada's underrepresented immigrant population are twofold. Not only does it draw new donors from the fastest growing segments of the Canadian population into the system, but it helps serve the need for more group O-Type Red Blood Cell (RBC) donations, which are more common in non-European ethnicities[19].

The question is, how can we characterize Canadian donors? We have a general image, but more detailed insight is required if we are to successfully target groups within the Canadian population to expand the pool of donors. Working under the assumption that donor status is influenced by neighborhood socio-demographics, and by analyzing the 2006 Census attributes of these neighborhoods, we can examine the relationship between Dissemination Area-level donor rates and various socio-economic and spatial indicators. In this manner, this paper seeks to examine what, if any, are the possible relationships of different areal socio-economic and demographic variables to blood donor rates in the Toronto Census Metropolitan Area (CMA). This area was chosen for its large population of 5.7 million persons, its relatively low donor rates per population when compared to other cities[20], and its status as an immigrant destination for most recent immigrants arriving in Canada[21].

3.2 BACKGROUND

3.2.1 Donor Motivation and Demographics

The choice to donate blood is influenced by a variety of factors. In a Canadian study conducted to determine student motivations for giving blood, logistical concerns regarding the inconvenience of the time or place of donation were found to be the primary reasons for donation avoidance, while simple altruism was found to be the primary reason for donation[22]. Altruism was again found to be the primary factor in giving blood in donor studies by Piliavin[23] and Oswalt[24]. While this factor is consistent throughout the literature, a 2002 review by Gillespie and Hillyer[25] identify the consistent need for new research to correspond with changing population demographics.

Godin et al. conceptualize the decision to donate using a cognitive theory framework drawing from Azjan's Theory of Planned Behavior[26,27]. As such, the intention to donate is shaped by personal attitudes, perceived social norms, and believed personal control. As researchers, we understand that personal and environmental factors work to shape "determinants of intention" with regards to donation, and that these factors are partially revealed by the national Census. Once the importance of these factors in influencing the choice to donate is understood and paths for intervention have been identified, Godin et al. explain that it is the responsibility of the soliciting agency to properly tailor their recruitment efforts towards fostering these attitudes and norms in order to increase donation[28].

An example of how personal motivators can be inferred by demographic characteristics is shown in a 1989 study by Lipsitz et al. regarding reminder calls for donation appointments[29]. This study found differences in response rates based on the age of the solicitee depending on whether the solicitor's statements were intended to either illicit social pressure, or reinforce internal motives. The study concluded that younger age groups respond better to social pressure, and older age groups to reinforcement. Furthermore, Glynn et al. found in 2003 and 2006 that the material incentives offered by various blood donation clinics in the United States appeal differently to potential donors based on their age[30], and ethnicity[31]. In this manner, while blood donation is ultimately a personal choice, this decision can be greatly influenced and encouraged. Furthermore, the most effective ways to influence potential donors depend on factors related to the demographics of the individuals being targeted.

Having established the importance of these factors and their influence on the decision to donate, several studies have identified the individual motivating factors that affect an individual's willingness to donate, or continue donating regularly after a first time donation[32,33,34,35,36]. The traditional demographics of the repeat donor, as found by Schreiber et al. in 2003, is that they are more likely to be born in the country of donation, and are white, better educated, and older[37]. A 2009 Dutch study by Veldhuizen et al. uses areal-level demographic data as possible correlates of blood donation behaviour, and finds similar effects of age, sex, and socioeconomic status on propensity to donate[38]. Age, race, education, and immigrant status have also been measured against donation frequency following a first time (FT) donation[39,40,41]. Analysis of the areal demographic correlates of donation rates by CMA across Canada been analyzed by Saberton et al. in 2009 using a 2006-2007 fiscal year dataset, finding that approximately 50% of the variance by CMA could be explained by a host of demographic variables as drawn from the 2008 census[42].

3.3 STUDY DESIGN AND METHODS

3.3.1 Study Area and Distributions of Donation

Figure 1 shows the distribution of clinics during the 2008 calendar year throughout the Toronto CMA, as divided into 24 Census Subdivisions. The following three figures show various spatial distributions of donation-related factors; Figure 2 shows donors as a percentage of the eligible donor population, Figure 3 shows the average frequency of donation throughout the year by those who donate within each DA, and Figure 4 shows a metric of the product of the previous values to show areas which have both a high percentage of the population donating and high frequency per donor. This metric highlights areas where the two previous values are substantial.

In Figure 4, these areas appear to be located in rural areas, which are typically only serviced by a single clinic location operating a handful of times per year. Meanwhile, more urbanized areas of Toronto, which happen to be the most heavily serviced with regards to density of clinics, typically seem to have lower rates. As a precursor to more in-depth demographic analysis, a Moran's I LISA was performed to determine whether the spatial distribution of donation rates was random, or influenced by patterned factors across the Dissemination Areas. With a resulting Moran's I index of 0.07, there exists less than a 1% chance of the distribution of donation rates across DAs being the result of random chance.

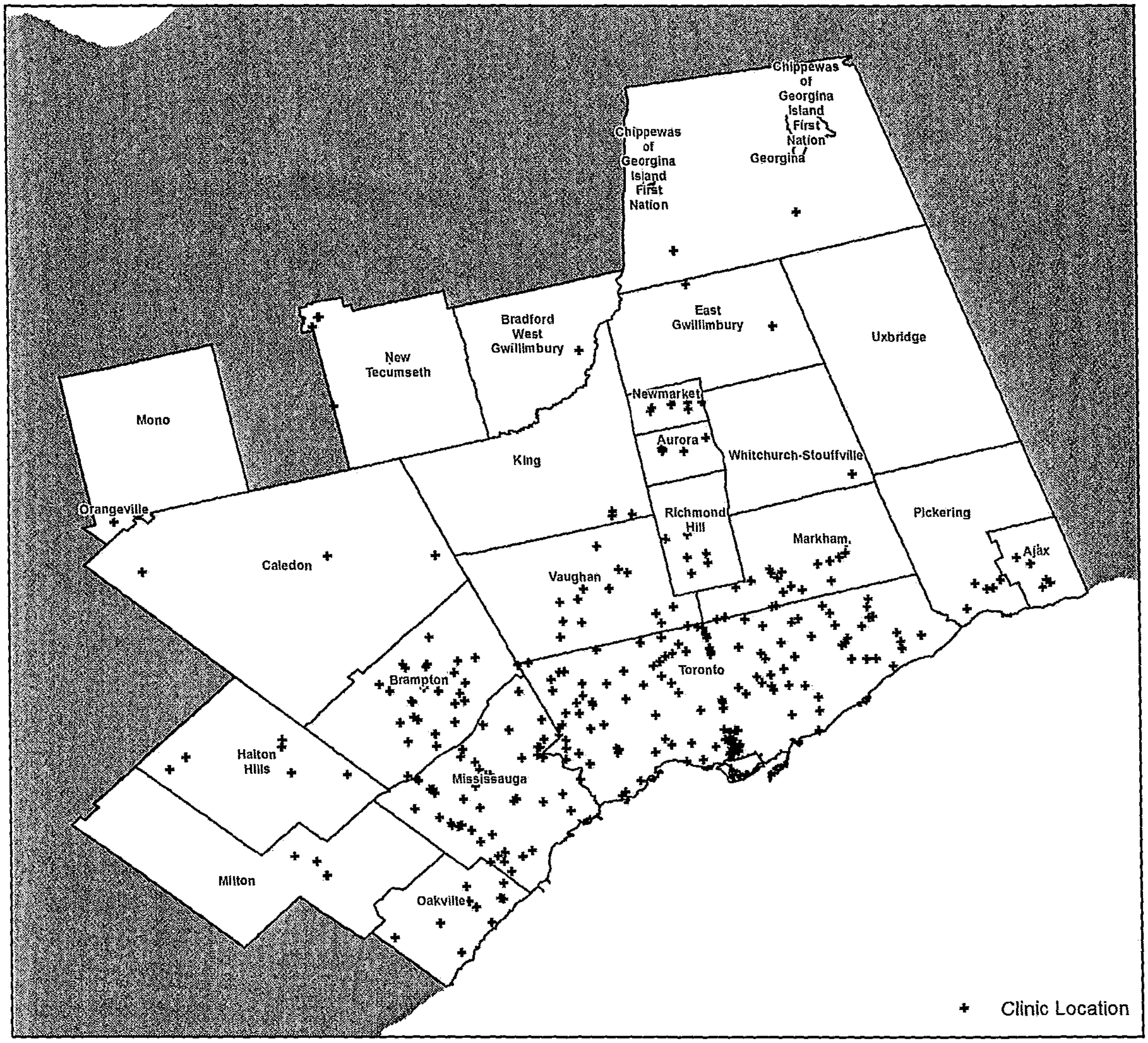

Figure 1: 2008 Clinic Distribution Across Toronto CMA

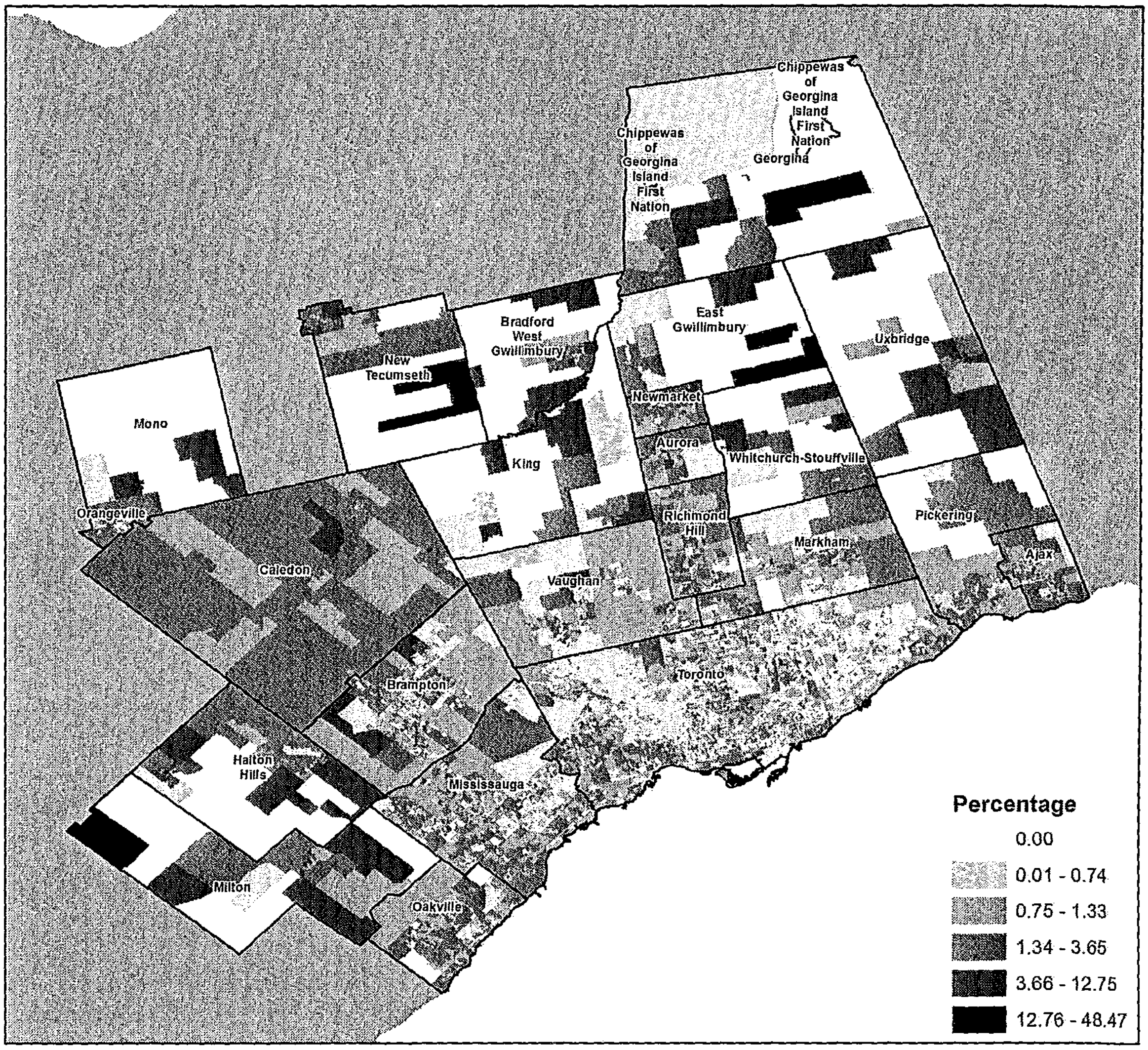

Figure 2: Percentage of Donating Eligible Population by DA

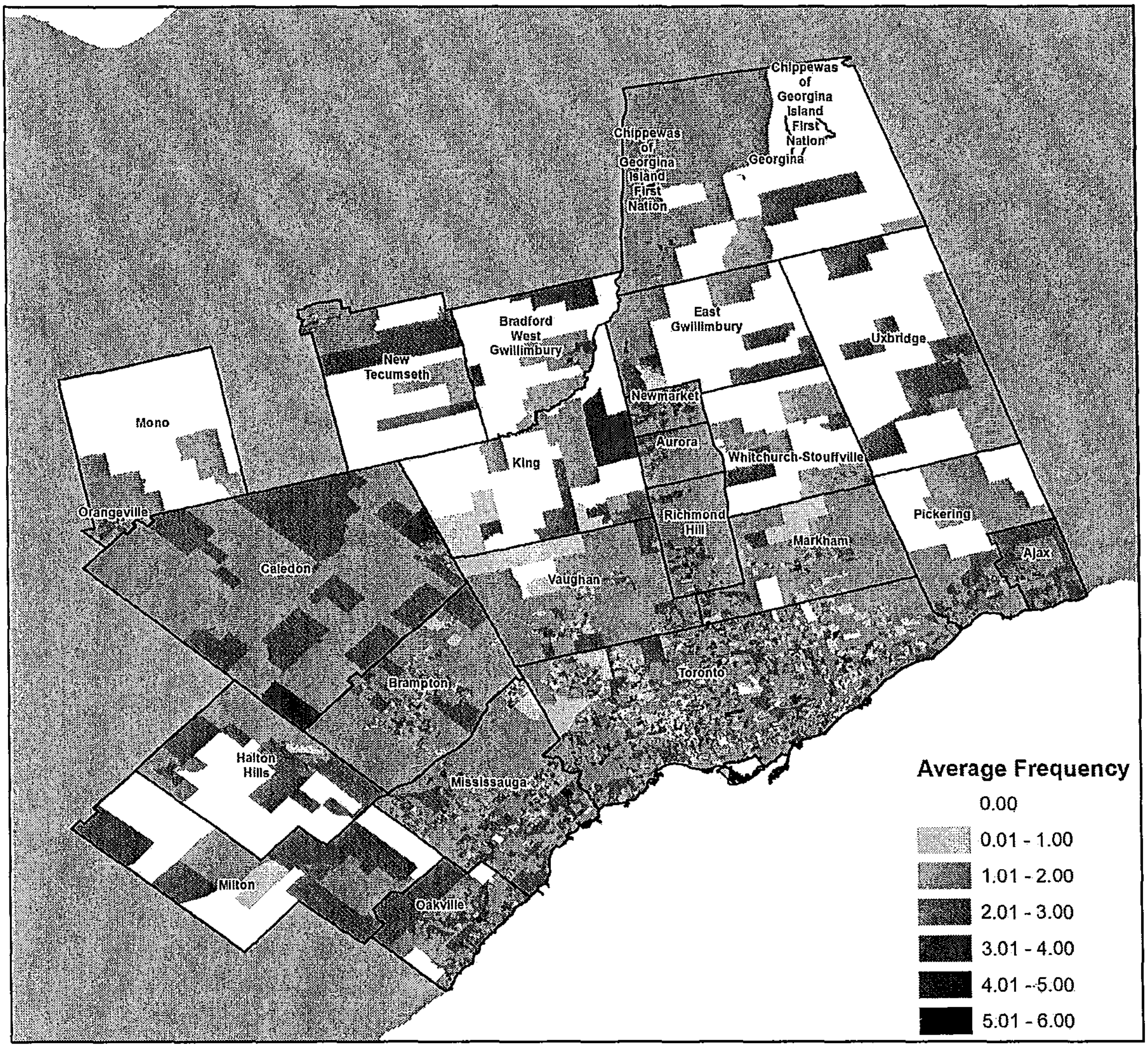

Figure 3: Average Frequency of Donation Per DA Donor Population

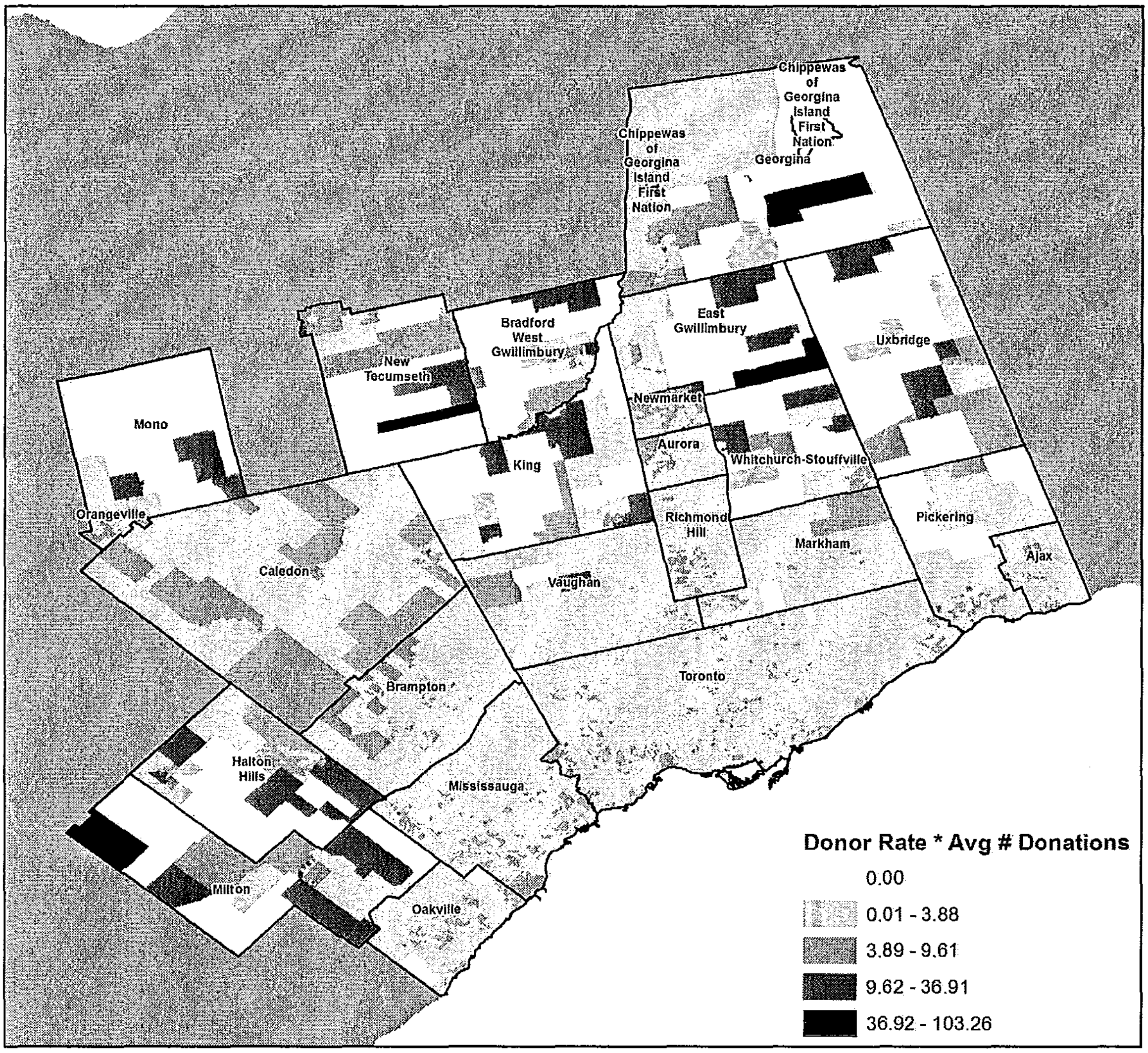

Figure 4: Product of Donor Rate and Average Donations Per Donor

3.3.2 Data Preparation

A Canada-wide dataset was obtained from Canadian Blood Services containing attribute donor, donation, and clinic data for calendar year 2008. In total, this dataset contained 903,014 individual donations made by 420,787 donors at 15,254 clinics across Canada (excluding Québec), and a subset specific to the Toronto CMA was extracted. Using the Postal Code information attached to each Donor and Clinic record, both could be roughly geolocated to both a Postal Code centroid and a 2006 Canadian Census DA centroid. Unfortunately, 25 Clinics known to be within the borders of the Toronto CMA according to their attribute data, and 304 donors donating at Toronto CMA clinics, could not be geocoded due to either not having valid Postal Codes, or having a Postal Code which could not be linked to a Dissemination Area through the Statistics Canada Postal Code Conversion File (PCCF). As a result, these records were excluded from analysis as there was no way of responsibly geolocating them within the Toronto CMA.

3.3.3 Independent Variables

Demographic variables were derived from the 2006 Canadian Census at the DA aggregate level, and only DAs belonging to the Toronto CMA were retained for analysis. Two dependent variables were generated from the 2008 CBS dataset. First, a flat rate of donors per eligible population per DA was generated. Eligibility was defined by age, and as such the denominator was population between the ages of 15-70 as derived from the five-year age group counts within the Census. While this does overestimate the eligible donor population slightly (by including ages 15 and 16 and those older than 70), this approach was deemed more acceptable than losing the combined population of 3 large younger age groups by increasing the threshold to age 20. While donors are allowed to continue donating past the age of 71, it requires annual medical assessments, and thus follows distinct criteria compared to the rest of the donor pool. The second dependent variable was a subset of the first, containing only the rate of donors who donated more than once in 2008 per eligible population. Both dependent variables were log transformed to improve the fit of the model.

Independent variables were generated from DA-level 2006 Canadian Census variables, expressed as percentages of the DA population for analysis. Variables capturing the percentage of population comprised of each gender and age group were created to investigate whether higher proportions of certain gender and age groups were related to increased DA-level donations, as found in other studies by Hollingsworth and Wildman[43], and Veldhuizen et al.[44]. The age cohorts were chosen to match those being used in a similar study by the INRS in partnership with Hema-Québec at the University of Québec. Additional demographic factors were chosen according to those selected by Saberton et al.; Language, Average income, Education, Employment, and Marital status/Family size. Variables related to immigrant population were categorized by immigrant region of origin as classified by the 2006 Census. To represent the effect of combined immigrant populations, a Shannon's Diversity Index was generated using all immigrant categories, plus a non-immigrant category for the remainder.

The attribute data for each WB clinic included hours of operation and the number of beds available for donors. The Accessibility measure developed by Saberton et al.[45] uses the product of (Beds) * (Hours) as a basis for capacity relative to the surrounding population within a specified distance from the clinic. The resulting accessibility value for each clinic is then summed for each DA within the specified distance band. While the metric was developed for use at the Census Tract scale, the 4 kilometre distance band retained due to best-fit purposes by Saberton et al. was used for our study as well.

In order to avoid underestimation of the population surrounding each clinic by using a centroid-based all-or-nothing catchment approach, a quadrat analysis approach was taken instead. The population surrounding each clinic was estimated by first calculating the average population per $100m^2$ within each DA and generating centroids for each $100m^2$ square. The sum of the estimated population values of these points as they fell within the 4 Kilometre clinic catchment areas represented the population surrounding each clinic. The clinic accessibility values were then passed along to any DA that intersected the distance band, and an aggregated sum of these accessibility measures was retained by each DA as a factor to include in the analyses.

Table 1: Independent Variables

	Max	Min.	Mean	St.Dev.
Age and Gender (AGE)				
Women 17-24 (%)	*0.18*	*0*	*0.07*	*0.02*
Women 25-39 (%)	*0.36*	*0*	*0.11*	*0.04*
Women 40-64 (%)	*0.29*	*0.03*	*0.18*	*0.03*
Women 65+ (%)	*0.51*	*0*	*0.07*	*0.05*
Men 17-24 (%)	*0.17*	*0*	*0.07*	*0.02*
Men 25-39 (%)	*0.36*	*0*	*0.1*	*0.04*
Men 40-64 (%)	*0.42*	*0.05*	*0.17*	*0.03*
Men 65+ (%)	*0.29*	*0*	*.0.06*	*0.03*
Language, Education, and Income (DEM)				
English Speaking (%)	*1*	*0.44*	*0.96*	*0.05*
Unemployment Rate (%)	*0.91*	*0*	*0.06*	*0.05*
Working in Health Occupations (%)	*0.32*	*0*	*0.04*	*0.07*
Bachelor's Degree or Higher (%)	*0.89*	*0*	*0.25*	*0.14*
Average Household Income (1000$)	*822.11*	*17.85*	*91.94*	*48.75*
Married Census Couples (%)	*0.94*	*0.06*	*0.52*	*0.11*
Avg. Number of Children per Family (#)	*3.3*	*0*	*1.25*	*0.32*
Immigration (IMG)				
Immigrants - United States (%)	*0.15*	*0*	*0.01*	*0.01*
Immigrants - Central America (%)	*0.23*	*0*	*0.005*	*0.01*
Immigrants - Caribbean (%)	*0.38*	*0*	*0.03*	*0.04*
Immigrants - South America (%)	*0.4*	*0*	*0.02*	*0.03*
Immigrants - Western Europe (%)	*0.39*	*0*	*0.01*	*0.02*
Immigrants - Eastern Europe (%)	*0.6*	*0*	*0.06*	*0.05*
Immigrants - Southern Europe (%)	*0.51*	*0*	*0.07*	*0.09*
Immigrants - Northern Europe (%)	*0.27*	*0*	*0.03*	*0.03*
Immigrants - Africa (%)	*0.34*	*0*	*0.02*	*0.03*
Immigrants - West Central Asia and the Middle East (%)	*0.36*	*0*	*0.02*	*0.09*
Immigrants - Eastern Asia (%)	*0.79*	*0*	*0.03*	*0.11*
Immigrants - South Eastern Asia (%)	*0.52*	*0*	*0.04*	*0.05*
Immigrants - Southern Asia (%)	*0.78*	*0*	*0.06*	*0.1*
Immigrants - Oceania and Other (%)	*0.07*	*0*	*0.002*	*0.01*
Immigrants - Non Permanent Residents (%)	*0.24*	*0*	*0.01*	*0.02*
Derived Variables (DER)				
Diversity Index	*2.36*	*0.02*	*1.33*	*0.42*
4 Kilometre Accessibility	*149.71*	*0*	*12.67*	*13.65*

3.4 RESULTS

3.4.1 Regression Analysis

Multiple linear regression analysis was chosen as the best method by which to examine the effect that varying DA-level proportions of the chosen socio-economic census variables have on rates of donors per population. For each dependent variable, four models were constructed by adding blocks of independent variables one at a time to observe the rate of change in the explanatory power of the model. These blocks were built around (i) Age and Gender, (ii) Language, Education, and Income, (iii) Immigration, and (iv) Derived Variables, and are shown in Table 1. An autoregressive coefficient was also added to control for residual spatial autocorrelation. In this way, we are able to ascertain which sets of variables are driving donation and repeat donation patterns. The results of this approach can be broadly generalized to Ontario based on the similar age and gender distributions for Toronto CMA donors compared to those of the rest of Ontario, as seen in Figures 5 and 6.

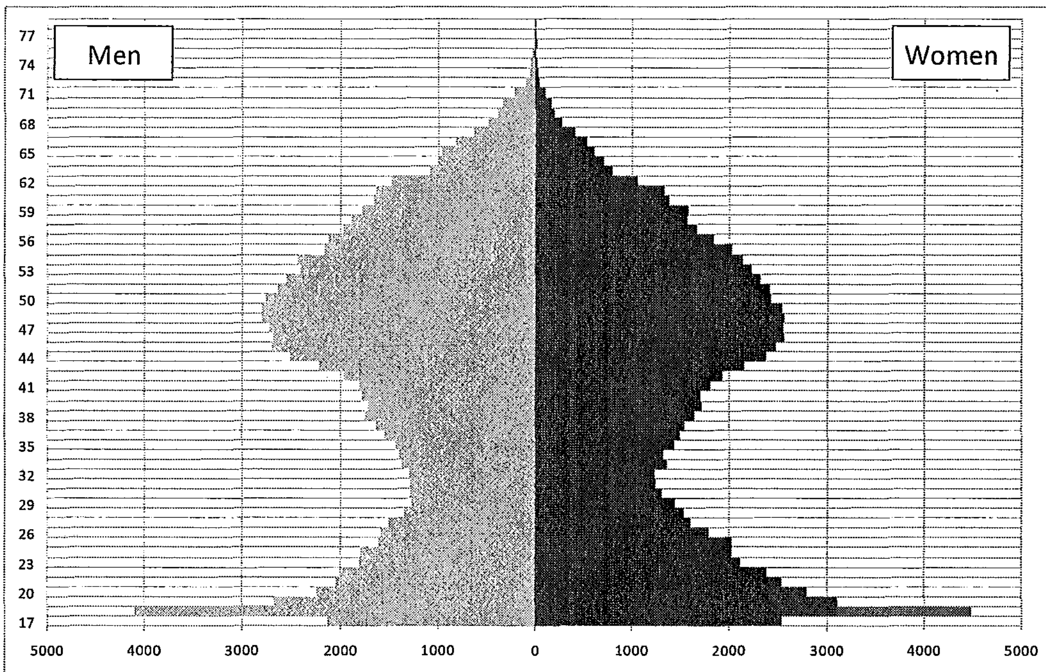

Figure 5: Donor Distribution by Age and Gender – Ontario

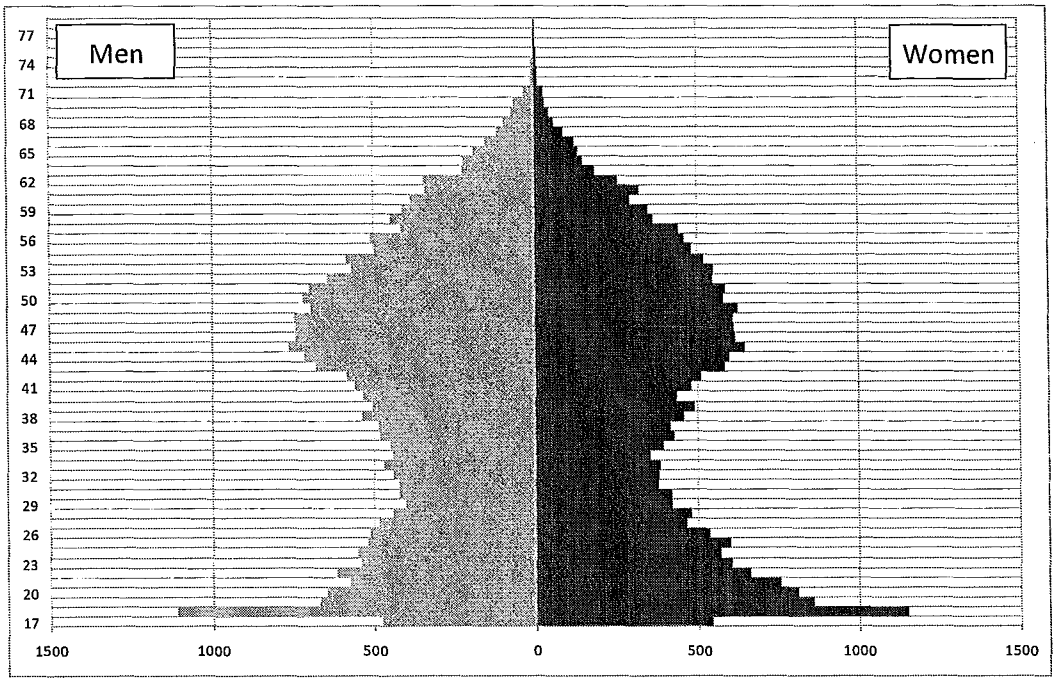

Figure 6: Donor Distribution by Age and Gender – Toronto CMA

Table 2: Regression Analysis of Rate of Donors per Dissemination Area ("A" Model)

	AGE *n = 6979* *Adj R^2 = 0.0941*		**AGE/DEM** *n = 6671* *Adj R^2 = 0.2203 **		**AGE/DEM/IMG** *n = 6671* *Adj R^2 = 0.3180*		**AGE/DEM/IMG/DER** *n = 6671* *Adj R^2 = 0.3203*		**AGE/DEM/IMG/DER/AUT** *n=6671* *Adj R^2 = 0.3343*	
	B	*p*	β	*p*	β	*P*	β	*p*	β	*P*
Intercept	0.12028	0.3576	***-3.10636***	<.0001	***-1.30863***	<.0001	***-1.33303***	<.0001	***-1.1696***	<.0001
Age and Gender (AGE)										
Women 17-24 (%)	***-2.25148***	<.0001	-0.39425	0.4569	***1.6907***	0.0009	***1.53256***	0.0026	***1.2095***	0.0098
Women 25-39 (%)	***-3.03388***	<.0001	***-3.01082***	<.0001	-0.70575	0.1479	-0.78294	0.1083	***-0.8387***	0.0134
Women 40-64 (%)	***2.71148***	<.0001	***1.00281***	0.0079	***1.65664***	<.0001	***1.73626***	<.0001	***1.5279***	<.0001
Women 65+ (%)	0.39421	0.1819	***0.87474***	0.0117	***1.49688***	<.0001	***1.48287***	<.0001	***1.2236***	<.0001
Men 17-24 (%)	***-1.92474***	0.0001	0.52244	0.3048	***2.15345***	<.0001	***1.98233***	<.0001	***1.6517***	0.0003
Men 25-39 (%)	-0.65022	0.0748	-0.08563	0.8364	***1.27525***	0.0014	***1.02217***	0.0112	***0.7652***	0.0284
Men 40-64 (%)	***2.27977***	<.0001	***1.24225***	0.0008	0.65331	0.065	0.53475	0.1312	***0.5777***	0.0393
Men 65+ (%)	***-3.29432***	<.0001	***-3.88116***	<.0001	***-1.84572***	<.0001	***-1.97661***	<.0001	***-1.7402***	0.0001
Language, Education, and Income (DEM)										
English Speaking (%)			***3.45366***	<.0001	***0.73809***	0.0005	***0.72223***	0.0008	***0.6871***	0.0002
Unemployment Rate (%)			***-1.69597***	<.0001	***-0.87544***	<.0001	***-0.83805***	<.0001	***-0.7368***	<.0001
Working in Health Occupations (%)			***-0.92642***	<.0001	-0.35385	0.0951	-0.33522	0.1133		
Bachelor's Degree or Higher (%)			***0.39673***	<.0001	***0.41855***	<.0001	***0.39203***	<.0001	***0.3685***	<.0001
Average Household Income (1000$)			***0.00047737***	0.0399	***-0.00135***	<.0001	***-0.0014***	<.0001	***-0.0012***	<.0001
Married Census Couples (%)			***0.89199***	<.0001	***1.56602***	<.0001	***1.6329***	<.0001	***1.5141***	<.0001
Avg. Number of Children per Family (#)			***-0.33219***	<.0001	***-0.0832***	0.0346	***-0.08002***	0.0424	***0.0881***	0.0024
Immigration (IMG)										
Immigrants - United States (%)					0.0036	0.9947	-0.33007	0.5572		
Immigrants - Central America (%)					***-2.50538***	<.0001	***-2.66113***	<.0001	***-2.2629***	<.0001
Immigrants - Caribbean (%)					***-1.66176***	<.0001	***-1.84875***	<.0001	***-1.7916***	<.0001
Immigrants - South America (%)					***-1.85951***	<.0001	***-2.02637***	<.0001	***-1.7931***	<.0001
Immigrants - Western Europe (%)					-0.00329	0.9944	-0.32963	0.4982		
Immigrants - Eastern Europe (%)					***-0.91462***	<.0001	***-1.09165***	<.0001	***-1.0396***	<.0001
Immigrants - Southern Europe (%)					***-1.86068***	<.0001	***-1.98256***	<.0001	***-1.8083***	<.0001
Immigrants - Northern Europe (%)					0.2791	0.3446	0.06361	0.8418		
Immigrants - Africa (%)					***-1.54139***	<.0001	***-1.85422***	<.0001	***-1.7311***	<.0001
Immigrants - West Central Asia and the Middle East (%)					***-1.19254***	<.0001	***-1.51116***	<.0001	***-1.3705***	<.0001
Immigrants - Eastern Asia (%)					***-1.24785***	<.0001	***-1.35405***	<.0001	***-1.2701***	<.0001
Immigrants - South Eastern Asia (%)					***-2.11321***	<.0001	***-2.32591***	<.0001	***-2.1136***	<.0001
Immigrants – Southern Asia (%)					***-1.33911***	<.0001	***-1.46515***	<.0001	***-1.3803***	<.0001
Immigrants - Oceania and Other (%)					-1.08469	0.365	-1.45289	0.2285		
Immigrants - Non Permanent Residents (%)					***-1.59067***	<.0001	***-1.82163***	<.0001	***-1.5493***	<.0001
Derived Variables (DER)										
Diversity Index							***0.09307***	0.0304		
4 Kilometre Accessibility							***0.00257***	<.0001	***0.0023***	0.0004
Autoregressive Coefficient (AUT)										
Lambda (λ)									***0.1670***	0.0000

Bold Italics denotes significance at the 0.05 Significance Level

Table 3: Regression Analysis of Rate of Multiple Donors per Dissemination Area ("B" Model)

	AGE *n = 6979* *Adj R^2 = 0.0639*		AGE/DEM *n = 6671* *Adj R^2 = 0.1131*		AGE/DEM/IMG *n = 6671* *Adj R^2 = 0.1887 **		AGE/DEM/IMG/DER *n = 6671* *Adj R^2 = 0.1977*		AGE/DEM/IMG/DER/AUT *n=6671* *Adj R^2 = 0.2038*	
	B	P	β	p	β	P	β	p	β	p
Intercept	-0.07634	0.5654	***-0.93525***	0.0028	0.60905	0.0527	0.20051	0.5261		
Age and Gender (AGE)										
Women 17-24 (%)	***-2.65883***	<.0001	***-2.12055***	0.0002	-0.2026	0.7155	-0.38566	0.4867		
Women 25-39 (%)	***-3.7795***	<.0001	***-4.17883***	<.0001	***-2.27226***	<.0001	***-2.07196***	<.0001	***-2.0874***	<.0001
Women 40-64 (%)	***0.74592***	0.0352	-0.51597	0.2008	-0.20505	0.6093	-0.0062	0.9876		
Women 65+ (%)	-0.32806	0.274	***-1.15166***	0.0019	-0.39963	0.2761	-0.29248	0.4231		
Men 17-24 (%)	***-1.03288***	0.0426	-0.06114	0.9105	***1.7336***	0.0011	***1.60428***	0.0025	***1.5868***	0.0010
Men 25-39 (%)	-0.45877	0.2157	***-1.07849***	0.015	-0.19476	0.6561	-0.0777	0.8594		
Men 40-64 (%)	***1.79315***	<.0001	0.68822	0.0816	0.25556	0.5089	0.30568	0.428		
Men 65+ (%)	***-1.21991***	0.0064	***-1.52576***	0.0019	-0.52574	0.2835	-0.52984	0.278	***-0.9058***	0.0159
Language, Education, and Income (DEM)										
English Speaking (%)			***1.99338***	<.0001	***-0.50022***	0.0298	-0.09249	0.6923		
Unemployment Rate (%)			***-1.43623***	<.0001	***-0.5136***	0.0078	***-0.53161***	0.0057	***-0.4963***	0.0088
Working in Health Occupations (%)			-0.39516	0.0973	0.1278	0.5813	0.13819	0.5488		
Bachelor's Degree or Higher (%)			***-0.34256***	<.0001	-0.07894	0.3664	-0.04061	0.6414		
Average Household Income (1000$)			***0.0008***	0.0007	***-0.00123***	<.0001	***-0.00123***	<.0001	***-0.0011***	<.0001
Married Census Couples (%)			-0.07691	0.4763	***0.75988***	<.0001	***0.76187***	<.0001	***0.7643***	<.0001
Avg. Number of Children per Family (#)			***-0.32552***	<.0001	***-0.0993***	0.021	-0.07251	0.0911	***-0.0842***	0.0209
Immigration (IMG)										
Immigrants - United States (%)					0.1685	0.7773	***1.42516***	0.0199	***1.5997***	0.0061
Immigrants - Central America (%)					***-1.30819***	0.0223	0.14894	0.8018		
Immigrants - Caribbean (%)					***-1.53816***	<.0001	-0.38098	0.1599		
Immigrants - South America (%)					***-0.84286***	0.0016	0.36274	0.2273		
Immigrants - Western Europe (%)					0.21385	0.674	***1.52386***	0.004	***1.6012***	0.0014
Immigrants - Eastern Europe (%)					***-1.24699***	<.0001	-0.29625	0.1387		
Immigrants - Southern Europe (%)					***-1.13248***	<.0001	***-0.38998***	0.0116	***-0.2547***	0.0271
Immigrants - Northern Europe (%)					***0.77592***	0.0162	***1.89241***	<.0001	***2.0467***	<.0001
Immigrants - Africa (%)					***-1.31016***	<.0001	0.00004	0.9999		
Immigrants - West Central Asia and the Middle East (%)					***-1.10778***	<.0001	0.06609	0.8038		
Immigrants - Eastern Asia (%)					***-1.30745***	<.0001	***-0.70891***	<.0001	***-0.5970***	<.0001
Immigrants - South Eastern Asia (%)					***-1.27871***	<.0001	-0.25214	0.212		
Immigrants - Southern Asia (%)					***-1.70098***	<.0001	***-1.01272***	<.0001	***-0.9443***	<.0001
Immigrants - Oceania and Other (%)					-0.60977	0.6413	0.83672	0.5241		
Immigrants - Non Permanent Residents (%)					-0.56002	0.1594	0.55767	0.1815		
Derived Variables (DER)										
Diversity Index							***-0.38778***	<.0001	***-0.4223***	<.0001
4 Kilometre Accessibility							***0.00178***	0.0052	***0.0018***	0.0054
Autoregressive Coefficient (AUT)										
Lambda (λ)									***0.0710***	<.0001

Bold Italics denotes significance at the 0.05 Significance Level

3.4.2. Assumptions of Regression

Upon completion of the regression analyses, residuals were examined to ensure that the results followed the principal assumptions of linear regression models, and to assess the accuracy of the results[46].

(i) Linearity

As the dependent variables were log transformed for analysis, the relationship between dependent and independent variables should be linear. Figures 7 and 8 show plots of Observed values vs. Predicted values for Models "A" and "B". In each of these, a nonlinear relationship would be characterized by a generally horizontal trend in the point cloud owing to the poor predictability of the model. Overall, the distributions follow diagonal trends, corresponding with the R^2 values of the models.

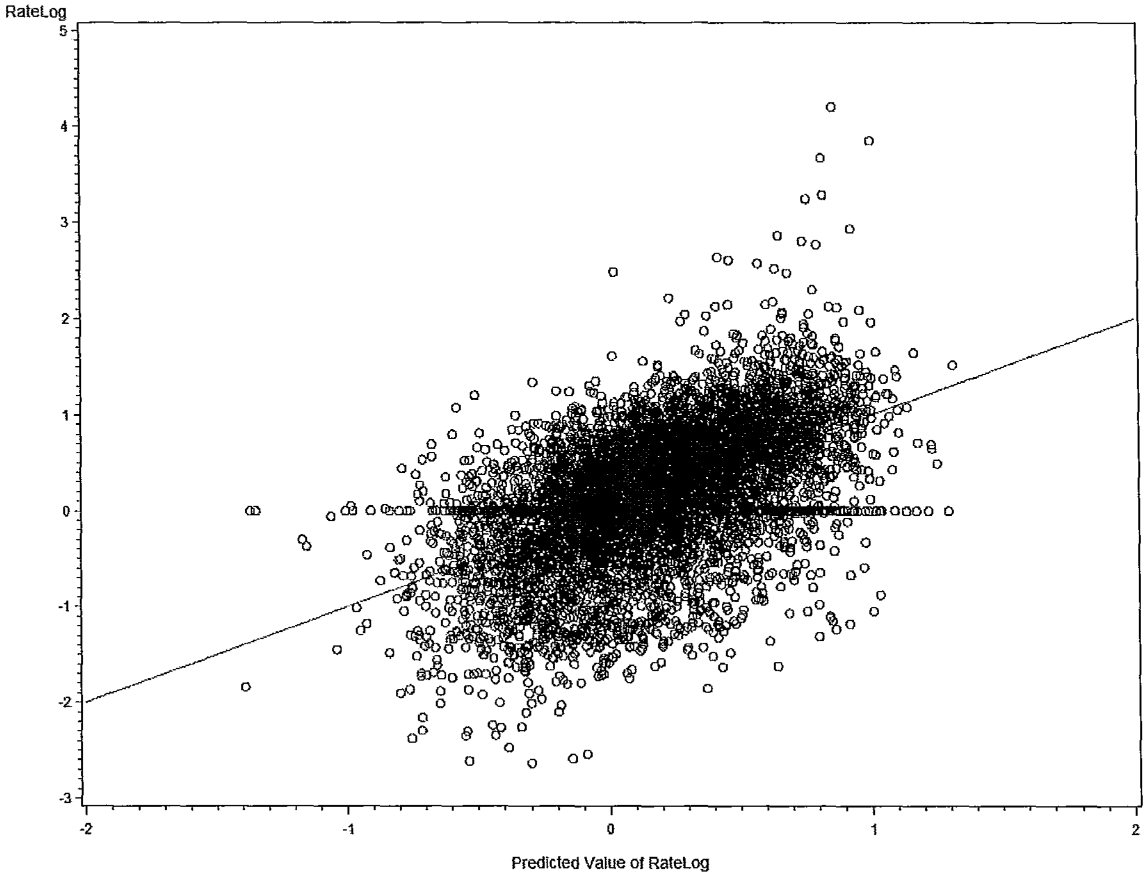

Figure 7: Observed vs. Predicted Values for Model "A"

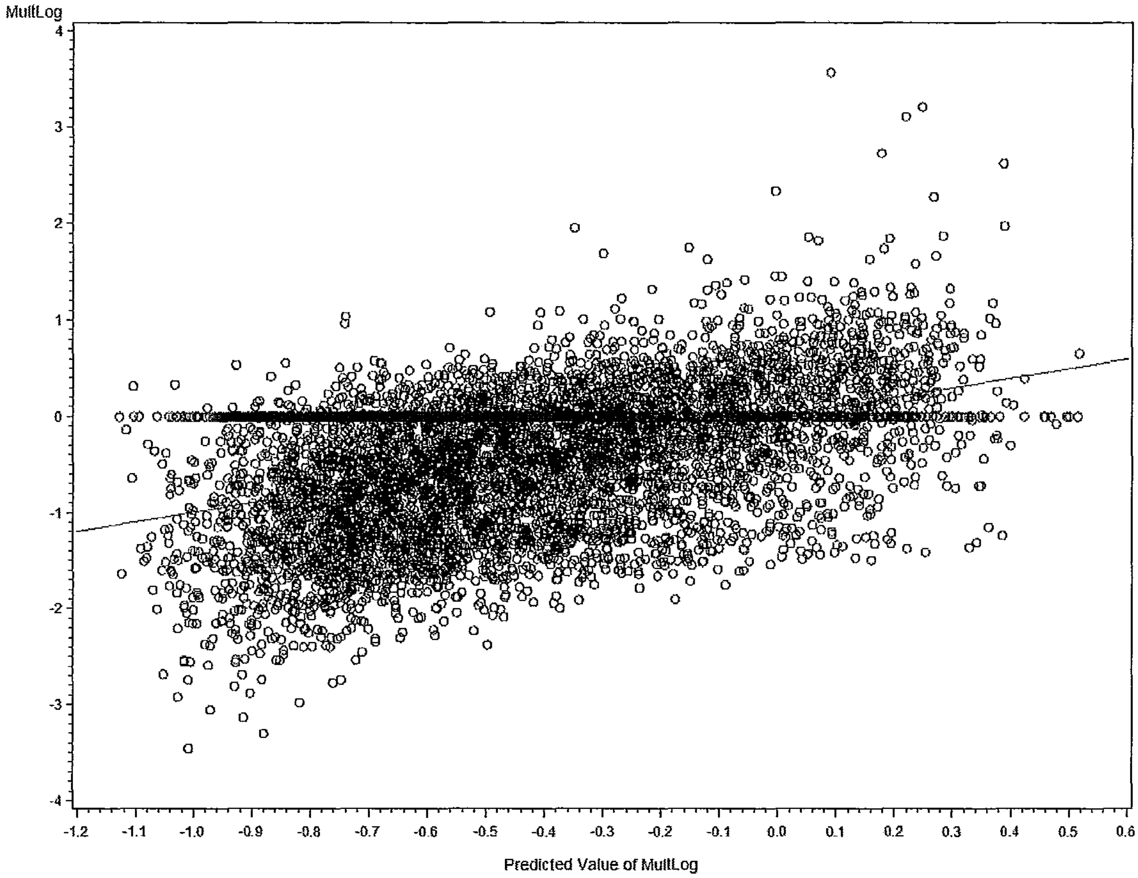

Figure 8: Observed vs. Predicted Values for Model "B"

Linearity can also be assessed by plotting regression residuals against predicted values. As shown in figures 9 and 10, residual error is distributed reasonably randomly throughout the data, and despite a notable linear pattern within the data clouds, higher predicted values of the dependent variables in general do not result in greater error. Overall, the assumption of linearity is satisfied for both models.

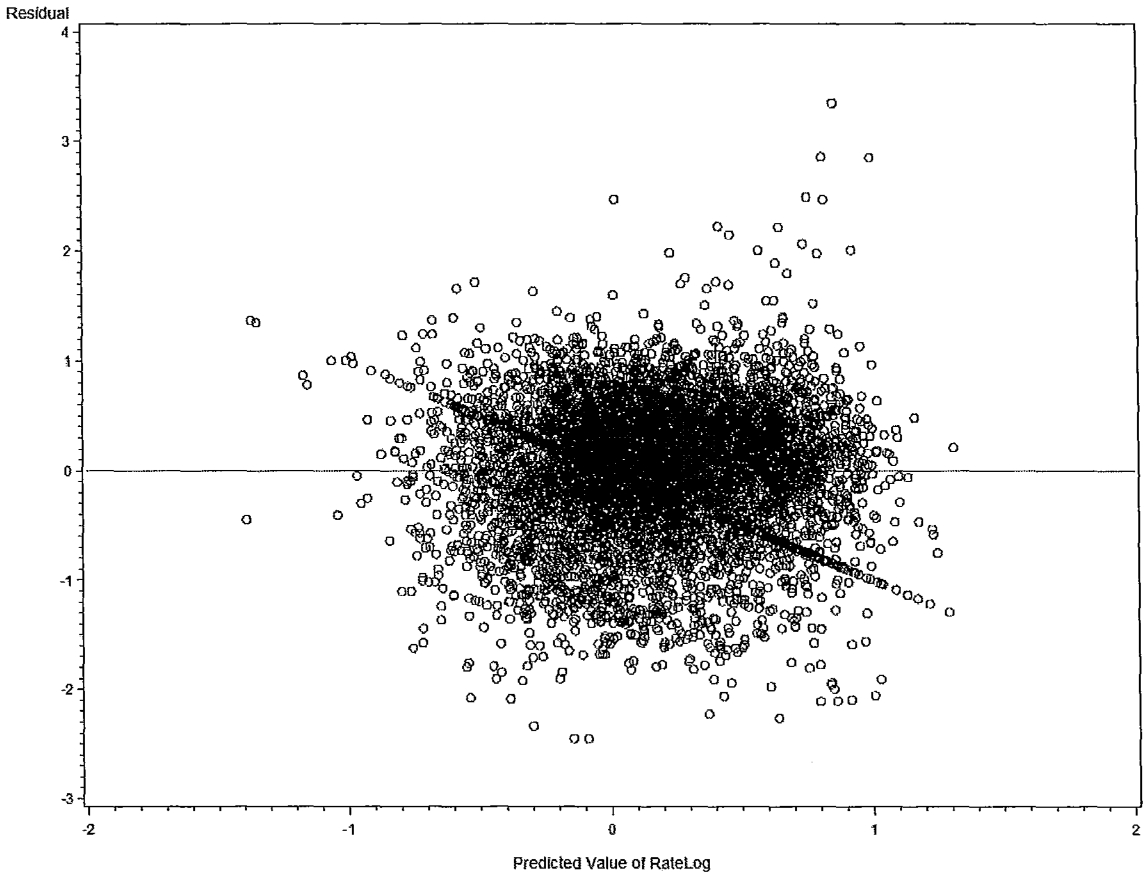

Figure 9: Residuals vs. Predicted Values for Model "A"

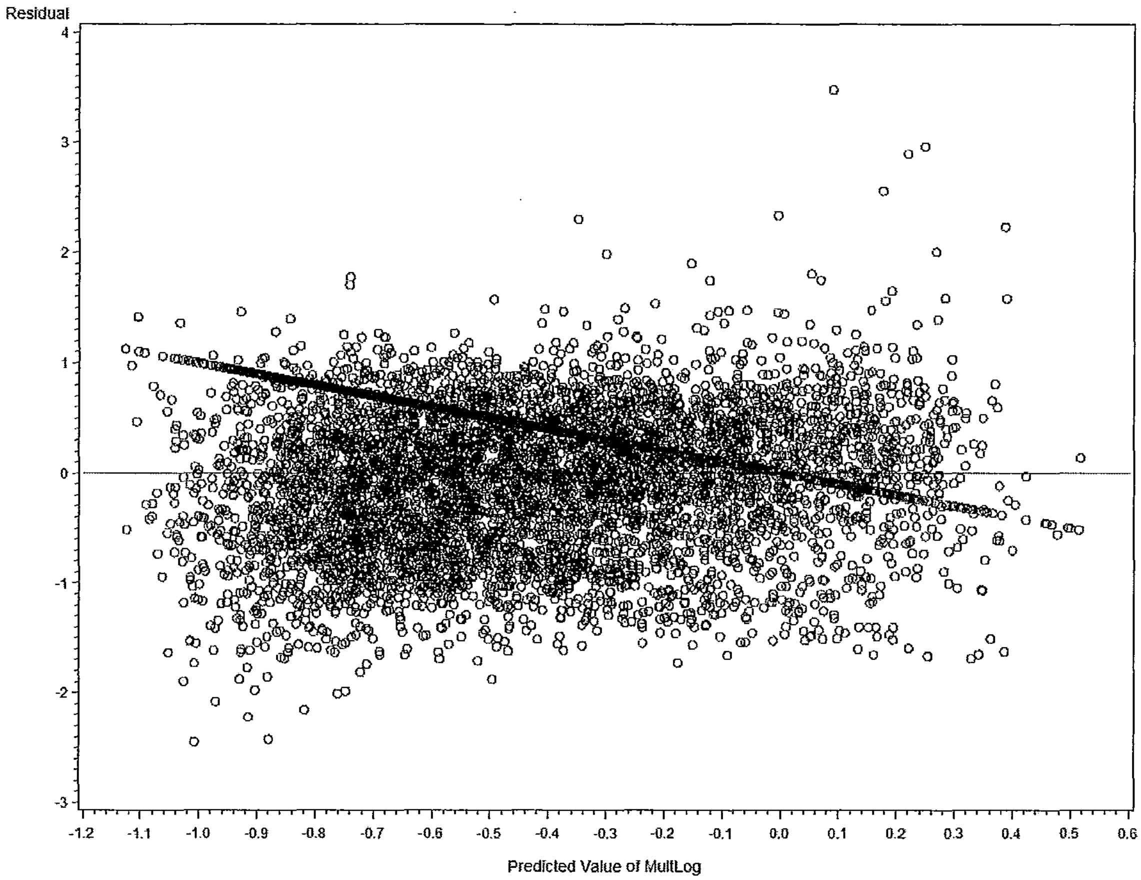

Figure 10: Residuals vs. Predicted Values for Model "B"

(ii) Independence

In order to control for spatial error autocorrelation within the model, a spatial autoregressive coefficient **λ** was generated for each Dissemination Area in the study area to supplement our findings with a spatial error model developed by Luc Anselin[47]. This model follows the linear regression formula $\mathbf{y} = \mathbf{X\beta} + \boldsymbol{\varepsilon}$, where $\boldsymbol{\varepsilon} = \boldsymbol{\lambda} \mathbf{W} \boldsymbol{\varepsilon} + \boldsymbol{\mu}$. $\boldsymbol{\lambda} \mathbf{W} \boldsymbol{\varepsilon}$ is a spatially weighted error vector derived from the topology of DAs in the Toronto CMA, and $\boldsymbol{\mu}$ is an error term which, as shown in (iii), follows requirements of independent identical distribution. Stepwise reduction of non-significant variables was performed as well. Overall, this supplement to the original regression model affirms the assumption of independence.

(iii) Homoscedasticity

With the exception of a few outlying values, as shown in the Residuals vs. Predicted Value plots in figures 9 and 10, the residuals do not generally increase or decrease with corresponding changes in the Predicted Value. Though not included due to the sheer volume of plots, this relationship is also not observed in relation to any independent variable included in our models. This suggests reasonably constant variance within the residuals, thereby fulfilling the assumption of homoscedasticity as well as the requirement for $\boldsymbol{\mu}$ in the spatial error model discussed in section (ii).

(iv) Normality

The standard normal distribution of the residuals of models "A" and "B" can be confirmed by the histograms in figures 11 and 12, respectively, and the normal probability plots in figures 13 and 14. The slight S shape observed in figure 14 is suggestive of slight kurtosis within the distribution of the model "B" residuals, but is likely caused by the increased number of zero values within this dependent variable.

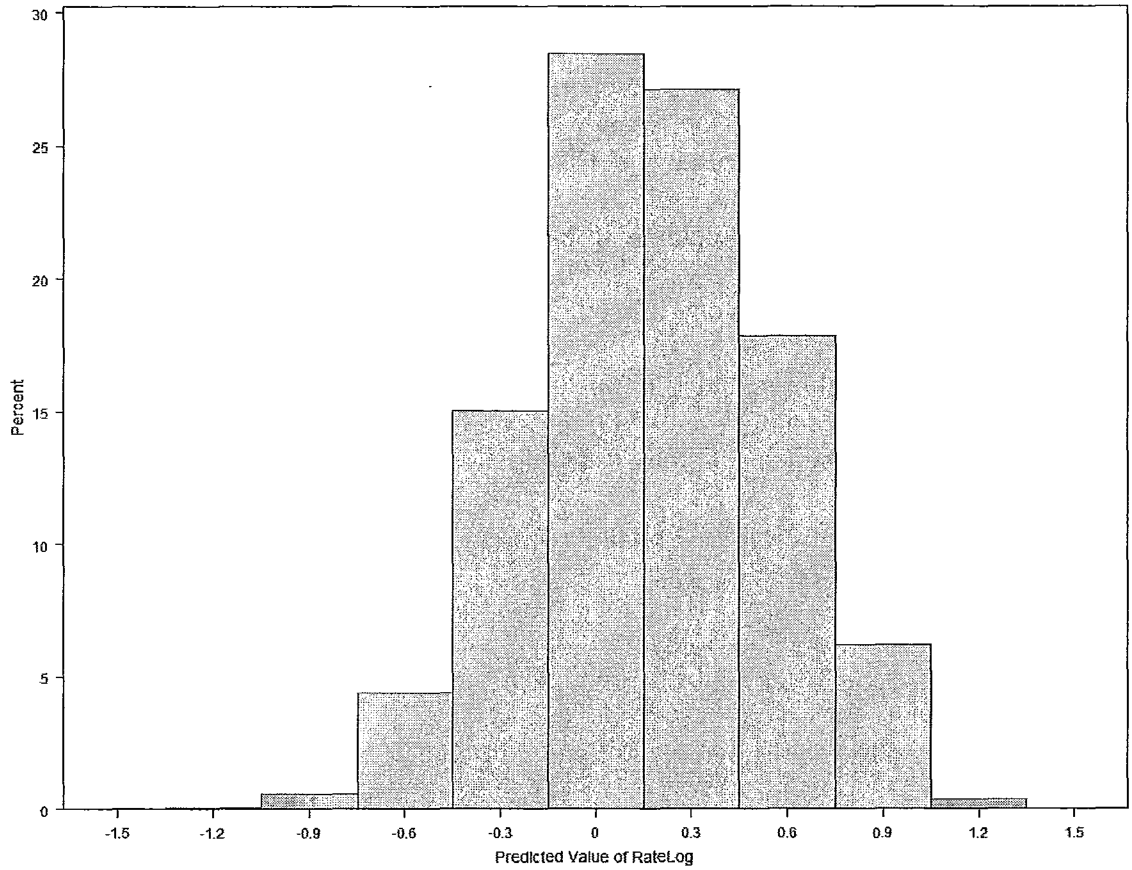

Figure 11: Histogram for Dependent Variable in Model "A"

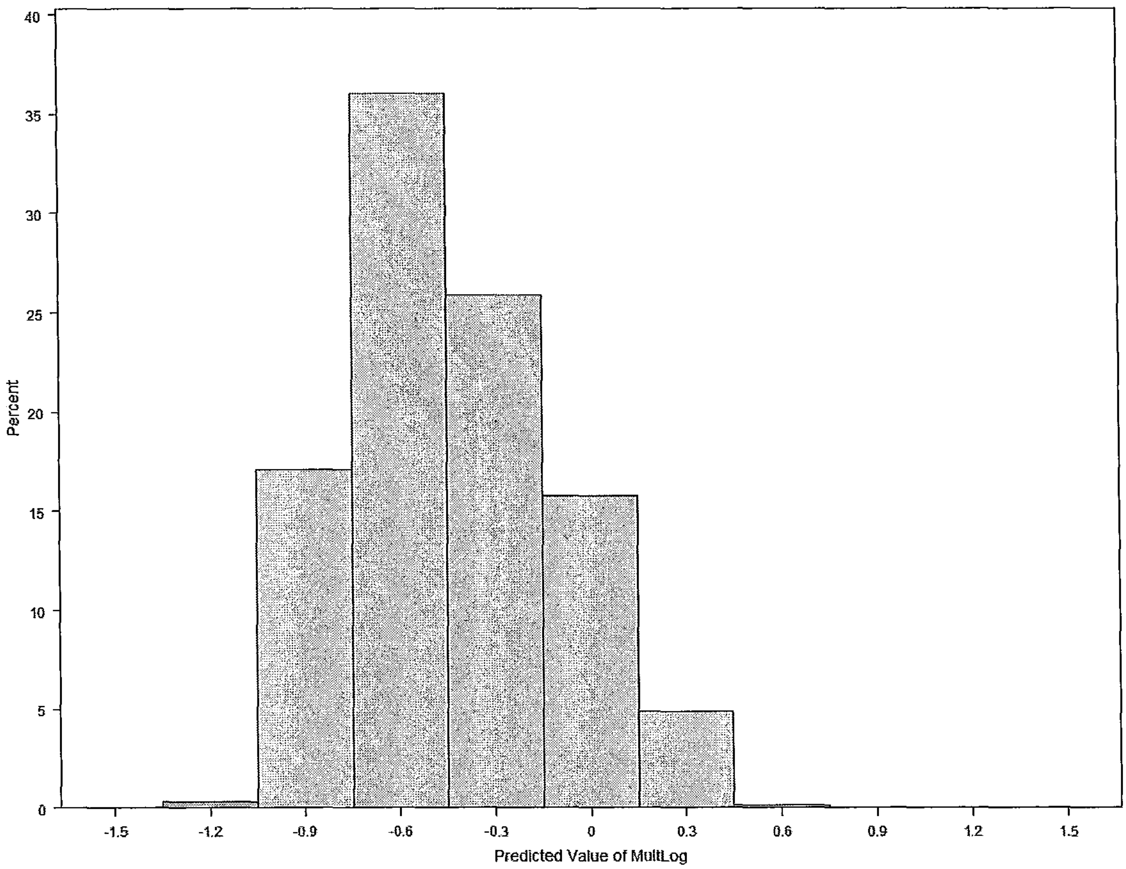

Figure 12: Histogram for Dependent Variable in Model "B"

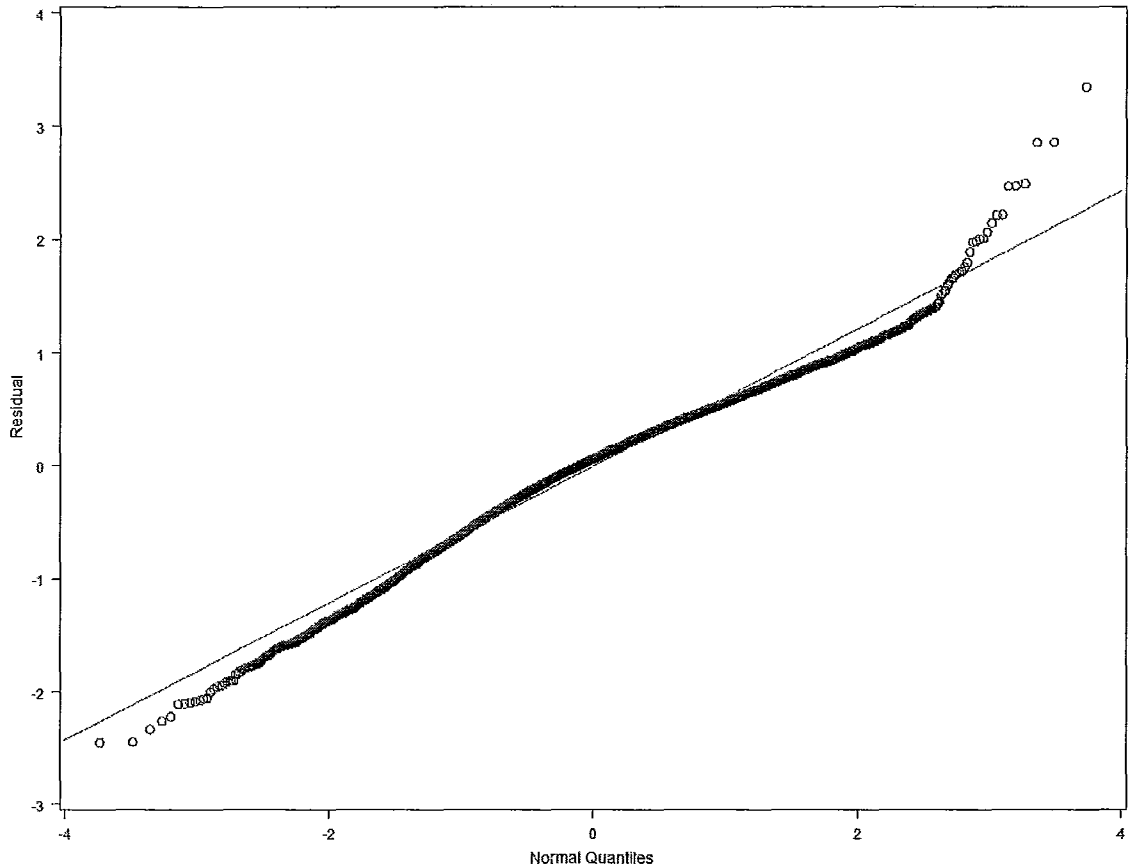

Figure 13: Normal Probability Plot for Dependent Variable in Model "A"

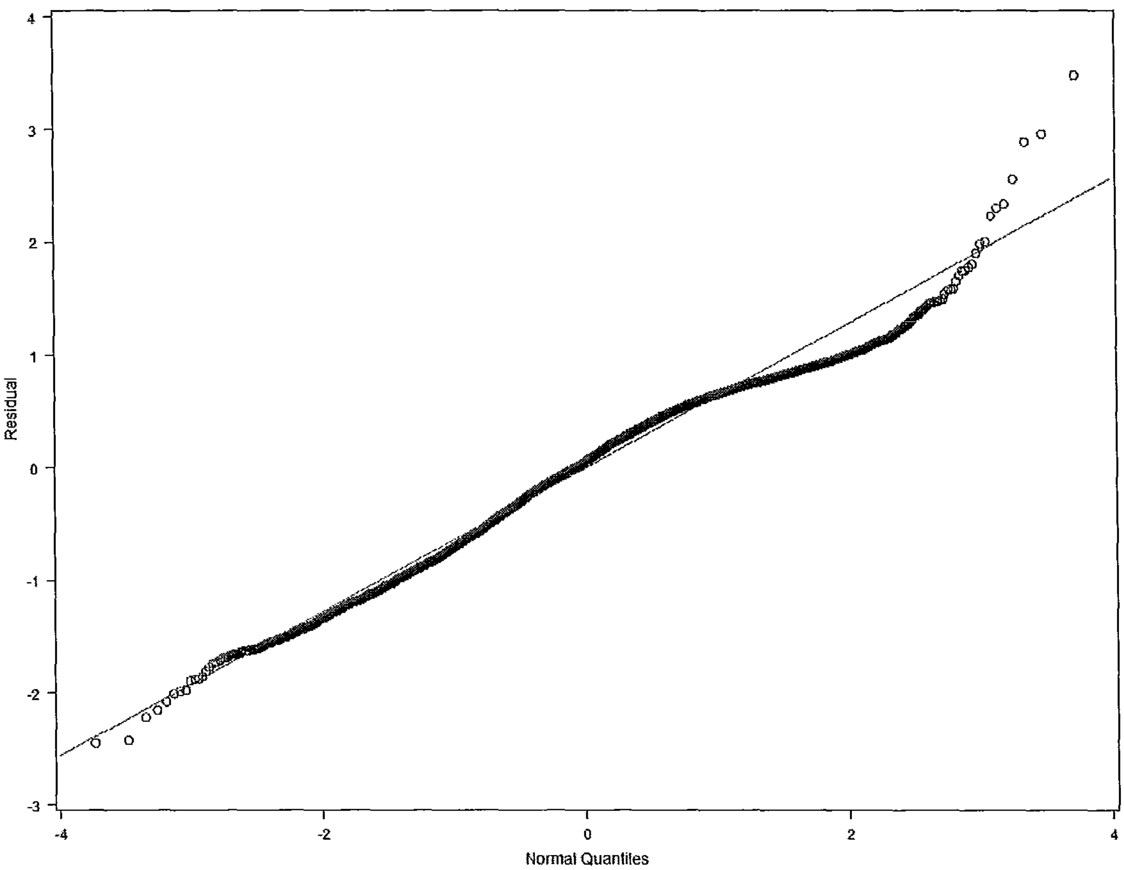

Figure 14: Normal Probability Plot for Dependent Variable in Model "B"

3.4.3. Regression Results

We first turn our attention to the results of the "A" Model, for which the dependent variable is the full donor rate as a percentage of the eligible population. Starting with our first block of AGE factors, a previous study based on this dataset had found that men donate in greater proportions than women in all cohorts other than the youngest[48], the results of this regression show similar results between genders, with slightly higher positive coefficients for women. Additionally, the importance of these "AGE" variables increases when controlling for additional blocks of factors.

Secondly, with the "DEM" general demographic factors, it is found that the "Working in Health-Related Occupations" variable is insignificant. This is likely a result of the fact that groups of people who work in health-related occupations are unlikely to live within the same DA to any significant degree, resulting in a variable with low explanatory power. Education and employment factors are significant, reflecting the literature, and most notably the value of the language variable drops greatly when the "IMG" immigrant factors are added, reflecting he increased language barriers of these groups. The negative coefficient of the "Avg. Number of Children per Family" variable makes sense when the time considerations of larger families are taken into account. Marital status is a positive indicator for donation, possibly because of an increased sense of extrapersonal responsibility, or its collinearity with other positive variables. Finally, the addition of the "DEM" block results in the greatest increase to the R^2 value of "A" Model.

Regarding the "IMG" immigrant factors, all variables except "Northern Europe", "United States", "Western Europe" and "Oceania and Other" appear as significant negative correlates in the "A" Model. This largely reflects what has been found in the literature regarding immigrant donation patterns being lower than that of the general population. Additional insight into these immigrant donation patterns arise from analyzing the "B" Model, below.

With regards to the final block of "DER" derived variables, the most interesting findings result from the contrasts between Model "A" and "B". Again, these will be described below, but in the "A" Model both the Accessibility Metric and the Diversity Index are both positive significant indicators of donor rate.

With regards to the "B" Model, some interesting differences arise between our two dependent factors. While the "A" Model measured overall donor rate per eligible

DA population, the dependent variable in the "B" Model is the donor rate of donors who donated more than once in 2008 per eligible DA population. As a subset of the dependent variable in Model "A", the Model "B" dependent variable has less variance and is more zero-heavy. As a result, in the "B" Model, independent variables with little variance typically lose explanatory power. The difference between the two models allows us to better identify habitual donor populations at the DA level.

Beginning with the "AGE" block, while in "A" Model the importance of these variables increases when controlling for the additional blocks, the opposite is true for "B" Model, where the only two significant AGE variables are a high negative coefficient for "B" Model women aged 25-39, and a positive coefficient for men aged 17-24. Previous studies of the 2008 Ontario CBS dataset that while men of this age cohort are less likely to be first time donors than women, they are more likely than women to donate multiple times throughout the year in Ontario[49]. The lone negative significance of women aged 25-39 makes sense, and is mirrored in the "A" Model results, though not significantly, as this age cohort is typically when many women could be assumed to be having children, and likely self-selecting themselves from donating. Notably though, high proportions of any AGE groups do not appear to have any significant effect on multiple blood donor rates within the "B" Model.

Demographically, "B" Model donors appear to be less affected by demographic factors than "A" Model donors. Marital status remains a positive factor in the "B" Model, as do income and unemployment. "Average Income" appears to have a slightly negative significant correlate in both, which may be a result of the wide range of average incomes throughout the Toronto CMA. It is likely that over a certain threshold, income stops having an effect on donation rates. The remaining factors, however, lose significance, perhaps indicating that the conscious self-selection of being a recurring donor transcends otherwise explanatory demographic factors.

The results of the "IMG" factors in the "B" Model are worth discussing due to notable divisions within this category. While all variables except "Northern Europe", "United States", "Western Europe" and "Oceania and Other" appear as significant negative correlates in the "A" Model, nearly the complete opposite is true in the "B" Model, with the first three of these factors resulting in significant positive correlates. The presence of "Northern Europe" as a significantly positive immigrant factor is particularly unexpected, as there are a number of deferrals and exclusions for individuals who have lived in the United Kingdom for a period of time due to CJD concerns[50].

Likely, within Toronto, the "Northern Europe" factor is largely comprised of immigrants from the United Kingdom who, due to a comparative lack of cultural and language barriers, are more likely to live within the broader Canadian population than within smaller immigrant enclaves. As a result, the significance of this immigrant factor, as well as "United States" and "Western Europe", are likely representative of what we see elsewhere in the regression model and the literature; non-immigrant Canadians are more likely to donate multiple times annually than are immigrant Canadians. These factors may actually represent the increased likelihood that DAs which do not contain large immigrant populations will have, on average, higher rates of multiple donorship than those that do.

The two other significant immigrant factors in "B" Model, "Eastern Asia" and "South Asia", represent two large immigrant populations known to reside in large numbers in Toronto; China/Hong Kong and Pakistan/India, respectively. Dense concentrations of these populations within DAs may result in the strong negative coefficients observed for these groups. It should be noted that the addition of the "IMG" block results in the greatest increase to the R^2 value of "B" Model.

Differences between models extend to the "DER" derived variables as well. The Diversity Index is not significant for the "A" Model but negative for the "B" Model, indicating that DAs containing varied immigrant populations are largely unrepresented in multiple donation rates. Furthermore, the fact that the Diversity Index weighs significantly negatively in the "B" Model corroborates the general finding that immigrant communities, from which the Diversity Index is derived, are less likely to donate than non-immigrant communities. Regarding the accessibility measure, its coefficient decrease in the "B" Model may be indicative of Piliavin's finding that as an individual becomes a habitual donor, the importance of convenience decreases[51].

3.4.4 Moran's I LISA on Regression Residuals

A Moran's I LISA was applied as a final step to test for remaining spatial autocorrelation in the residuals of the regression. The Index value of the "A" Model residuals was determined to be 0.03, suggesting spatial clustering within the model residuals. This could potentially represent important unmeasured factors within Toronto, but the relatively low Index value does confirm that the explanatory power of the models are explaining a strong portion of the spatial pattern observed in the donor rates.

3.5 CONCLUSIONS

As Canada changes in the wake of broad demographic shifts, national approaches to blood donation recruitment and retention should evolve as well. The results of this study suggest that a potentially large portion of the growing Canadian immigrant population will continue to be underrepresented without new methods encouraging these groups to donate.

The results of this study corroborate several findings related to demographic indicators of donor status found in the literature, including the effects of education, employment, marital status[52], accessibility[53], and particularly immigrant status. It has been observed in the literature that while new Canadians may be more concerned with achieving stability and success in their new country of residence than with civic life, there is evidence that these groups encourage their children to gain social capital for professional benefit, particularly with regards to volunteerism[54,55]. As blood donation can be conceptualized as a form of volunteerism, one possible approach to increasing donor rates amongst younger immigrant groups would be to encourage the use of blood donor status as valuable community service experience for young people on University applications and resumes. While younger age groups are typically shown to donate in high proportion due to school-based donation locations and unique susceptibility to peer pressure[56], the encouragement of a self-serving benefit to donation may result in ongoing personal motivation to donate blood, potentially increasing habitual donorship.

It should be remembered, however, that despite efforts intended to encourage donation motivations in immigrant groups, high rates of travel-related deferral may prevent the benefits of this approach. Travel to any designated Malaria risk zone, for example, results in a one-year deferral[57]. With such a barrier in place, immigrant groups who travel to their places of birth frequently face the possibility of ongoing annual deferrals, effectively being prevented outright from donating. Recent Canadian Blood

Services outreach campaigns encouraging donation just prior to travel may help to mitigate rates of travel-related deferral, but within immigrant groups whose choice of donation location may be closely tied to community events, this practice may not be widely successful.

Regardless of policy approaches to encourage donorship, the results of these models show a broad and diverse portrait of the Toronto donor population. Future studies should focus on applying the model to other major Canadian cities to investigate whether the associations seen within Toronto are unique, or representative of broader trends across Canada.

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CHAPTER FOUR: Conclusions

4.1 INTRODUCTION

The objectives of this thesis have been met through the forecasting and analyses undertaken in Chapters 2 and 3. Age-based forecasts resulted in a strong picture of the effect of Canada's aging population on donation and transfusion rates within Ontario. Multiple Linear Regression analyses within the Toronto CMA provided additional insight into which segments of the Canadian population are currently being effectively motivated to donate, and which segments remain underrepresented. In this way new policies can be developed to increase donorship for current donors and draw additional donors into the donor pool from underrepresented segments of the population.

4.2 SUMMARY OF MAJOR FINDINGS

The logistic regression in Chapter 2 reveals that men are more likely than women within all four age cohorts to donate more than once throughout the year. While gender does not appear to play a large role in First Time donorship for the 17-24, 25-39, and 65+ age groups, men are significantly less likely than women to become first time donors between the ages of 40 and 64.

The forecast reveals potential supply shortfalls related to greatly increased demand, and these are anticipated to occur as soon as 2014. The driver of this shortfall appears to be increased demand from the oldest age cohorts (Age 70+), as their absolute number increases with an aging baby boomer population. Proportionally, RBC transfusions required by the 70+ age group will grow from approximately one half of all RBC transfusions in 2008 to two thirds of all RBC transfusions by 2036.

The multiple linear regression analyses in Chapter 3 reveal that based on 2008 Toronto CMA donation data, environmental factors related to socio-economic and immigrant status appear to have the largest associations with overall donor rates and multiple donor rates, respectively. Specifically, post-secondary education, language, accessibility, and marital status appear positively correlated with increased donor rates within Dissemination Areas, while factors related to employment and immigrant status appear to be negatively correlated. This is consistent with similar studies from the literature.

4.3 RESEARCH LIMITATIONS

Limitations were faced in both studies. Within Chapter 2, while it would have been a more effective use of the national dataset to forecast supply vs. demand for the entire country, only transfusion data for Ontario could be obtained. Furthermore, within the Ontario transfusion data, a uniform average number of units per transfusion had to be applied to all age cohorts due to the lack of consistently recorded data in the DAD/NACRS dataset. Realistically, since different age cohorts can be expected to have different age-specific health problems, the average number of units used per transfusion likely changes substantially between age cohorts, with the greatest needs amongst the oldest cohorts. This would have the potential of greatly changing the demand trends of our age-based forecast, and potentially delay the date at which demand exceeds supply.

Within Chapter 3, while the Postal Code Conversion File allows for Postal Code data to be geocoded to census geographies, there is an inherent possibility of error when assigning non-spatial Postal Codes to spatial units. Furthermore, the census data used for the regression analyses was collected in 2005-2006, and as such is not necessarily best representative of the populations in the 2008 CBS data. There are additional issues which may confound the use of Postal Code information, such as cases where donors may have provided a previous Postal Code for various reasons, but no longer actually live in that area. These cases can be expected to be few, but as some Dissemination Areas only have a handful of donors, the mistaken addition of even one donor has the possibility of disproportionally confounding the results. Furthermore, while other studies have used this method of investigating the relationship between environmental demographic factors and donor rates, it still cannot be reliably used as replacement for detailed individual-level donor demographic information.

4.4 CONCLUSIONS AND FUTURE RESEARCH

Based on forecasts generated from the 2008 CBS data, it is clear that the Ontario blood supply will face shortages within a few years without drastic intervention. While Ontario is the most populous province in Canada, these shortages can be anticipated to be faced in other provinces with time. This can be confirmed by expanding the scope of the forecast by introducing transfusion data for provinces other than Ontario. Additionally, the forecast can be improved with the introduction of reliable transfusions-per-patient data.

Chapter 3 shows us that while these shortages are forecasted solely on the basis of Ontario's changing age demography, environmental factors beyond age are associated with propensity to donate. By applying the model used in Chapter 3 to other CMAs across Canada, city-specific profiles of donor pools can be created, which could be used to inform more effective recruitment and retention efforts. Furthermore, the accuracy of the areal-level approach could be evaluated by gathering individual donor demographic information for a corresponding area, geocoded similarly by Postal Code.

Overall, blood donation in Canada remains a largely underexplored area of study. With an aging national population potentially affecting the future stability of the national blood supply, new research will be necessary to inform targeted outreach campaigns and increase donorship. In this regard, developing strong literature concerning the demographics of Canada's current donors, and how these demographics can be expected to change in the future, is essential to the continued sufficiency of the national blood supply.